A Description Logic Architecture to Reconstitute the Minimal Semantic Representation Equivalent to the Unique Solution of Bongard's Ill-Posed Problems Considered to be Incapable Without Human Intuition

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A Thesis

submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

by

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Abstract

Human intelligence relying on brain information processing has two aspects of implicit memory and explicit memory functions. A possible hypothesis is that human intelligence is a consequence of the fusion of those two aspects, and then a question is addressed as to how the flexibility of making a frame of thinking depending on the context is reconstructed by the fusion. In the assumption that an autonomous classifier provides primitive labels indicating parts in a picture and a generalizer to represent the whole in an abstract way, the problem that remains unsolved is how semantic information can be coordinated to reach a conclusion to connect parts and the whole. Bongard problems question such an issue in the form of logical picture puzzles to request to seek the unique minimum description of pictures to discriminate two groups, throughout abductive reasoning.

Bongard Problems (BPs) are a set of 100 visual puzzles introduced by M. M. Bongard in the mid-1960s. BPs have been established as benchmark puzzles for understanding the human context-based learning abilities to solve ill-posed problems. The puzzle requires the logical explanation as to the answer to distinguish two classes of figures from redundant options, which can be obtained by a thinking process to alternatively change the target frame (hierarchical level of analogy) of thinking from a wide range concept networks as D. R. Hofstadter suggested. Some minor research results to solve a limited set of BPs have reported based a single architecture accompanied with probabilistic approaches; however the central problem on BP's difficulties is the requirement of flexible changes of the target frame; therefore non-hierarchical cluster analyses do not provide the essential solution, and hierarchical probabilistic models need to include unnecessary levels for learning from the beginning to prevent a prompt decision making. Only possible combinations of primitive descriptions like '*circle in a triangle*' are arisen as a test hypothesis to represent them commonly, and

then it is verified whether it matches all pictures totally in each group. The tested hypotheses from two groups are compared, and it will be the solution if there are logically different, such as '*circle in a triangle*' v.s. '*triangle in a circle.*'

We hypothesized that the logical reasoning process with limited numbers of meta-data descriptions realizes the sophisticated and prompt decision-making, and the performance is validated by using BPs. In this study, a semantic web-based hierarchical model to solve BPs was proposed as the minimum and transparent system to mimic the human-logical inference process in solving of BPs by using the Description Logic (DL) with assertions on concepts (TBox) and individuals (ABox). Our computer experiment showed that 65 Bongard problems were solved in the proposed framework. It indicates that the semantic information coordinator works well to solve a type of frame problem by coupling with an autonomous classifier and generalizer. The framework may contribute to the design of the general artificial intelligence in part, especially on coordination against autonomy in semantics.

In summary, this thesis helps to pave the practical approach of understanding ill-posed problems and working towards solving them using ontologies. This demonstrates the effectiveness of the semantic network and description logic, and then the common principle is expected to be formulated, and the principle explains why the semantics and logic work well to solve the BPs to avoid an infinite time for the calculation. Our results demonstrated that the proposed model not only provided individual solutions as a BP solver but also proved the correctness of Hofstadter's idea as the flexible frame with concept networks for BPs in our actual implementation, which no one has ever achieved. This in fact will open the new horizon for theories for designing logical reasoning systems, especially for critical judgments and serious decision-making as expert humans do in a transparent and descriptive way of why they judged so.

Keyword

Bongard Problem (BPs), Meta-data Ontology, Resource Descriptive Framework (RDF), Semantic Web Rule Language (SWRL), Web Ontology Language (OWL) .

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This reminds me -

Guru Govind duo khade, kake lagu pao...
Balihari gurur aapne, govind deo bataye...

(Translates to- If guru (Teacher) Govind (God) appear together in front of me, whom should I pay my first respect (i.e., touching the feet), further Kabir Das says - It is better to pay, first respect to the teacher because he is the one who guides us towards God.)

I would particularly thank my parents, who supported me emotionally throughout this beautiful Ph.D. degree. Thank you so much; you always there for me. You genuinely define unconditional love. And a special thanks to my little brother Manish for his emotional support and sympathetic ear.

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Chapter 1

Introduction

Recently, multi-layer neural network models and machine learning approaches for computer vision and the first-order symbol grounding or automatic meta-labeling in the language processing accompanied with massive digital data with an amount of computer hardware performances have made prominent progress in mimicking a part of abilities of humans [29, 28], which are called Artificial Intelligence technologies or 'AIs' simply and highlighted as 'technological singularity' [5]. It sometimes exceeds human abilities related to the memory capacity and information processing speed, as is demonstrated in human-machine matches of board games [4]. However, the realization of mechanisms to reproduce higher-level abilities remains unsolved, such as sharing human values concerning emotional reactions, understanding human intentions and semantics in communication without explicit background information and adaptivity/flexibility of making an arbitrary frame of thinking to solve the facing problem depending on individual 'situation,' known as 'frame problem' [31]. Those abilities autonomously emerge in the human brain, and therefore the generality and autonomy in AIs beyond conventional machine learning schemes are highly expected [12].

Even an infinite number of possible options are abounding in front; the human intelligence can focus on possible and vital options for making a decision to avoid the Frame Problem that McCarthy and Hayes formulated in 1969 [1]. The ability on multi-dimensional problem-solving is a clue for providing an intelligent machine

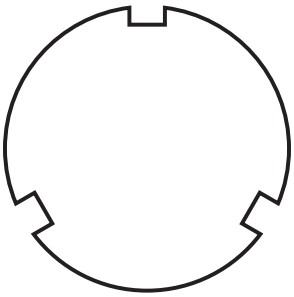


Figure 1-1: 'A kind of circle', or 'circular shape with notches.' An abstraction and then it becomes a simple representation.

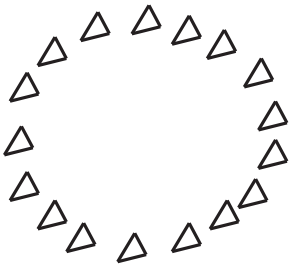


Figure 1-2: 'A kind of circle', or 'circle made of triangles.'

equivalent to our intellectual level in the case of context-dependent problems or ill-posed problems, and it requires the machine to solve the following issues as primitive functions-

1. Problem-solving ability in bounded time,

2. Abilities to select a minimum set of clues to solve the target problem and compensate lacks of information depending on circumstances in ill-posed problems,

3. Integration of past and present knowledge and the accumulation into a consistent internal (knowledge) model for providing intelligent behavior (selection),

4. Understanding of analogies that we usually use in perception and action naturally [2, 3], which can be built by probabilistic approaches [4].

A possible hypothesis to answer the question of why the human brain is flexible and autonomous for generating an appropriate frame of thinking is that it is realized from an integration of different types of computations, which are briefly classified into two domains related to implicit memory and explicit memory. In the former one, the procedural memory, for example, is maintained the basal ganglia and related brain regions, which is considered to be reproduced by the reinforcement learning scheme,

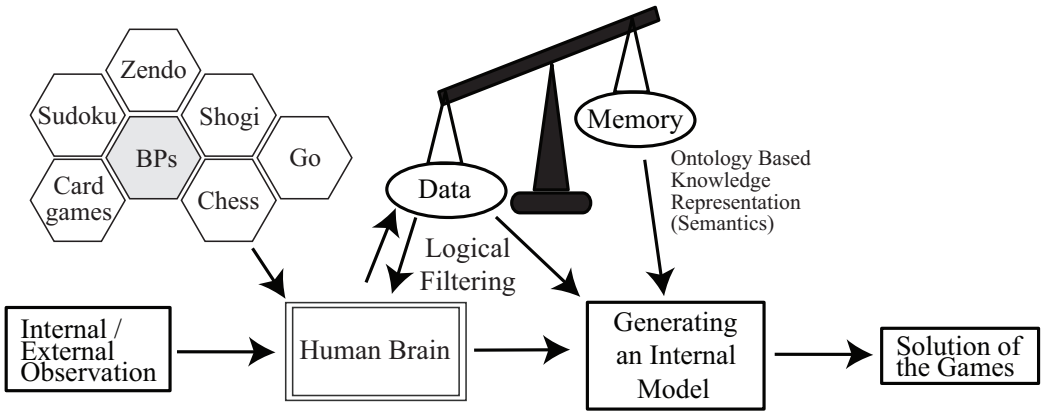


Figure 1-3: Why are BPs really difficult compared to other ill-posed problems

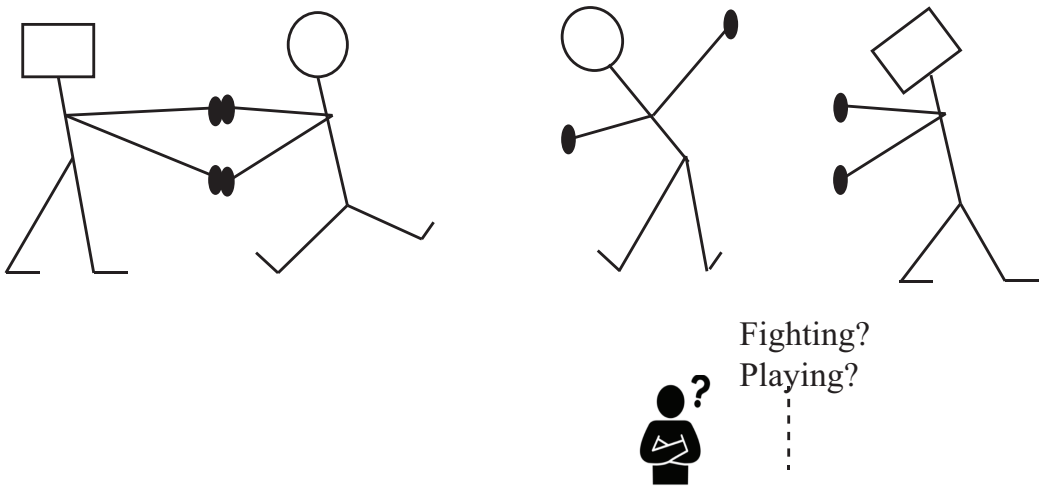
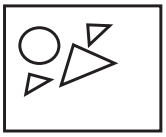


Figure 1-4: An visual puzzle- what are the kids doing? [37]

while the human has no awareness of what is going on in the learning process but posses abilities to discriminate what it is as an automatic classifier and to take the best action to maximize the benefit, which can be formulated by the Markov process. In contrast, the latter function is associated with human consciousness. The mechanism of how the consciousness emerges in the brain is still an unreached problem, or mystery, in spite of our tremendous efforts of integrative research fields, while there are significant ambitions in constructive and embodiment approaches to build it artificially. In the present study, the working hypothesis is addressed that the flexibility of making a frame of thinking depending on the context is reconstructed by the fusion of implicit and explicit memory functions, as the basement assumption, and then it

BP #21 Box-L_6



three shapes
or
four white space
or
three Triangles
or
a circle on the left
or
one upward pointing triangle
or
two large shapes and two small shapes
or
two triangles with same kind of shape
:

Figure 1-5: An example of the picture in a BP, which is represented by redundant and polysemic representations in word, as D. R. Hofstadter discussed in his book [15].

allows us to focus on a conscious process of how the brain simply represents what happens in the world, , *i.e.* analogy by words. In particular, the logical reasoning process in such representations can be considered as a dynamic process from the low-level meta-label generation to semantics observed in the higher cognitive functions [11, 1].

According to the advancement of Semantic Web approaches, semantic information and its relevance to the brain information processing can be discussed in the framework of computational models based on the theory of logic.

As McCarthy and Hayes (1969) proved in the form of the frame problem [7], the machine has a limited power to classify necessary and unnecessary events with respect

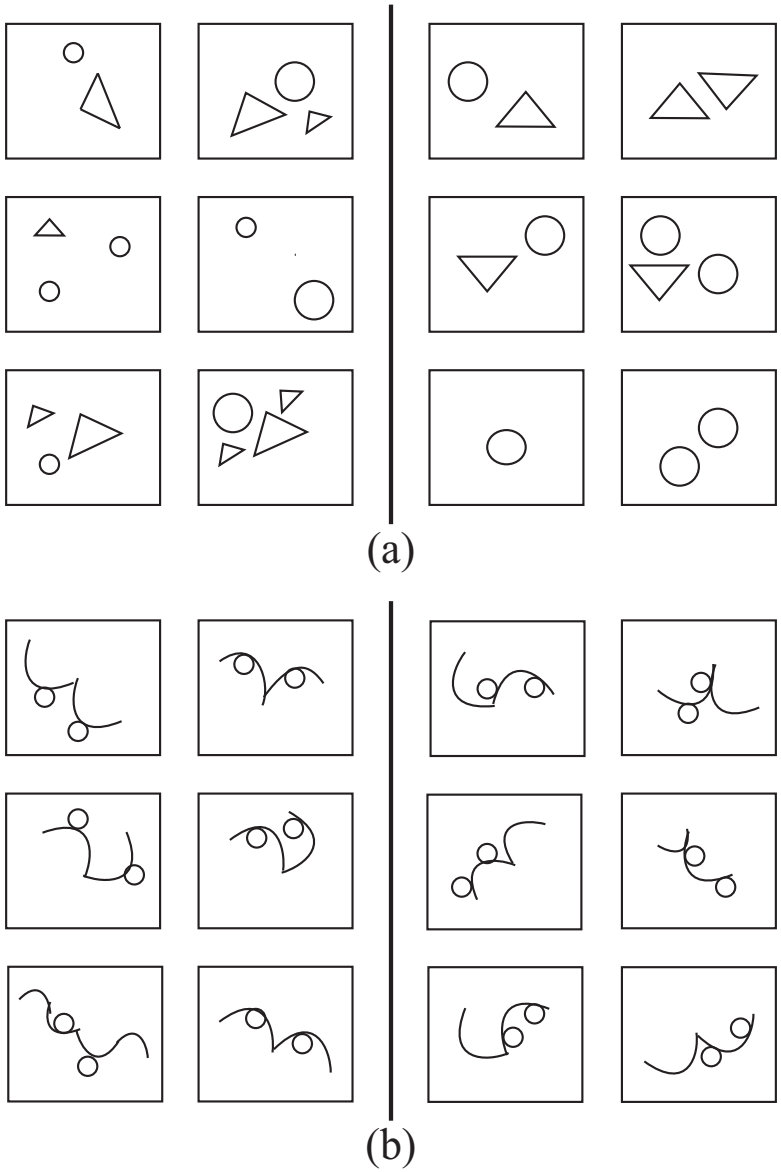


Figure 1-6: (a) BP #21 Small figures versus large figures; (b) BP #44 Circle on different curves versus Circles on same curve [15, 16]

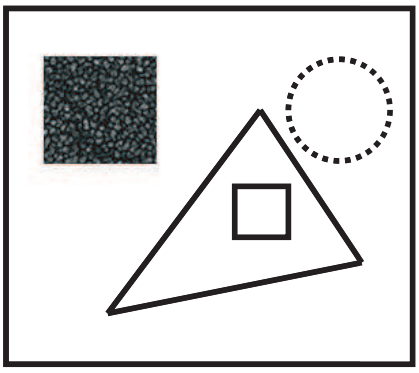


Figure 1-7: Understanding a box in an BP.

to the current context for making a decision at each short moment if the events are described as an infinite number of discrete and countable representations. Therefore, a key question of why the human intuition can avoid the frame problem and prevents the halt of thinking can be replaced by the question of the existence of the ability in the brain to change abstraction and analogy levels flexibly depending on the current context.

A good example is the Steiner Tree Problem in graphs, which is a NP-hardness in computational complexity theory. For example, the problem asks us to 'find the point to minimize the summation of distances from every node of the rectangle' and the answer can be found easily as the crossing point of two lines connecting two most distant points individually, by introducing the concept of 'connecting lines' instead of finding a point from $R \times R$ infinitely [10]. The fact indicates that the human intelligence focuses on vital information that is crucial for current decision making by using an appropriate abduction with logic. Some researchers have tried to introduce the semantics in the form of annotations with classified data obtained by probabilistic approaches [2, 3]; however the practical combinations with semantics into the data analysis do not provide the right answer to our cognitive ability to set an appropriate level of abstraction [11, 12]. In the early stage, such a higher level cognitive function was modeled with long-term memory, planning, and logical decision-making abilities

as conceptual models [13, 18], which were far from an actual benchmark validation of how the fine logical reasoning process contributes to the function.

In consideration of semantics in higher cognitive functions, a systematic progression can be recognized based on the theoretical advancement of the symbol logic and its implementation in the form of the semantic web technology, with respect to AI symbolic approaches in 1970-1980 [11, 1].

1.1 Ill-posed Problems

In our everyday life, we are continually dealing with ill-posed problems. With an excellent visual and mental perception of this world, we can quickly and effectively solve such problems. Ill-posed problems are most demanding in solving because of their solution instability (i.e., a small error in the data measurement may lead to an infinite significant error in solution). Hence the mathematical term ill-posed problem has the following significant criteria-

1)a single solution so not exist

2)the solution is not unique

There exists many ill-posed problems (games like Go, Zendo, etc.; and even issues like allocation in real life-cycle inventories, etc., or simple tasks like deciding what to eat for lunch) which requires complex problem understanding solving, rather than a trial-and-error method for the approximation of solution (like- well-posed problems). Similarly, what if we see two children, as in Fig. 1-4, at a park. We can easily come at multiple hypotheses such as- the kids are playing/ the two kids are fighting/ two kids are playing pulling and pushing game..etc. Hence there are multiple predictions possible (not unique), which varies with the observer. This brings us at- How do we understand such puzzles and make machines make such open-world predictions?

Simailar to this example of two children, there are multiple ways to represent an image (as shown in Fig. 1-5 and Fig. 1-7). This also brings us to an question, what is the best representation in the current context for an image?

Looking into the theory of evaluation, in the past, our ancestors had a simple

eye design including few light receptors and few neurons carrying the information to the brain. However, with the passing time frame, the process of natural selection and adaptation led to the modification of this primitive eye into a sophisticated eye with a large number of light receptors and muscles. However, this time, the neurons carrying the information from billions of light-receptors were getting in the way of light. Nevertheless, evolution did not give up and decided to stick with the original plan and make a significant modification by bringing all the nerves together and forming a big optical bundle and taking it through the retina, making a hole leaving us with a blind spot (no receptors).

However, in ordinary life, we do not notice two blind spots. So, -*Does our brain fill missing pieces of information to cover the gap? Are we just making guesses or assumptions about what is there?*

Scientists like Dennett believe in the concept of conceptual filling-in and making guesses (assumptions) every time we look around. This idea of blind spot intrigued my curiosity to know more about visual perception and the cognitive abilities of the human brain through visual games.

According to the above mentioned ill-posed issues, Hofstadter introduced Bongard problems in his book [15] as a benchmark to test an intelligent level of the agent, in the form of the logical picture puzzle. Bongard Problems are a set of 100 visual puzzles that will be the benchmark test for understanding the flexible change of the analogy level fit to the given problem as D. R. Hofstadter suggested [15], which is considered as an NP-hardness similarly to the Steiner Tree Problem. These puzzle requires a coupling between meta-cognition and logical reasoning for providing a higher level of analogy like human naturally do, and it was originally proposed by Mikhail M. Bongard. In this problem, three core architectures are considered to cooperate together,

1) an auto-generative system to represent characteristics in the target picture with primitive forms (autonomous label generator),

2) a semantic network coordinator to find an appropriate representation without redundancy (coordinator/evaluator), and

3) an analogy maker to bind a set of the characteristics and to set a consistent representation in a simple form by ignoring unnecessary parts to conclude (generalizer).

In other words, autonomy and generality are not enough for designing an intelligent agent to solve the Bongard problems, and then the architecture design will be completed to add a complementary architecture as the semantic network coordinator to mediate two systems.

As shown in Fig. 1-3, there are similarities of logical reasoning processes in games such as Chess, Go and so on [5, 6], in the sense of recursive searching on all the possibilities from the current situation, which may cause a combinatory explosion. However, it is restricted by constraints by rules and the player's strategy [7]. In a formal way to simplify the games, Bongard Problems consistently have nearly infinite infeasible possibilities to find the unique and minimum necessary and sufficient conditions to solve the puzzle. Hence, among such vast choices in the field of ill-posed problems, we were more fascinated by BPs and their universality.

In this study, we focused on second and third issues through the exploration of a solver of BPs. There are studies focusing on semantics to solve games [5, 6, 7, 8, 9, 10, 11, 12]; however, those are mostly in case studies. We believe that a systematic treatment by using the mathematical formulation of the solver and the implementation into a standard logic description is crucial for the elucidation of internal mechanisms of the brain to solve BP problems.

1.2 Bongard Problem

Bongard problems (BPs) are a set of 100 visual puzzles introduced in the mid-1960s by the Russian scientist Mikhail Moiseevich Bongard in his book *Pattern Recognition* [15]. This set of two-dimensional graphical puzzles involves pattern recognition, categorization, and logical decision-making tasks to infer the similarity and dissimilarity that govern them. Every BP inherits the quality of universality of unique solutions. Although BPs are an excellent means to validate the interaction of human vision and

cognitive abilities, they impose tremendous challenges in the field of AI in mimicking human logical thinking abilities.

A BP consists of 12 boxes, as shown in Fig. 1-6, with a lump of six boxes on the left side and another lump of six boxes on the right side. The goal of a BP player is to find contradictory rules to logically discriminate the two given lumps, which means that the rule applicable on one side of the BP will not hold true for the other side.

A line separates six boxes of the BP as left and right sides. For the mathematical formulation, each side in a given BP is indexed as L_i and R_i $(i = 1, \cdots, 6)$. As shown in Fig. 1-5, each box holds potentially a potentially infinite number of properties per feature, and the interrelations between each preexisting property also lead to a new set of dependent properties, as an analogy. Thus, if it is possible to reproduce a BP solver artificially, the system can be considered to mimic the human decision-making ability in ill-posed problems by the performance to find the simplest representation from an infinite number of possible combinations in the form of the set of properties.

1.2.1 Problem Definition

If a problem is in BPs, there exist two sets to be determined by contradictory rules each other. Therefore, if $\mathbf{S}_A$ and $\mathbf{S}_B$ are assumed to be the sets, every picture in left boxes is a element of $\mathbf{S}_A$ and every picture in right boxes is a element of $\mathbf{S}_B$ and then there is no overlap, which is formulated as

$$\mathbf{S}_A \cap \mathbf{S}_B = \emptyset \tag{1.1}$$

For example, if rules are given as *'there exist a triangle'* and *'the number of circles is larger than one'* as a first abduction, the result is

$L_i \in \mathbf{S}_A$ $(i = \{1, 2, 3, 5, 6\})$,
$R_i \in \mathbf{S}_A$ $(i = \{1, 2, 3, 4\})$,
$L_i \in \mathbf{S}_B$ $(i = \{3, 4\})$,
$R_i \in \mathbf{S}_B$ $(i = \{4, 6\})$ and

$L_4 \notin \mathbf{S}_A \wedge L_4 \notin \mathbf{S}_B$

Thus, it does not satisfy Eq.1.1. In the second abduction, if rules are given as *'there exist shapes with different sizes'* and *'the shape size is consistent at all'*, the result becomes much better as

$L_i \in \mathbf{S}_A$ $(i = \{1, 2, 4, 5, 6\})$,
$R_i \in \mathbf{S}_B$ $(i = \{1, 2, 3, 4, 5, 6\})$ and
$L_3 \notin \mathbf{S}_A \wedge L_3 \in \mathbf{S}_B$

However, the performance of the logic puzzle is not evaluated according to the error rate numerically, and then it is clearly rejected as the BP solution. Finally, the solution is obtained as *'there exist a small shape'* and *'there are no small shapes'* under the complementary assumption of *'small means that the largest length of sides, or diameter, is smaller than one-fifth of the base length of the picture area'* as a hidden knowledge. The solution satisfies Eq.1.1 without any exception.

Considering two properties P_a and P_b, where both the properties do not overlap, could be considered as the best possible solution to a given BP (as in Eq.1.2)

$$(L_i \notin P_a) \cap (R_i \notin P_b) \cap (L_i \in P_b) \cap (R_i \in P_a) \cap (P_a \cap P_b = \emptyset) \tag{1.2}$$

Each box in a given BP have multiple object instances (Eq.1.3 and Eq.1.4) to solve. In principle, every picture of the box can not only has an infinite set of independent properties (IP) to represent how the picture is categorized, such as *circle* or *triangle* (as characteristics of the object) but also has dependent properties (DP) as determined by relations with other objects such as *smaller/larger*, *close/far* and *left/right* and so on.

$$\mathbf{x^{L1}} = (x_1^{L1}, x_2^{L1}...., x_n^{L1}, ...) \tag{1.3}$$

$$\mathbf{x^{R1}} = (x_1^{R1}, x_2^{R1}...., x_n^{R1}, ...) \tag{1.4}$$

The fact implies that the BPs require relative information (Independent and dependent properties) to solve. These relationships can be described as follows (for each box in BP),

where,

$$Properties(x^{L1}) = (IP_{objects}, DP_{within\_objects})_{L1} \tag{1.5}$$

$$Properties(x^{R1}) = (IP_{objects}, DP_{within\_objects})_{R1} \tag{1.6}$$

Considerable properties are classified into two, at least, and they are independent and dependent properties. The independent properties include elementary features such as size, shape, color, texture, spatial relationship such as the absolute position in the box, which represents with prepositions and adverbs as "*below*" and "*above*" and so on and numeric count. On the other hand, even independent properties have an infinite number of representations. For example, a name of shape "triangle" can be represented by three edge shapes, and a shape consisted of lines only, which goes to more primitive elements of what "triangle" means. In the same way, the numeric count has a high degree of freedom for the selection of the target property, such as the number of "*black circles*", "*edged objects*", "*squares in the corner*" and so on (as shown in Fig. 1-7). In addition, dependent properties are apparently infinite. Therefore, the parameter space to find the solution which is defined frequently in conventional data-driven approaches is not given a prior. The hint to solve this problem is coming from the abduction of the initial frame of thinking.

In the consideration of the properties, the box $\mathbf{R_2}$ in Fig. 1-7 can be described as follows:

$$\mathbf{x^{R2}} = (Line, Circle, Triangle, ...) \tag{1.7}$$

$$
\begin{aligned}
&properties(Circle) = \\
&((Rounded, ..{}_{independent}), (leftOf, ..{}_{dependent}))
\end{aligned}
\tag{1.8}
$$

It is because that *'triangle'* can be decomposed of three lines.

In the same way, in the process of the abstraction or simplification, Fig. 1-6 (b) requires us to think of *'position'* by ignoring the difference in color, shape (rounded or edged) and detail textures. Since possible BP solution are distributed in infinite numbers of axes, it is difficult to find the solution by using random search algorithms targeting spaces with a fixed number of axes. To reach the solution in a finite time, a gradual increase in the number of properties for the combination (search space expansion) is required and associated with a contraction of space dimension by abstraction (search space contraction) as an optimization problem. In the present study, we hypothesized that the property management for controlling the space dimension and the logic rule implementation are well organized in an ontology-based approach as a BP solver.

For the sake of simplification, we assumed that the image segmentation and feature extraction are automatically processed prior to the proposed system, and then this study focused on the rule generation and evaluation process with respect to the judgment as Eq.1.1. It highlights the importance of effective knowledge representation for making logical inferences for solvers of BPs.

A condition that satisfies the relation is:

$L_i \notin P_a \cap R_i \notin P_b \cap L_i \in P_b \cap R_i \in P_a$, this relation could be considered as the best possible solution to a given BP. From this condition, it is clear that a property satisfying one of the side of a BP must hold false for the other side. Based on the original assertions, logical rules must be formulated to evaluate the relationships-

$||(L_i \notin P_a) \wedge (R_i \notin P_b) \wedge (L_i \in P_b) \wedge (R_i \in P_a) \wedge (P_a \cap P_b = \emptyset)||$-> $||(L_i has P_b)|| \wedge ||(R_i has P_a)||$,

Hence, this relationship (either independent or dependent properties) can be used to carry out deductive reasoning of two distinct features on either side of a given BP.

Since possible BP solution are distributed in infinite numbers of axes (Properties(x^{L1}), Properties(x^{R1})..... Properties(x^{L6}), Properties(x^{R6})), it is difficult to find the solution

by using random search algorithms targeting spaces with a fixed number of axes. To reach the solution in a finite time, a gradual increase in the number of properties for the combination (search space expansion) is required and associated with a contraction of space dimension by abstraction (search space contraction) as an optimization problem.

In the assumption of a high-quality visual processing will be treated appropriately by algorithms based on probabilistic models, , *i.e.* machine learning scheme, the target problem will be addressed as a dynamic association among possible items to represent what it is in a minimum way and to maximize the fitness for requirements in the context. There are multiple ways to represent what the picture is, which is consisted of redundant and polysemic representation in words (as shown in Fig. 1-1 and Fig. 1-2). The question arises what is the best representation in the current context and how we can solve the problem.

In the present study, we hypothesized that the property management for controlling the space dimension and the logic rule implementation are well organized in an ontology-based approach as a BP solver.

1.2.2 Why are BP's Interesting in the Field of AI

Currently, the number of the BPs is more than 200 pieces. The most important point of the puzzles that differ from other visual puzzles is that the solver has to get rules to discriminate groups of visual patterns and provide a simple logic.

Looking at a few BPs like- BP#61, BP #70, etc. makes it clear that ones' intuition gained from a wide variety of seeing and handling of objects in wide space is a key factor in solving these puzzles. Understanding of real-world objects like- *leaf*, *flower*, *train*, etc., play a crucial role in guiding a BP solver towards finding the solution to the puzzle. So, we believe that solving BPs have a significant contribution in the field of AI in understanding the core of "pure" intelligence.

From the theoretical point of view, the problem can be treated conventionally, such as the definition of the solution space by the combination of all possible properties, while it apparently faces two difficulties. The first one is an infinite number

of combinations of properties, and the latter one is the computation time in such an ample solution space. Therefore, the parameter space to find the solution which is defined frequently in conventional data-driven approaches is not given a prior. The hint to solve this problem is coming from the abduction of the initial frame of thinking.

Hofstadter [15] has discussed in his book about a concept of a systematic recursive approach to the context-based description to set an appropriate abstraction level in the beginning based on semantics and logic and then proposed a combination of functional components as-

i) concept network,

ii) frames,

iii) meta-descriptor,

iv) filtering and

v) sameness detector.

As illustrated in Fig. 1-11, there are different levels of concepts, and it might be treated in the design of the concept network for minimizing the frame to find a solution, which is accompanied by an effective filter based on meta-data descriptions. If it is possible, the solver can deal with BPs in varying levels of complexity. Piaget [6] was also discussed the developmental process in the cognitive development of children in his theory, and it explains that there are stages of analogy from schema to mental operation of actions. In BPs with advanced versions added by Foundalis [16], Some BPs also requires an action-related representation obtained by the combination of the cognitive perception and mental object manipulation as classified.

1.3 Literature Review

Although BPs are popular among AI researchers as a challenging task for an intelligent system to make logical decisions as humans do, only a few approaches were formulated to try to solve a handful of BPs. RF4 is an adaptive concept learning algorithm that could solve 21 of the 100 BPs using pre-written first-order logical formulas. RF4 completely avoids the visual input by coding the images manually by human

intervention. Phaeaco, on the other hand, was a two-layer architecture emphasizing on retinal and cognitive level computation using visual input. It was more prone to ambiguity in logical inferences from the set of infinite visual information (visual noise) available. Phaeaco could solve nearly 10 out of the 100 BPs.

1.4 Objective of Dissertation

There are two main objects of this dissertation. The following subsection highlight the objectives -

1.4.1 Solving Ill-posed problems with Semantics Web Technology

The main objective of this dissertation is to introduce a method to solve BPs using the semantic web technology to treat hierarchical semantic information arisen in the abduction and the logical reasoning to obtain the conclusion and then proposed a computational model for solving the problems by using an architecture of hierarchical abductions. Possible combinations of primitive descriptions like '*vertical triangles and horizontal ellipse*' are arisen as a test hypothesis to represent them commonly, and then it is verified whether it matches all pictures totally in each group. The tested hypotheses from two groups are compared, and it will be the solution if there are logically different, such as '*vertical triangles and horizontal ellipse*' v.s. '*horizontal triangles and vertical ellipse*'.

Ontologies help in categorization / creating a hierarchical model of some concept. Each concept in the real world can be semantically grouped hierarchically. For example, as in Fig. 1-10, a category *cat* can be separated from class *dog* for easy understanding of the distinctions and related features of both the categories. Using a Semantic Web technique, one can create a database that has both logical and conceptual models in sync. Here input data was dynamically stores in a $<s, p, o>$ format along with the properties of each instance in an easy human and machine-

understandable format.

OWL (Web Ontology Language) uses an open-world inference (it can not only say "yes" and "no", but can also say "i don't know"). Hence we believe that using abstract grouping using Ontology in an infinite (multidimensional space) for a puzzle like BP can be a key solution towards understanding abductive human logical inference.

Our computer experiment showed that 65 selected Bongard problems were successfully solved using the proposed framework. It indicates that the semantic information coordinator works well to solve a type of the frame problem, by coupling with autonomous classifier and generalizer. The framework may contribute to the design of the general artificial intelligence in part, especially on coordination against autonomy in semantics.

1.4.2 Working towards General Artificial Intelligence- by integrating Hofstadter's idea

Dr. Douglas R. Hofstadter[15] believed in the concept of *Concept networks*, where it is a kind of semantic net in which all the known nouns, adjectives, etc., are linked in ways which indicate their interrelations. In other terms it is a vast static knowledge where both the nodes and links convey information.

To simply understand the Fig.1-11, this concept network depicts two kind of informations, where (1) are simple informations and (2) are higher level of relational information-

(1)

"*Right*" and "*Left*" are "*Opposite*"
"*High*" and "*Low*" are "*Opposite*"
"*Up*" and "*Down*" are "*Opposite*"
"*High*" and "*Up*" are "*Similar*"
"*Low*" and "*Down*" are "*Similar*"

"*High-Low*" distinction is similar to "*Right-Left*" distinction

(2)

"*Square*" "*is*" "*composed of*" "*4*" "*Line Segments*"
"*Triangle*" "*is*" "*composed of*" "*3*" "*Line Segments*"

According to the concept by Hofstadter [15], we rebuilt the components based on the theory of sets and tools in the semantic web and proposed the system to solve BPs with-

i) ontology-based description to represent the necessary concept network,

ii) Description Logic (DL) with assertions on concepts (TBox) and individuals (ABox) to provide minimum frames,

iii) meta-data template,

iv) SPARQL Protocol and RDF Query Language shortly SPARQL for the filtering function and

v) Semantic Web Rule Language (SWRL) rules as sameness detector.

According to Dr. Douglas R. Hofstadter[15], the mental representation of a situation is a layer by layer architecture. Here the lowest layer is constant information, which is static and contains the most in-depth information about the given context. The successive layers would be more unstable and would include the background information according to the situations. In our approach, we have employed such a hierarchical knowledge base with fixed and volatile data.

The detail formulation is given in following sections and the validation of the system as the BP solver is shown in the chapter 4's result section.

1.5 Organization of this Dissertation

This dissertation is organized into two major parts *i.e* mathematically understanding the complexity of Bongard Problems and designing a new hypothesis to solve the BP puzzles. The first part consists of understanding BPs and their importance in AI

along with its multidimensional complexity. The second part consists of a detailed study of OWL language and implementing OWL in solving ill-posed problems (a step towards general AI).

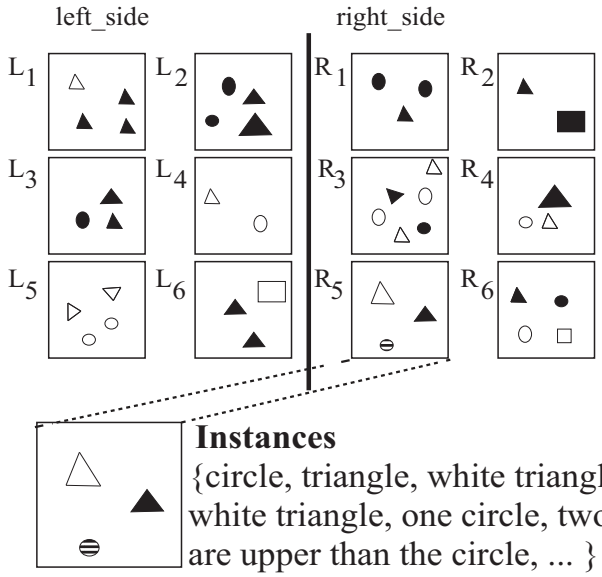
Chapter 2: This chapter comprises all preliminary knowledge and information related to Ontologies and the RDF/OWL language for modeling ontologies. This chapter introduces about Semantic Web technologies through an example of applying ontologies to solve real-world issues.

Chapter 3: This chapter comprises of the preliminary studies carried out on understanding the hierarchical structure of classes and the properties required to solve a simple BP (BP#37). In this study, a Semantic Web based meta-knowledge was developed using Protégé along with a hierarchical logical inference.

Chapter 4: By studying the use of RDF based inference of BP #37 (as studies in the previous chapter), we could partially demonstrate the effectiveness of the semantic network. To extend the use of semantic networks, in this chapter, we could effectively prove that the semantics and logic work well to solve the BPs to avoid an infinite time for the calculation. We applied this method to solve a set of 65 BPs based on visual inputs from a perceiver (through an interface) and successfully demonstrated the system to find the unique distinction between the two classes in a given problem.

Chapter 5: This chapter discusses the Challenge faced while solving BPs that use dependent properties. In this Chapter, we have addressed BP#38 using Protégé.

The rest of the dissertation includes the discussion and conclusion in Chapter 6. Chapter 6 also discusses the future scope of our approach.



Independent Properties
Circle1: { Size, Texture, Color, Shape, Position, The number of items,...};
Triangle1:..
Dependent Properties
Circle1: { Smaller than ... (relative size), To the bottom of ... (relative position)};
Triangle1:..

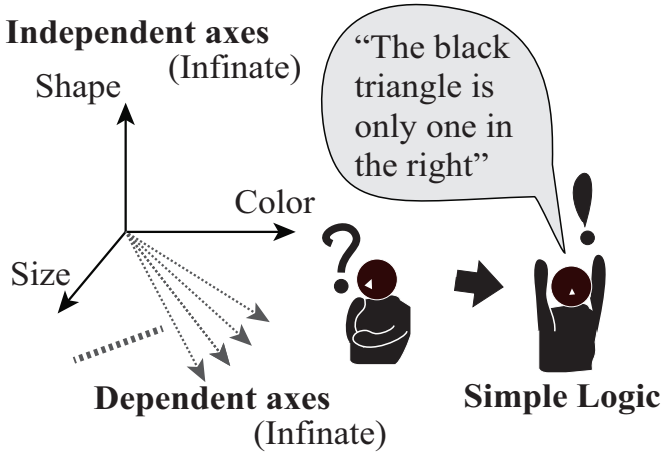


Figure 1-8: Complexity in solving BPs (each objects in a box has multiple independent and dependent properties, which increase exponentially with increase in the object count).

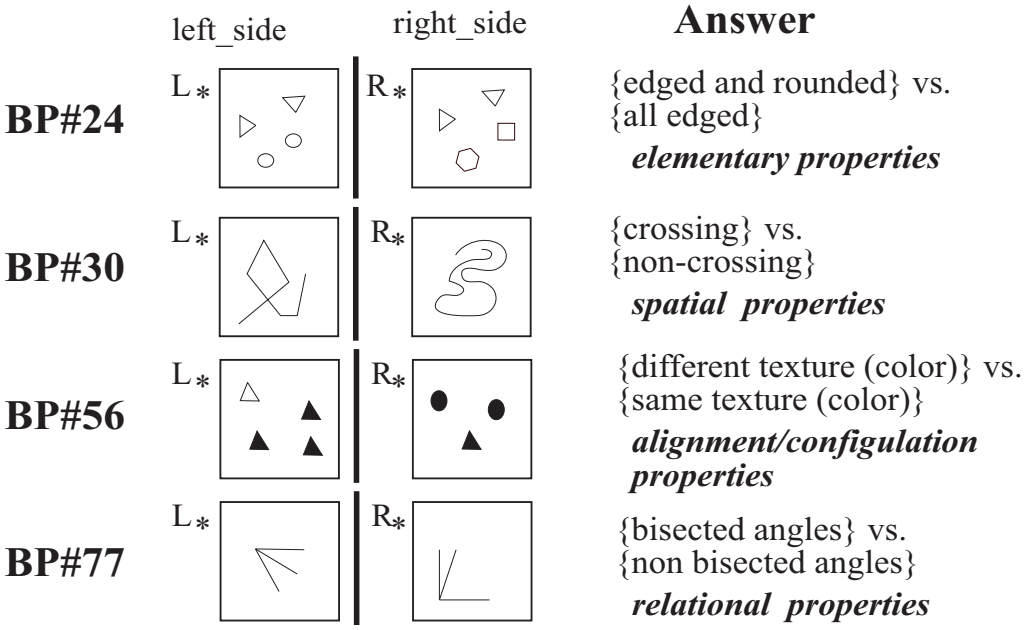


Figure 1-9: Levels of difficulty is consistent with abstraction levels.

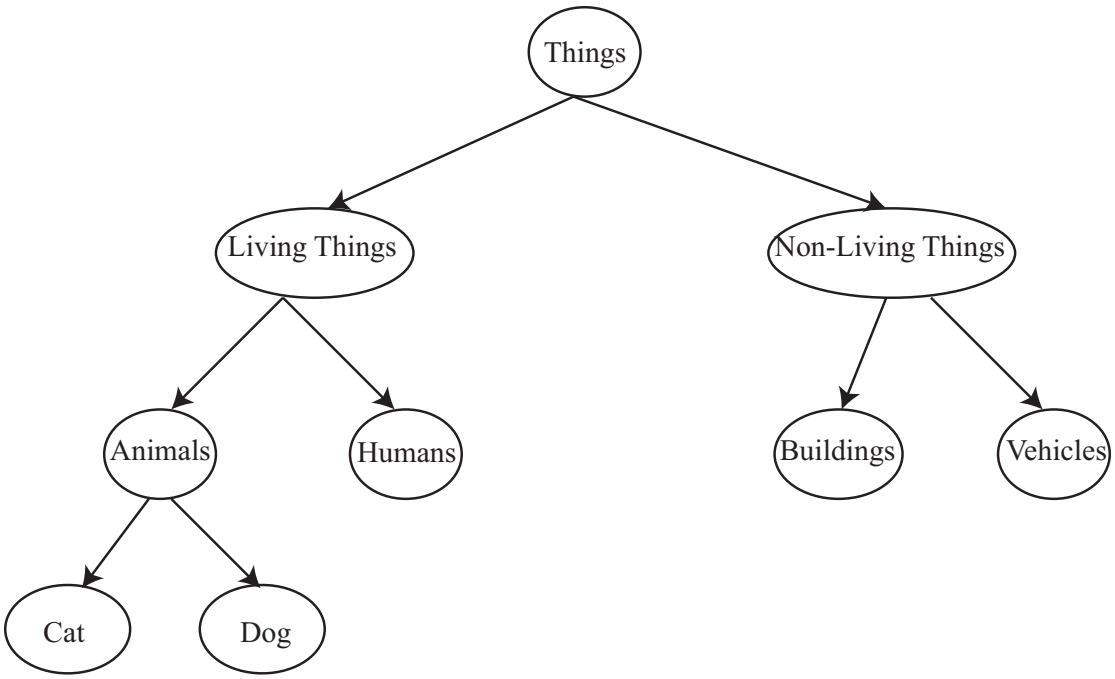


Figure 1-10: A hierarchy (grouping) of real world entities.

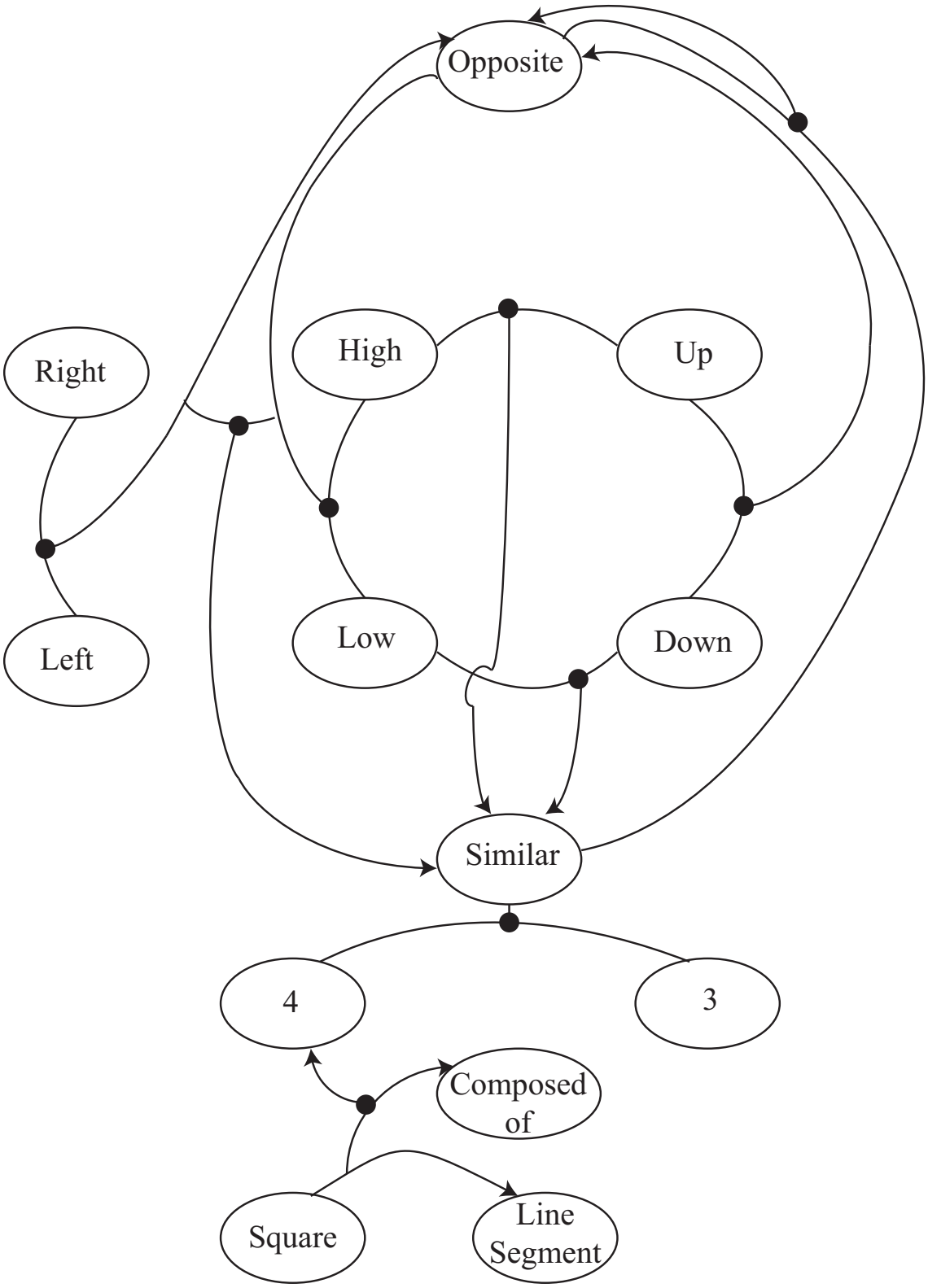


Figure 1-11: Re-written form of Hofstadter's Concept Network.[15]

Chapter 2

Semantic Web Technology

2.1 What is Ontology?

Ontology is a model that represents a concept in linked data format, and OWL is a formal language for expressing the ontology. It communicates what kind of things there are and how they are related to each other in a way that supports automated reasoning. An ontology can also be used informally to communicate shared meaning among humans (Like real word hierarchical grouping of information in Fig. 1-10).

OWL was designed to extend RDF, a pre-existing W3C Recommendation. RDF provides a straightforward graph-like data model, with each statement, for a triple, representing a labeled, directed edge in the graph. In simple words, RDF is a language used by OWL to represent triples, while OWl extends RDF by incorporating additional constraints, such as cardinality, restrictions of values, or characteristics of properties such as symmetry. It is based on description logic and so brings reasoning power to the semantic web. A triple consists of three elements called the subject, predicate, and objects, and they are often written as-

$$<s,p,o>$$

where,

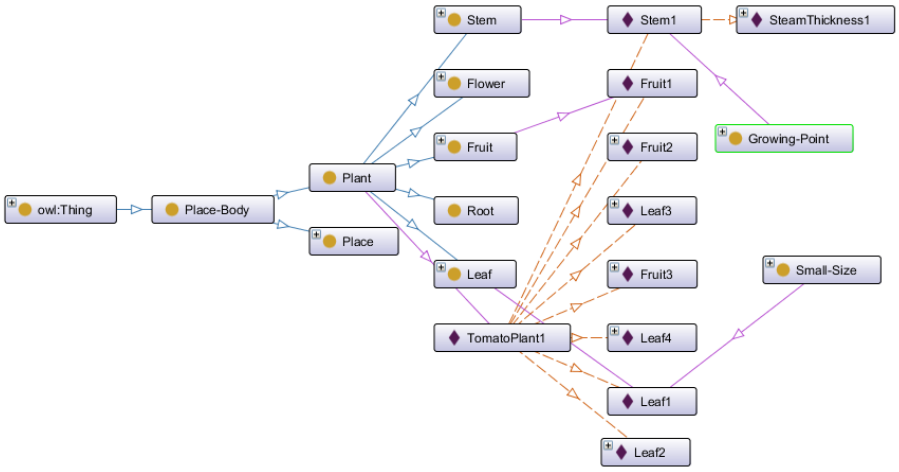


Figure 2-1: Visualization of Tomato Risk Management Ontology.

s is the subject about which (an individual) something is said (or described) e.g.-from Figure 2-1 subject is *TomatoPlant1*

p is the predicate which often corresponds to verbs (i.e relations between a subject and object) e.g.-from Figure 2-2 predicate is *Has*. Predicates are of three type- object properties, data properties, and annotation property., and

o is the object which is represented by individuals or literal (a value) e.g.-from Figure 2-2 object is *Fruit1*

Such a triple represents a *p* labeled edge from vertex *s* to vertex *o*; it can also be thought of as a first-order logic ground atomic formula *p(s,o)*, where *p* is a binary predicate and *s* and *o* are constants. A predicate *p*, can be either object property or data property. Object property relates an individual to another individual, while a Data property relates an individual to a literal (value). Unlike object and data properties, annotation property does not participate in interference and help in relating an individual to an IRI or literal.

Object Properties can have different characteristics-

1)Functional Property

IF: *HasBirthMother* rdf:type owl:FunctionalProperty. and

x *HasBirthMother* y. and x *HasBirthMother* z.

THEN: y owl:sameAs z

2)Transsistive Property

IF: *HasAncestor* rdf:type owl:TranssistiveProperty. and

x *HasAncestor* y. and y *HasBirthChild* z.

THEN: x *HasSibling* z

3) Symmetric Property

IF: *HasSibling* rdf:type owl:SymmetricProperty. and

x *HasSibling* y.

THEN: y *HasSibling* x

4)Inverse functional Property

IF: *HasBirthChild* rdf:type owl:InverseFunctionalProperty. and

x *HasBirthChild* y. and z *HasBirthChild* y.

THEN: z owl:sameAs x

5)Asymmetric Property

IF: *HasChild* rdf:type owl:AsymmetricProperty. and

x *HasChild* y.

THEN: ¬(y *HasChild* x)

6)Reflexive Property

IF: *Knows* rdf:type owl:ReflexiveProperty. and

x *Knows* y.

THEN: x *Knows* x. and y *Knows* y.

7) Irreflexive Property

IF: *MotherOf* rdf:type owl:IrreflexiveProperty. and

x *MotherOf* y. and x *MotherOf* z.

THEN: ¬(x MotherOf x)

As shown in Figure 2-2, a prefix is used to abbreviate the Uniform Resource Identifier (URI). OWL uses Internationalized Resource Identifiers (IRIs) (IRI is an internet protocol standard that builds on the URI protocol by greatly expanding the

set of permitted characters). In OWL, IRI uniquely identifies a resource (as shown in Figure 2-2, an IRI= name-space prefix + local name). There are different syntax and notations of OWL, e.g.-RDF/XML is the original OWL syntax (used in this thesis), Turtle, Manchester, N-triple, etc.

An example of RDF based data representation is DBpedia, which is a database version of Wikipedia and can be quries using SPARQL.

2.2 Description Logic

Description Logic (DLs) are a family of knowledge representation language that can be used to represent knowledge of an application domain in a structured and well-understood way. Description logic typically separated domain knowledge into two components, a terminology part, and an assertion part. The combination of both terminology and the assertion part forms a knowledge base (KB) [i.e.K=(T,A), where K is the Knowledge Model which consists of both TBox T and ABox A]. The terminology box defines the knowledge about the domain (database schema), e.g. *a fruit1 is a part of tomatoplant1, central stem is a part stem which is a part of the plant,...* ; while the assertion box represents knowledge about a concrete instance or situation, e.g. *tomatoplant1 is tomatoplant, growth is quickGrowth.*

To better understand ABox and TBox, the information provided above can be rendered as sentences in first-order logic as follows-

---

Terminology Box:

$$\forall y(TomatoPlant(y) \Leftrightarrow\ Plant(y) \wedge \exists\, x(HasFruit(y,x) \wedge Fruit(x) \wedge PlaceBody(x)))$$

$$\forall x(Stem(x) \Leftrightarrow\ CentralStem(x) \wedge\ \exists\, y(TomatoPlant(y) \wedge\ Has(y,x)))$$

Assertion Box:

TomatoPlant(TomatoPlant1)

Stem(Stem1)

Fruit(Fruit1)

Growth(QuickGrowth)

In Description logic syntax the above information can be stated as follows-

$TomatoPlant \equiv Plant \sqcap \exists HasFruit.Fruit \sqcap \exists HasFruit.PlaceBody$

$Stem \equiv CentralStem$

$TomatoPlant1 : TomatoPlant$

$Stem1 : Stem$

$Fruit1 : Fruit$

$QuickGrowth : Growth$

Here the first two statements of this knowledge base represent the TBox and the last two statements represent the ABox. In DL, the three main building blocks are- 1) Concepts: This represents a set of classes like: *plant*, *TomatoPlant1 isa Plant*..etc. 2)Roles: This represents the relations on elements like: *HasFruits*, *HasThickness*..etc. 3)Atomic and Compound concepts like: $\top$ (top of concepts), $\bot$ (bottom of concepts), $\neg$ (negation), $\sqcap$ (conjunction), $\sqcup$ (disjunction), $\exists$ (value restriction), $\forall$ (existential restriction).

The logic-based semantics of DLs means that we have a clear understanding of the knowledge base. From the above knowledge base, we can infer that *Fruit1 might be on Stem1 of TomatoPlant1.* Common reasoning tasks using DLs include checking the consistency of the knowledge and answering different queries on the KB. The power of DLs derives from the fact that reasoning tasks are performed to the whole KB.

2.3 OWL Tools and its Applications

The correspondence between OWL and DL means that the system can be used to provide logical reasoning for the OWl applications. There several DL based OWL reasoners available online (e.g., `https://www.w3.org/2001/sw/WebOnt/impls`).

On the other hand, there are OWL tools and environments that provide a conve-

nient and practical means to develop a DL knowledge base from scratch as per our application. In Chapter 3, we have employed a Pellet based OWL Reasoner. Some of the examples of other prominent OWl reasoners are- HermiT, FACT++, etc.

OWL API is a Java API used for creating and editing OWL ontologies in a various syntax like N-triple, RDF/XML, Turtle, etc. To understand the semantic web in solving a BP (BP #37), we have used the Protégé tool for developing and maintaining the OWL ontology. Protégé is an ontology editor (`https://Protege.stanford.edu/`), developed by the Center for Biomedical Information Research at Stanford University, which is free and open source. Protégé uses reasoning to support the development and maintenance process,e.g., checking for inconsistent classes, discovering implicit subsumption relationships, and answering queries over the ABox. Protégé interfaces to reasoners via the OWL API, and so can explore a wide range of reasoners [24].

Recent Applications of OWL were to develop several large scale biomedical ontologies like- The biomedical Pathway Exchange Ontology, the GALEN ontology, the Foundation model of Anatomy, the National Cancer Institute thesaurus, etc. The National Center for Biomedical Ontology supports the ongoing development and maintenance of Protégé and provides ontology-based tools for accessing and analyzing biomedical data.

Another relevant ontology is the SNOMED CT ontology, with more than 3,00,000 classes, which is used in the healthcare systems of many countries (27 countries). The Electricite de France Energy Management Adviser uses the HermiT OWL reasoner to produce personalized energy saving advice for their customers. The Energy Management Adviser uses an OWL ontology to model both relevant features of the domain (housing, environment, and so on) and a range of energy-saving tips. Customers are then described using RDF, and SPARQL queries are used to generate a personalized set of tips for each customer. The system has been used to provide tips to more than 3,00,000 customers in France.

2.4 Application-Independent Ontology Design and its reasoning

In Japan, according to the circumstances of an aging population, plant automation is highly expected due to the inevitable decline in the labor force in the aging society and supplements the dwindling workforce.

The problem is that nourishment control including temperature and humidity level regularization can be governed by the automation as well as automated factories, while the growth management and monitoring to prevent sudden changes and ill conditions require human experts with well-organized knowledge.

In principle, the biological system has an abrupt change with less predictable properties in a visible manner, and then traditionally, we understand that only the expert farmer can predict based on knowledge-based interpretation to fulfill a missing piece from observable data. Hence, to address this issue of automation, we had developed an ontological model for the monitoring of growing conditions for tomato plants and in checking the nutrient deficiencies from the symptoms (plant conditions).

Here, the natural language data is collected from the expert farmer or from books related to farming as follows-

Growth *is* **delayed**. The **leaves** *become* **compact**, the **stems** close to the *growing* point *become* **thinner**, the **upper leaves** *become* extremely **small and hard**. It *turns* **yellow** from the **lower leaf** to the **upper leaves** successfully. Although the number of **fruits** *is* **reduced**, it *grows* relatively **quickly**.

As an Ontologist, we convert the natural language information into RDF format. Here the information in bold like- **Growth**,**Leaves**.. etc., defines the subjects and objects for the OWL-based Knowledge graph (O_s and O_s). While the information in italics like- *is*,*turns* etc represents the predicates (O_p).

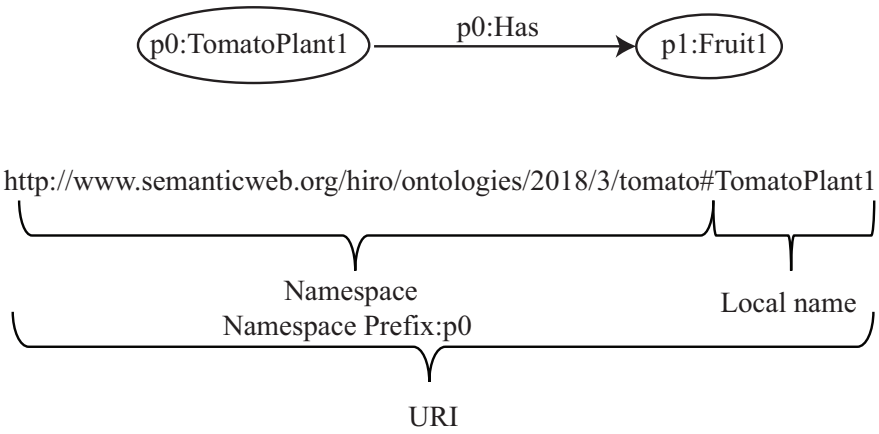
After selecting the suitable subjects, objects and predicates for the ontology, an RDF based triple data is generated as-

<Stem,growth,delay>,<leaf,growth,delay>,<leaf,size,small>,
<stem/growing_point,thickness,hard>,<leaf/upper,size,extremely_small>,
<leaf/upper,hardness,hard>,<leaf/upper/color,is_yellow_than,leaf/lower/color>,
<fruit,number,low>,<fruit,growth,faster>

From the above mentioned RDF triple, we formulate the SWRL rule as follows-

$Plant(?x) \wedge Leaf(?x) \wedge Has(?x, ?z) \wedge Small\_Size(?z) \wedge Stem(?x2) \wedge Growing\_Point(?x2)$
$\wedge Thin(?x2) \wedge Leaf(?z2) \wedge Has(?x, ?z2) \wedge Extremely\_Small\_Size(?z2) \wedge Hard(?z2)$
$\wedge Leaf(?z3) \wedge Has(?x, ?z3) \wedge Lower(?z3) \wedge Yellow\_level(?z3, ?p) \wedge Leaf(?z4)$
$\wedge Has(?x, ?z4) \wedge Upper(?z4) \wedge Yellow\_level(?z4, ?q) \wedge is\_darker\_than(?p, ?q)$
$\wedge HasFruits(?x, ?b) \wedge Has(?x, LessFruits)$
$\rightarrow N(?x) \wedge Has\_Deficiency\_of(?x, Nitrogen)$

Figure 2-6 shows the outcome of the Tomato Risk Management ontology using the SWRL rule described in Fig. 2-5 for nitrogen deficiency.




```
.....................
<Prefix name="p0" IRI="http://www.semanticweb.org/hiro/ontologies/2018/3/tomato#"/>
.....................
  <Declaration>
       <NamedIndividual IRI="#TomatoPlant1"/>
    </Declaration>
.....................
<Declaration>
       <NamedIndividual IRI="#Fruit1"/>
    </Declaration>
<ClassAssertion>
       <Class IRI="#Plant"/>
       <NamedIndividual IRI="#TomatoPlant1"/>
    </ClassAssertion>
.....................
<ClassAssertion>
       <Class
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       <NamedIndividual IRI="#Fruit1"/>
    </ClassAssertion>
.....................
<ObjectPropertyAssertion>
       <ObjectProperty IRI="#Has"/>
       <NamedIndividual IRI="#TomatoPlant1"/>
       <NamedIndividual IRI="#Fruit1"/>
    </ObjectPropertyAssertion>
.....................
```

Figure 2-2: An simple RDF based triple representation.

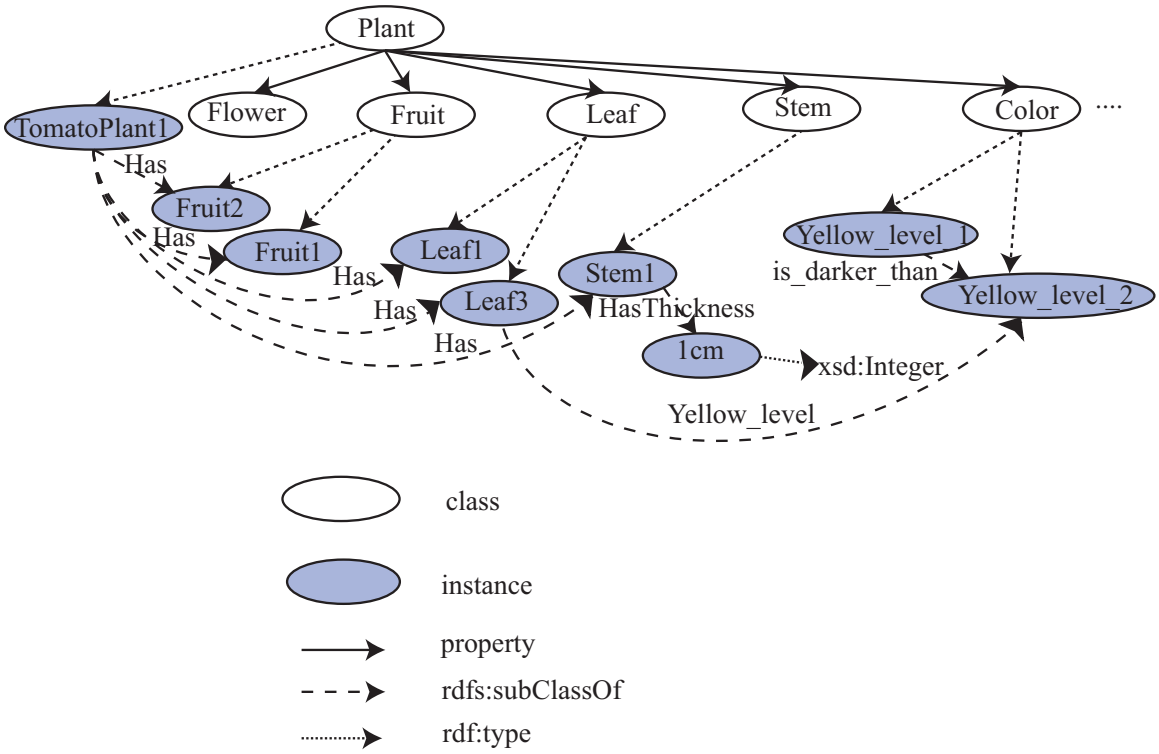

Figure 2-3: RDF Resources and their relations in Tomato Ontology.

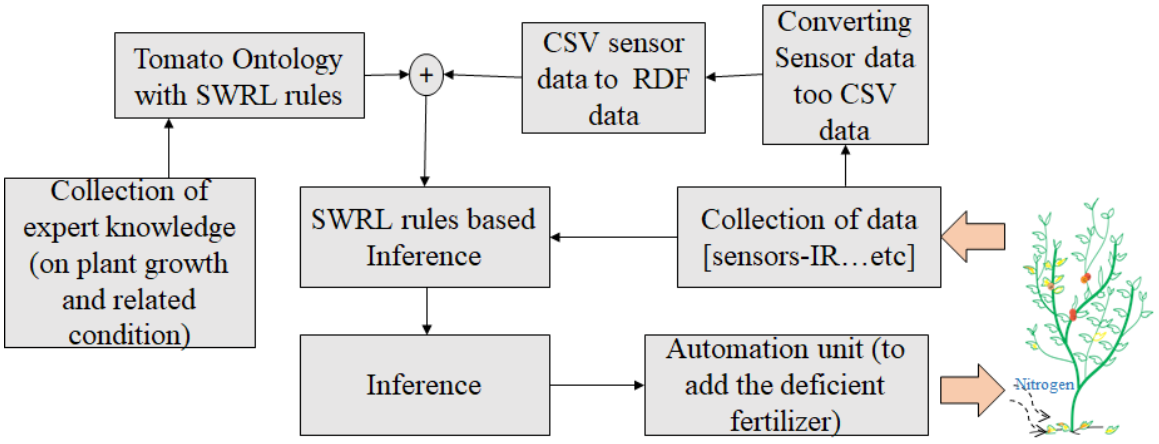

Figure 2-4: Agriculture Risk Management Hypothesis.

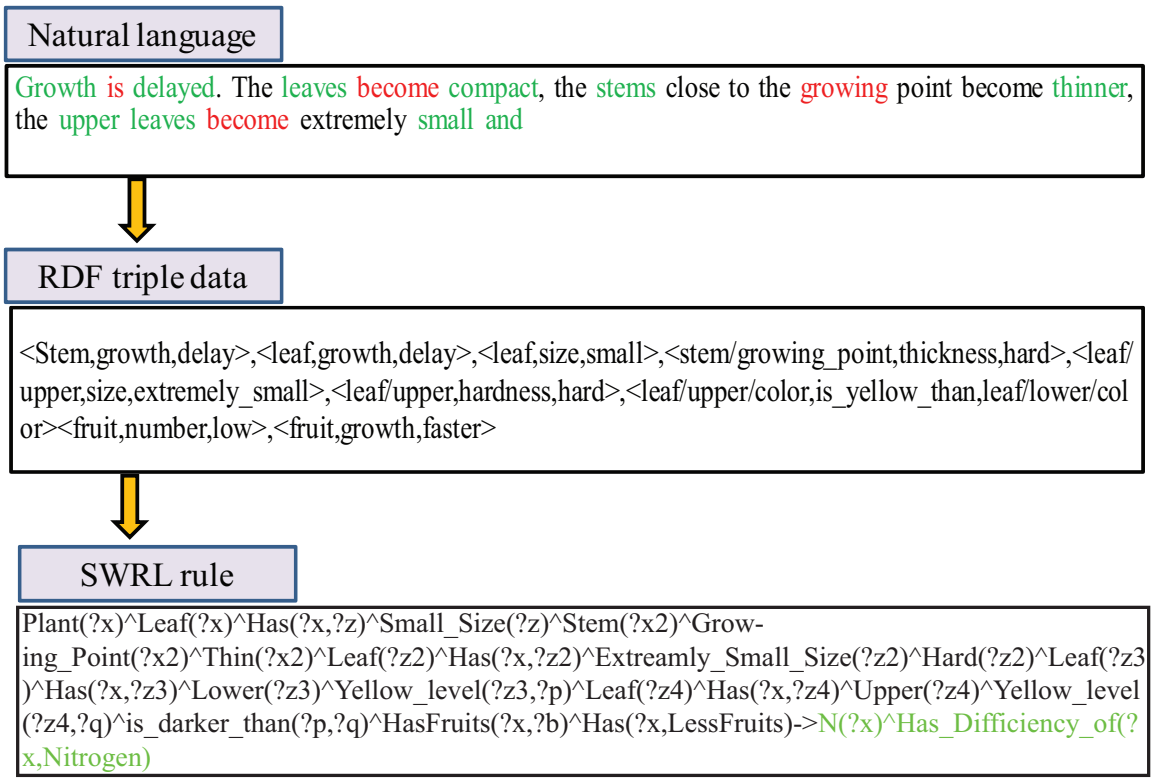

Figure 2-5: Tomato Risk Management ontology with SWRL description for Nitrogen Deficiency

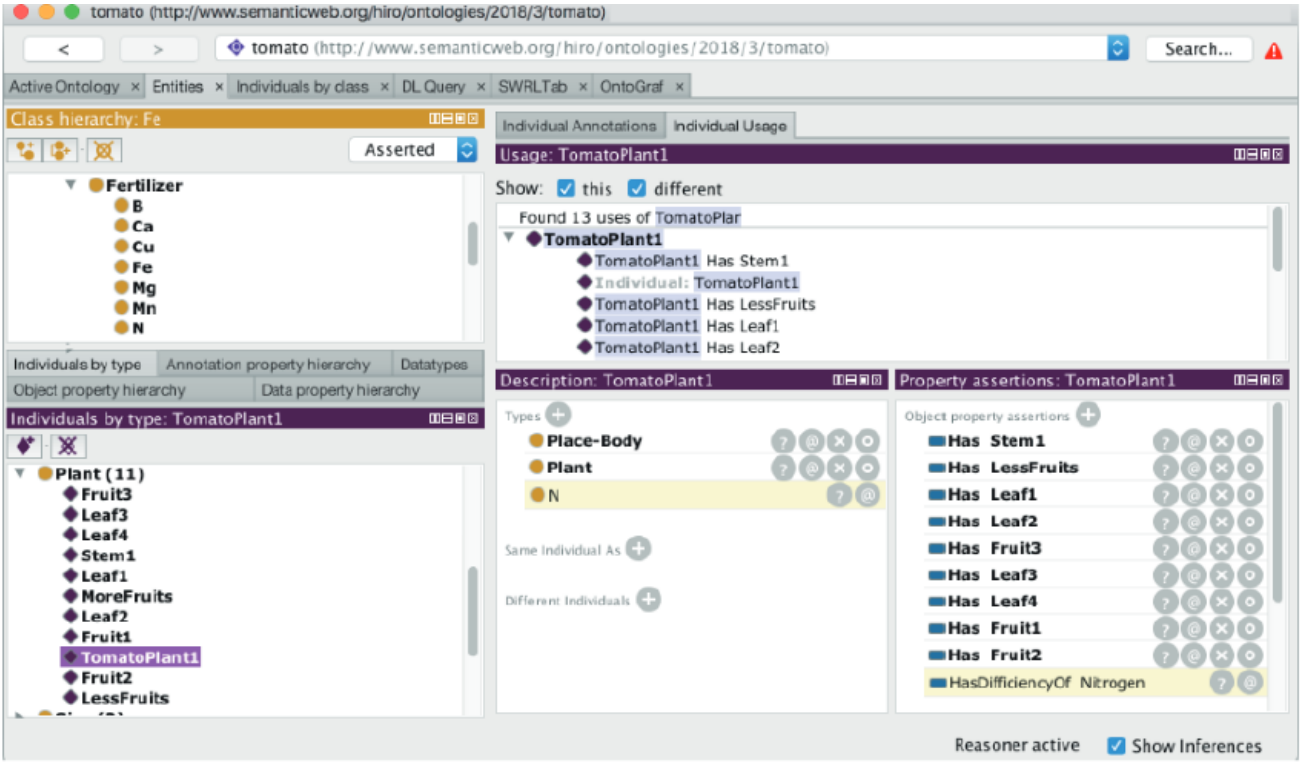

Figure 2-6: Logical inference carried out on the Agriculture ontology using Protégé.

Chapter 3

An RDF Based Knowledge Representation Towards Solving BP #39

Flexible logical reasoning is a necessary ability for humans living in a society, which involves implicit knowledge and common sense that is usually unshown. In consideration of artificial intelligence to solve BPs, we proposed a way to introduce semantic web tools, including Resource Description Framework (RDF) as the transparent, logical reasoning process. In the form of RDF triples, i.e., subject-predicate-object expressions, which allow BPs to apply for Web Ontology Language (OWL) such as Pellet incremental reasoner. According to this methodology, object and data properties were employed as a small set of OWLs to find the critical relationship to solve a specific BP, for example, $IsParallelTo$, $IsPerpendicularTo$ were object properties and $HasLength$ $4.0mm$ as data property, and then an RDF triple was given as $< Line1, IsParallelTo, Line2 >$ for a part of the solution of BP #39 which is solved by rules of *parallellines* v.s. *non-parallellines*. This study hence holds a prominent position in exploring the modeling of logical reasoning processes in human intelligence as opposed to probabilistic approaches in artificial intelligence (AI), highlighted in the recent trend.

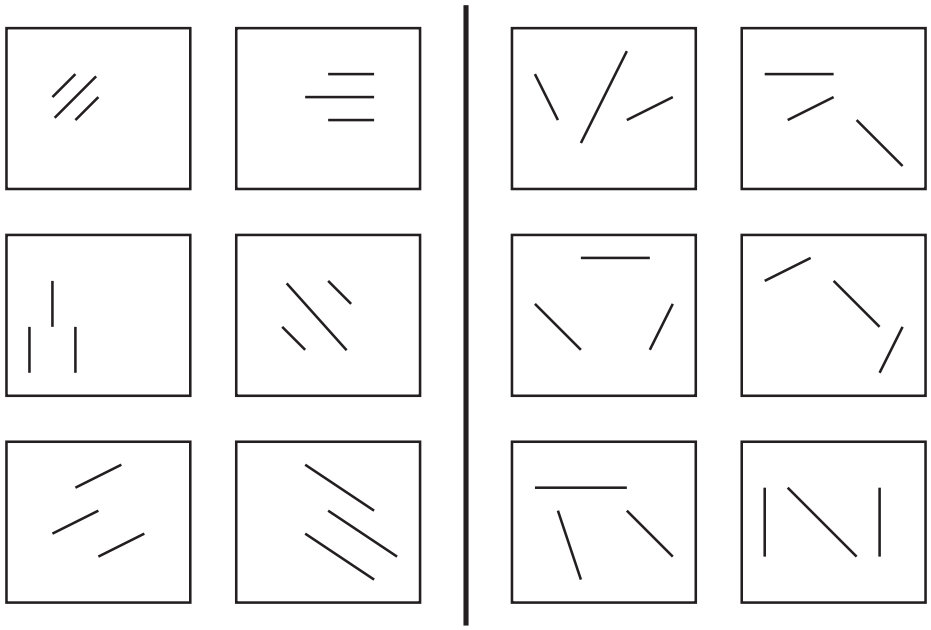

Figure 3-1: BP#39.

3.1 Implementation

Here we focused on the implementation part of BPs into a standard logical expression such as a machine-readable and understandable format. For this study BP #39, as shown in Fig. 3-1, was considered. Efforts have been made to study knowledge representation in artificial intelligence [3], called Semantic Web. The present study introduces the following tools.

- RDF (Resource description framework): consisting of the vocabulary
- OWL (Ontology web rule language): containing the restriction
- Semantic Web Rule Language (SWRL): rules for actions in the logical reasoning
- SPARQL: a query language to retrieve and manipulate the data stored in RDF.

We hypothesized that the logical description part of BPs could be described by using ontological data representation. Each RDF vocabulary representation was generated based on Protégé API [24], for class and literals. Sets of RDF triples, constituting an OWL data, are considered as a Long-term memory (LTM), and a set of SWRL is a decision-maker according to the logic. SPARQL acts accessibility to LTM, written by RDF formats.

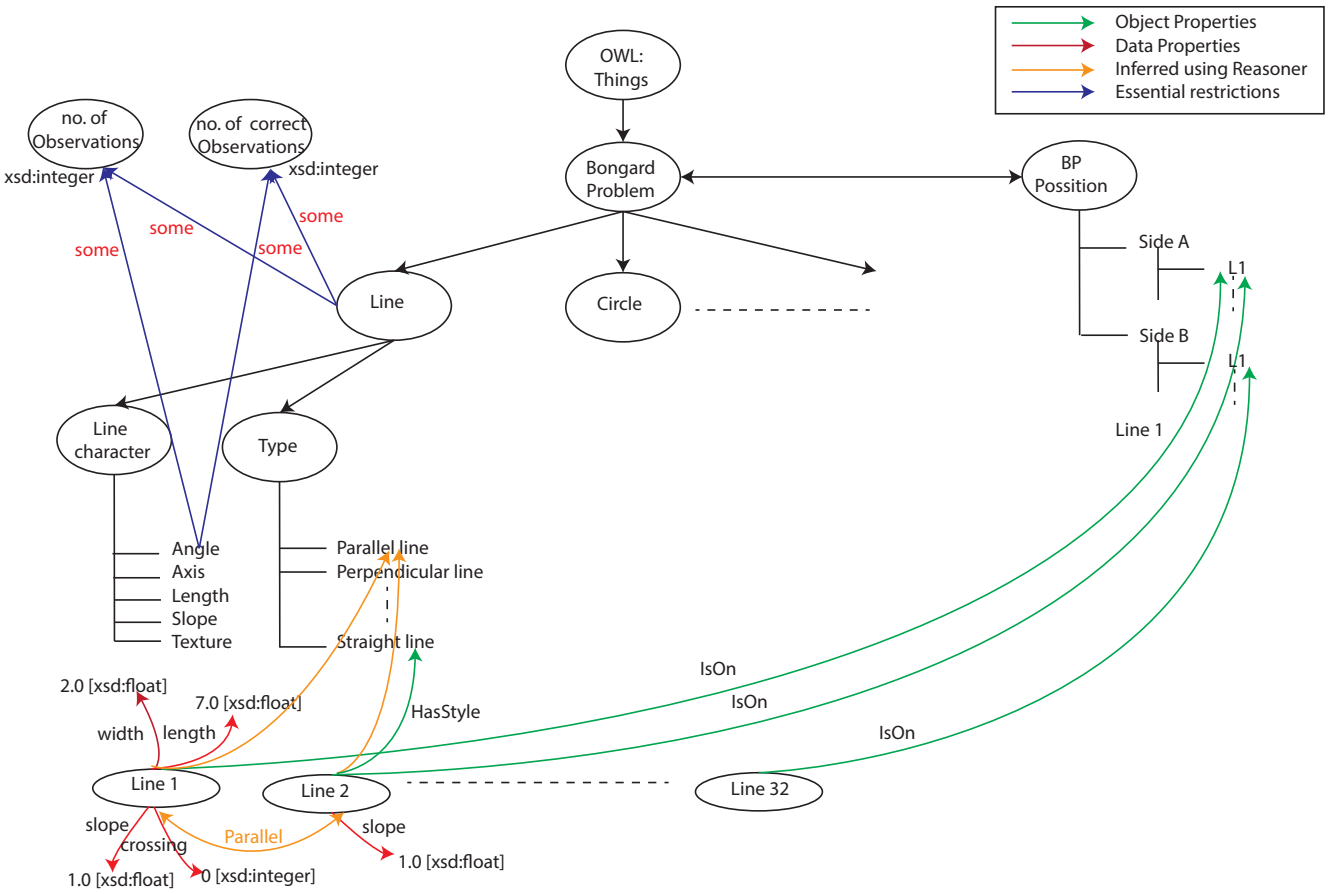

Figure 3-2: KB designing for BP#39

As a preliminary result, BP #39 (shown in Fig. 3-2 (left)) was treated by our proposed scheme. For $S_{\mathbf{A}}$ as a set of boxes on left and $S_{\mathbf{B}}$ as a set of boxes on the right side, as shown in Algorithm1, let $L_1, L_2, \ldots L_{\mathrm{N}}$ be lines detected from the given problem. Let us consider $L_{\mathrm{A1}}, L_{\mathrm{A2}} \ldots L_{\mathrm{Ai}}$ and $L_{\mathrm{B1}}, L_{\mathrm{B2}} \ldots L_{\mathrm{Bj}}$ as lines on individual boxes of $Side_{\mathrm{A}}$ and $Side_{\mathrm{B}}$. The slope feature ($slope(\forall L)$) of each instance on either side is used to make the inference for classification as parallel lines and perpendicular lines. As in Algorithm (Table 3.3), if slope values of all the instances (for i lines on $Side_{\mathrm{A}}$ and j lines on $Side_{\mathrm{B}}$) in a given lump is same, it is inferred to be an instance of class parallel lines.

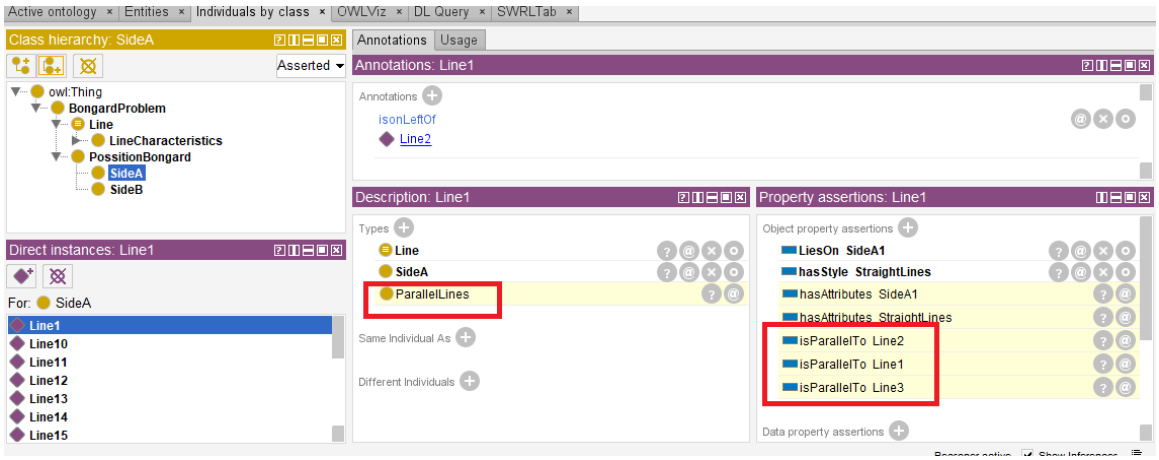

Figure 3-3: Protégé based inference of parallel line.

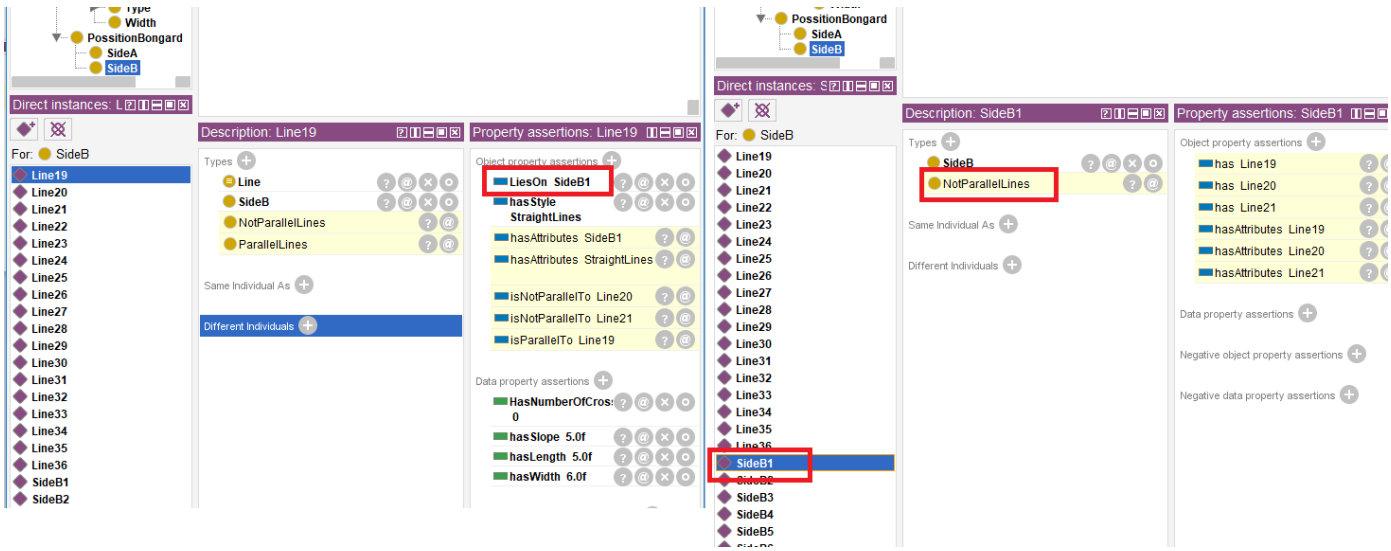

Figure 3-4: Protégé based inference of non-parallel line.

From the list of defined data properties and object properties, the SWRL rules are used to detect lines, which fall into two categories such as "*parallel lines*" and "*not parallel lines*" respectively. The rules can be mathematically interpreted as shown in Algorithm1. Using Protégé API the "*line ontology*", to solve BP #39, was generated using multiple classes (instant domains), properties (relationships), instances (individuals) and conditions (domain and range values) (Fig.3-5 and Fig. 3-6).

In this analysis, five SWRL rules were executed to detect that the lines on $Side_{\mathrm{A}}$ are parallel to each other while the lines on $Side_{\mathrm{B}}$ are not parallel to each other.

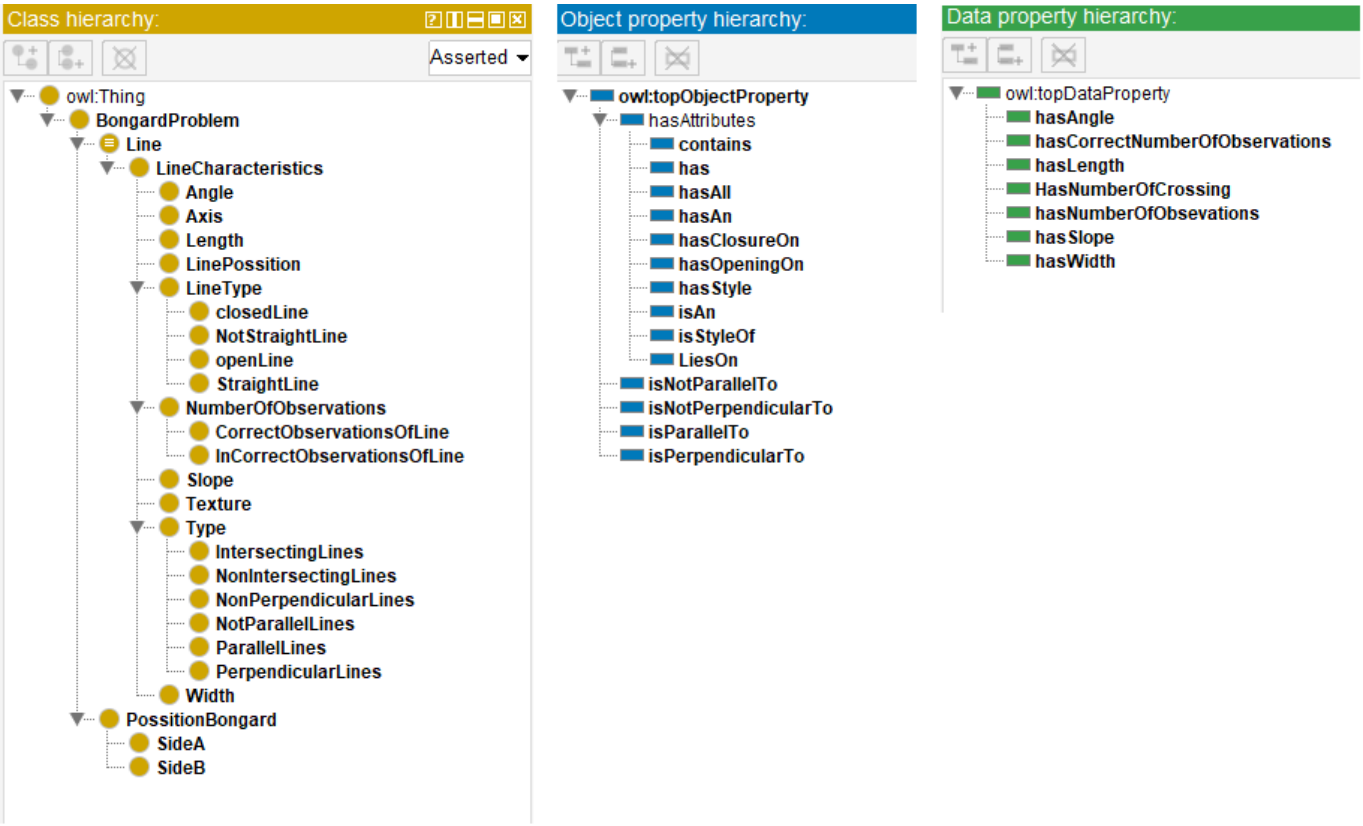

Figure 3-5: Class structure, Object Properties and Data Properties for BP#39.

Figure 3-5 and Figure 3-6 represents the hierarchy of the classes and instances with their respective data and object properties from the line ontology. Each data and object property has a bounded range, provided using domain and range values.

3.2 Hypothesis

In this research, an ontology-based approach was used to make the machine solve the given Bongard problem (BP #39). Protégé ontology editor was used to develop the ontology. The OWL file is opened in Protégé API, and Pellet based reasoning is carried out based on the SWRL rules for the knowledge inferences. These following SWRL rules (Table 3.3) were used to detect the existence of parallel lines on a given side in BP #39 by evaluating the relationship between each instance.

The inferred XML representation by using the RDF stream as an OWL file was

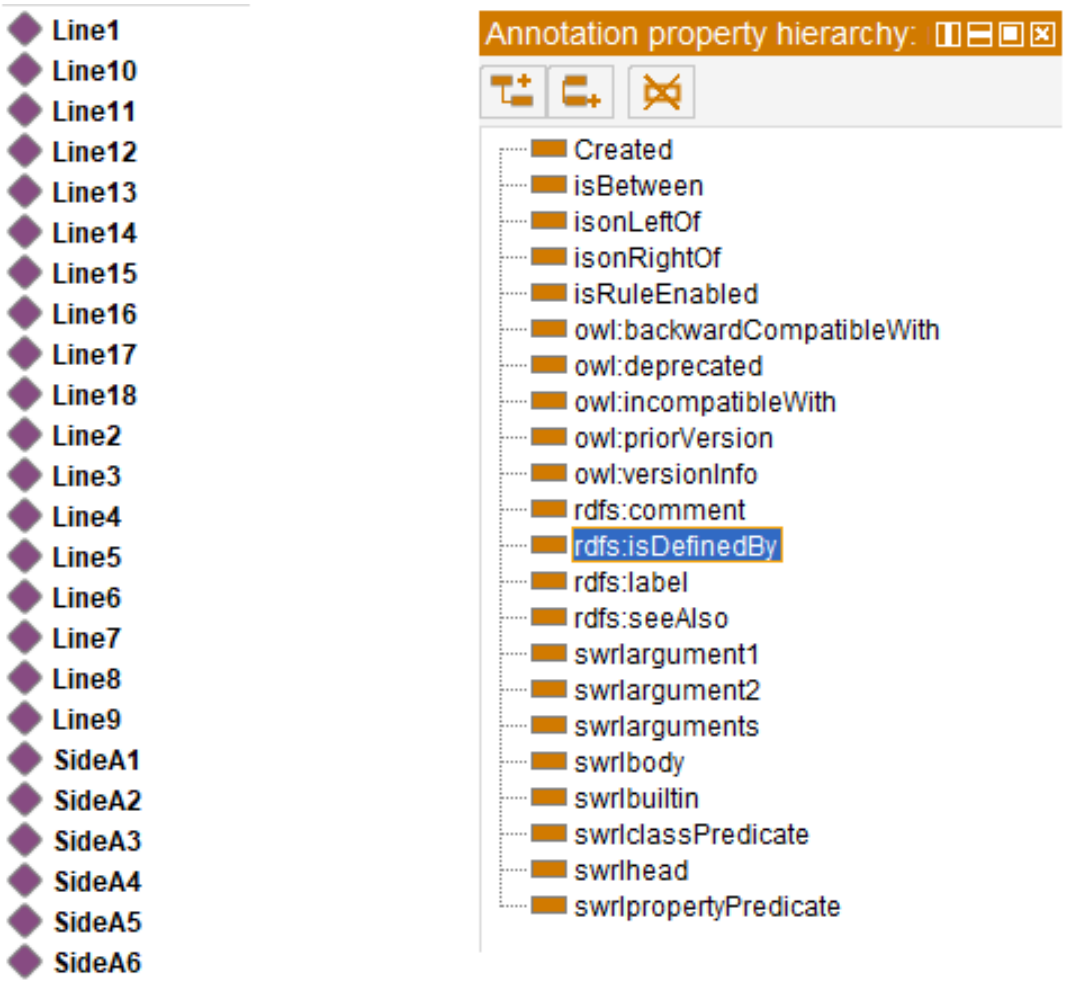

Figure 3-6: Literals (Visual Instances) and Annotation Properties for BP#39.

used, and the description consists of the Uniform Resource Identifier (URI), which are resources and temporary locations where the data is preserved. For example, for class *Lines*, as a subclass of $TypeofObject$, there exist a subclass perpendicular lines with a property of restricted angle in the range of 89.0 to 91.0 as float value ($89.00 \leqslant \phi \leqslant 91.00$).

$$\textbf{PerpendicularLines:} hasAngle\ exactly 1\ xsd:float\ [\geqslant 89.0f, \leqslant 91.0f] \tag{3.1}$$

$$\textbf{IntersectingLines:} HasNumberOfCrossing\ some\ xsd:integer \tag{3.2}$$

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns>
PREFIX owl: <http://www.w3.org/2002/07/owl>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema>
PREFIX lineOntology:
<http://www.semanticweb.org/admin-1/ontologies/2017/jisha/lineOntology>
SELECT ?predicate ?object
WHERE { lineOntology:Line1 ?predicate ?object }
```

Here the relationship between each instance, as $Line_1$, $Line_2$ and $Line_3$ is represented as an RDF data as triples. A combination of multiple RDF data gives rise to an OWL, which can be further inferred using a Java-based reasoned after checking the consistency of the generated hierarchy in Protégé API (as shown in Fig. 3-3). The literals and their data properties need to be updated from the output of the image processing block based on robust classification. Such an updation, along with static SWRL rules, can evaluate the relationship between each object detected in a given image. Such a relational database, along with proper inferences, can, in the future, lead us towards autonomously solving the analogy related tasks.

Since the Bongard problem does not depend merely on the asserted or prior (existing) knowledge, a metadata description and efficient pattern matching approaches are essential to enhance the ability to solve BPs. The automatic solver of BPs has the potential to apply the proposed scheme to other applications. Therefore, this approach contributes to the existing problem of assistive technologies using artificial intelligence and robots, helping our daily life. Furthermore, it could be a clue to understanding the internal mechanism of the human brain to treat decision making in actual, prompt, and critical problem-solving in the dynamic and social environment.

3.3 Discussion

The main objective of the present study was to develop a semantic web-based approach to solve the Bongard analogy problems with the aim of transparency in the logical reasoning process and generalization of the ill-posed problem. The utilization of the RDF description in the framework of ontology as the knowledge-based representation helps to understand our reasoning process in the puzzle.

As further analyses and development of the proposed system, the actual integration with the minimization of axes (properties) in the state space, as described in problem definition (1.2.1), is necessary for the completion of an automatic solver of BPs. Another important point is how the obtained knowledge was accumulated into the system consistently in the sense of the fitness for the SWRL rules. Data-driven approaches including clustering methods, machine learning, neural network models are beneficial for applying an image processing part in the primary sensory system in our proposed system and separation of subspace between two figure groups after reconfiguration of the state space to be a minimized state space and plotting individual figures on the space, while the function of the reconfiguration of the state space as continuous optimization problem cannot be replaced by the data-driven approaches simply. The present result demonstrated that the Linked data approach would be useful in solving of more BPs with meta-data descriptions, and then this consequence provided a large potential of multidimensional analogies with a significant relation with daily life problems that we intuitively solve from common sense.

Table 3.1: Mathematical interpretation of rules for detecting the relations

SWRL framework for features in BP #39
$\boldsymbol{F_{SA}}$= *feature (Side A*$\{L_{A1}, L_{A2}.... L_{Ai}\}$*)* $\boldsymbol{F_{SB}}$= *feature (Side B*$\{L_{B1}, L_{B2}.... L_{Bi}\}$*)* $F_{SA} \cap F_{SB} = \emptyset$ $S_A = \{iL_A \mid i \in NL_A \in F\}$ $S_B = \{jL_B \mid j \in NL_B \in F\}$ S_A= *F(*$\{L_A\}$*)= hasParallelLines* $(slope(\forall L_{A1}))=(slope(\forall L_{Ai}))$ ..... S_B= *F(*$\{L_B\}$*)= NotParallelLines* $(slope(\forall L_{B1}))(slope(\forall L_{Bi}))$ .....

Table 3.2: SPARQL query output to check for relations of instance Line1 in BP #39.

?predicate	?object
rdf:type	owl:NamedIndividual
hasStyle	StraightLines
rdf:type	owl:NamedIndividual
rdf:type	SideA
rdf:type	owl:NamedIndividual
rdf:type	Line
rdf:type	owl:NamedIndividual
lineOntology:hasLength	”10.0” <xsd:float>
rdf:type	owl:NamedIndividual
lineOntology:hasSlope	”5.0” <xsd:float>
rdf:type	owl:NamedIndividual
lineOntology:LiesOn	lineOntology:SideA1
rdf:type	owl:NamedIndividual
lineOntology:isonLeftOf	lineOntology:Line2
lineOntology:hasWidth	”2.0” <xsd:float>
rdf:type	owl:NamedIndividual
lineOntology:HasNumberOfCrossing	”0” <xsd:float>
rdf:type	owl:NamedIndividual
Here- PREFIX lineOntology:	<http://www.semanticweb.org/admin-1/ontologies/2017/jisha/lineOntology#>
PREFIX xsd:	<http://www.w3.org/2001/XMLSchema#>
PREFIX rdf:	<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl:	<http://www.w3.org/2002/07/owl#>
PREFIX rdfs:	<http://www.w3.org/2000/01/rdf-schema#>

Table 3.3: SWRL list to represent relationships of features in BP #39.

#1	$lineOntology : Line(?a)$ $\wedge lineOntology : Line(?b)$ $\wedge lineOntology : HasSlope(?a, ?s1)$ $\wedge Side(?S1)$ $\wedge Side(?S2)$ $\wedge lineOntology : HasSlope(?b, ?s2)$ $\wedge swrlb : equal(?s1, ?s2)$ $\wedge lineOntology : LiesOn(?a, ?S1)$ $\wedge lineOntology : LiesOn(?b, ?S2)$ $-> lineOntology : isParallelTo(?a, ?b)$
#2	$lineOntology : Line(?a)$ $\wedge lineOntology : Line(?b)$ $\wedge lineOntology : HasSlope(?a, ?s1)$ $\wedge Side(?S1)$ $\wedge Side(?S2)$ $\wedge lineOntology : HasSlope(?b, ?s2)$ $\wedge swrlb : notEqual(?s1, ?s2)$ $\wedge lineOntology : LiesOn(?a, ?S1)$ $\wedge lineOntology : LiesOn(?b, ?S2)$ $-> lineOntology : isNotParallelTo(?a, ?b)$
#3	$lineOntology : isParallelTo(?a, ?b)$ $-> lineOntology : ParallelLines(?a)$ $\wedge lineOntology : ParallelLines(?b)$
#4	$lineOntology : isNotParallelTo(?a, ?b)$ $-> lineOntology : NotParallelLines(?a)$ $\wedge lineOntology : NotParallelLines(?b)$
#5	$lineOntology : ParallelLines(?a)$ $lineOntology : NotParallelLines(?a))$ $\wedge lineOntology : Line(?a)$ $-> lineOntology : NotParallelLines(?a)$
	Here PREFIX lineOntology: <http://www.semanticweb.org/admin-1/ontologies/2017/jisha/lineOntology#>

Table 3.4: XML data representation

XML data for Perpendicular Lines
− <owl:Class rdf:about="lineOntology:PerpendicularLines"> <rdfs:subClassOf rdf:resource="lineOntology:Type"/ > − <rdfs:subClassOf> − <owl:Restriction> <owl:onProperty rdf:resource="lineOntology:hasAngle"/ > <owl:qualifiedCardinality rdf:datatype="xsd:nonNegativeInteger">1 < /owl:qualifiedCardinality> − <owl:onDataRange> − <rdfs:Datatype> <owl:onDatatype rdf:resource="xsd:float"/ > − <owl:withRestrictions rdf:parseType="Collection"> − <rdf:Description> <xsd:minInclusive rdf:datatype="xsd:float">89.0< /xsd:minInclusive> < /rdf:Description> − <rdf:Description> <xsd:maxInclusive rdf:datatype="xsd:float">91.0</xsd:maxInclusive> < /rdf:Description> < /owl:withRestrictions> < /rdfs:Datatype> < /owl:onDataRange> < /owl:Restriction> < /rdfs:subClassOf> < /owl:Class>
Here- PREFIX lineOntology: <http://www.semanticweb.org/admin-1/ontologies/2017/jisha/lineOntology#> PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

Chapter 4

A Semantic Web-based Representation of Human-logical Inference for Solving Bongard Problems

BPs set of two-dimensional graphical puzzles involves pattern recognition, categorization, and logical decision-making tasks to infer the similarity and dissimilarity that govern them. Every BP inherits the quality of universality of unique solutions. Although BPs are an excellent means to validate the interaction of human vision and cognitive abilities, they impose tremendous challenges in the field of AI in mimicking human logical thinking abilities. The most important point of these BP puzzles is that they differ from other visual puzzles is that the solver has to get rules to discriminate groups of visual patterns and provide a simple logic, as illustrated in Fig.1-8.

According to the concepts, mathematical formulation is possible based on the theory of sets. Here, each side in a given BP is indexed as left side and right side as L_1 to L_6 and R_1 to R_6 (Fig. 1-8). Each box on either side of a given BP holds a potentially infinite number of properties per objects, as discussed above, while if there exists an appropriate filter to select instances from a well-organized database based

on defined classes (independent properties and dependent properties) with respect to requirements, it is possible to find the solution. The solution of properties P_b and P_a satisfies following conditions.

$$(L_i \notin P_a) \cap (R_i \notin P_b) \cap (L_i \in P_b) \cap (R_i \in P_a) \cap (P_a \cap P_b = \emptyset) \tag{4.1}$$

Then the problem is how we can build the system to reproduce the above conditions. Recent advancements of semantic knowledge representation and actual implementations can help to build the system with raw concepts and flexible relationships [22, 23, 24]. Some of the approaches with the semantic network and some hybrid approaches applied to the limited numbers of BPs have contributed to the reaffirmation of the importance of semantics and logic. This demonstrates the effectiveness of the semantic network and description logic, and then the common principle is expected to be formulated, and the principle explains why the semantics and logic work well to solve the BPs to avoid an infinite time for the calculation.

4.1 Proposed Framework for Solving BPs

4.1.1 Ontology-Based Scheme for Knowledge Representation

Each box, on either side, of a given BP, holds a potentially infinite number of independent and dependent properties. To enable the machine to understand this massive amount of raw data obtained from a BP, we need a semantic knowledge representation of the raw concepts and their flexible relationships.

Ontologies can represent the knowledge in an organized and machine-understandable format with concepts and relationships among the obtained data instances. For consistent modeling of data, the context descriptions are designed using the Resource Descriptive Framework (RDF). To express rules and logical expressions for inferring the perceived visual data, Semantic Web Rule Language (SWRL) is used along with SPARQL Protocols and RDF Query Language (SPARQL). The SPARQL querying tool helps the semantic web query static RDF knowledge in a more interactive fashion.

Ontologies are usually expressed as the following entities:

- Classes: These are the main instances of the domain of interest and play a vital role in defining an ontological structure (such as Web Ontology Language [OWL]: shapes; Owl: texture).
- Properties: Properties in an ontological knowledge base fall into three distinct categories, namely object properties, data properties, and annotation properties. They define the relationship-based predicates for the RDF data format (such as 'LeftOf' and 'InBetween')
- Instances: These are the subjects/predicted-individuals in the given domain (such as shape name, , *i.e.* 'Circle' and 'Square').
- Rules: These are the logical statements governing the categorization and carrying out of logical inferences in the ontology.

4.1.2 Analysis of BPs using ontology

Douglas R. Hofstadter in his book *Gódel, Escher, Bach: An Eternal Golden Braid*, had discussed about the necessity of "concept networks"[15], in which all the data are interlinked in a way that indicates their interrelations; however he did not yet complete to propose an actual solution to connect an implementation into machines. Therefore, his hypothesis on the BP solver is of interest to researchers who are interested in the limitation of the machine intelligence and the possibility of the reproduction of the human intelligence, while the process of carrying out similarity checks and funneling the inferred possible relationships between either side of the BP still remains unsolved.

As a first step to dig into the point of view, we proposed a way of the implementation with an ontology-based knowledge representation with large-scale interoperability and axioms, which can be easily extended for general use.

In our proposed model, Static ontology is the basic knowledge structure about shapes and all the possible general knowledge of the environment. This was created to

replicate the high-level cognitive state (long-term memory) of the human brain. The dynamic analogy-making block provides the visual context-based information, which varies depending on the type of BP. This block mimics the lower-level cognitive state of the human brain by providing the ontological knowledge base with instantaneous processed visual information (using Java-based graphical user interface [GUI]).

Since the complexity related to a BP increases with increases in visual instances and their properties, a meta-description (description of description) is formulated at the dynamic memory block. The logical reasoning capability and inherited knowledge about events and shapes are represented in the form of semantic rules and queries. We used the OWL reasoner based on descriptive logic for reasoning on the objects (visual instances) and their relationship to a wider perspective. As shown in Fig. 4-1, in our approach, the inference of the best-fitting rule, as the most promising solution to a given BP, is an outcome of the logical intersection between the metadata-based description and the logical rules governing a BP. Figure 4-3 and Figure 4-4 show the overview of the logical decision system using the dynamic ontological knowledge base to make logical inferences governing the possible solution for a given BP. The operations carried out in our framework are as follows:

1. The visual instances are obtained from the GUI-based receivers and are imported into a static ontological knowledge base.

2. The SWRL rule reasoner is formulated in a way to create new inferred properties from the perceived instances. This rich knowledge base is then fed into the SPARQL query engine.

3. If the solution to the given BP can be formulated at this stage, the predictions are generated. Otherwise, a recursive process of inference is carried out as follows in the steps below.

4. The SPARQL query engine, along with SWRL rules, access the knowledge base to retrieve information about the instances and their respective classes. This helps in the categorizing objects and characterizing the new inferred properties.

5. The SWRL rule reasoner adds some inference based on the respective side of the BP—for example, detecting the common properties and understanding the dissimilar instances.

6. SWRL rule-based reasoning is performed on the updated knowledge base, and new inferences are made.

7. The SPARQL query retrieves all the relationships for every instance from all the 12 boxes.

8. SWRL checks for the possible solution based on the new inferred knowledge base (outcomes of the SPARQL query). If the solution to the given BP can be formulated at this stage, the predictions are outputted. The newly added inferred knowledge is removed from the static ontology-knowledge base.

9. If the solution to the given BP could not be formulated, the above-mentioned recursive process of inference is carried out again.

Here, the context-based decision-making system mainly consists of the visual instances receiver, a dynamic ontological knowledge base, logical rules, and query engines. Figure 4-6 represents the visual notation of the static ontological knowledge base. This ontological knowledge base, along with logical rules and queries, coincides with Hofstadter's idea of concept networks and sameness detector [15]. Using ontology, we formulated a back-and-forth interaction between each individual and their descriptions (where every node is linked to every other node via properties).

It is generally known that the visual cortex in humans helps in the processing of visual information and object recognition. But it is still unclear how the human brain can select a set of minimum possibilities from a wider set of information in the real world. Such conscious recognition of shapes, colors, and so on from an output of the visual cortex is a challenging mystery. We implemented a funneling-based approach to narrow down the inferences (i.e., taking the minimum possible decisions from multiple relations).

According to the concept by Hofstadter [15], we rebuilt the components based on the theory of sets and tools in the semantic web and proposed the system to solve BPs with-

i) ontology-based description as concept network,

ii) DL with assertions on concepts (TBox) and individuals (ABox) as frames,

iii) meta-data template,

iv) SPARQL for the filtering function and

v) Semantic Web Rule Language (SWRL) rules as sameness detector.

The detail formulation is given in the following sections, and the validation of the system as the BP solver is shown in the chapter of results.

Knowledge Base as *Concept network*: In our approach towards solving BPs, we have developed an Ontology-based Knowledge Base (KB) with large-scale interoperability and axioms for our use. An ontology O can be represented as: $O = (O_v, O_a)$, where O_v represents terms (vocabularies) in an ontology and O_a represents a set of ontological assertions made using the set of Vocabulary.

Here the vocabulary $O_v = O_c \sqcup\ O_p \sqcup\ O_e$, where O_c is a set of ontology classes (*i.e. size, texture* etc.), O_p is a set of ontology properties (they define the relationship based predicates for RDF data format (like: *hascount, hasshape* etc.) and fall into three distinct categories, namely- object properties, data properties and annotation properties) and O_e is a set of instances (entities comprising of labels, comments and literals). Assertion $O_a = O_{ca} \sqcup\ O_{pa}$, where O_{ca} is a set of ontological class assertion and O_{pa} is a set of ontological property assertion. These subsumption relations constitutes an assertion set *i.e.* -

---

$circle : geometric\_shape$

$left\_side \sqsubseteq\ side.$

In our ontology the above assertion set can be explained as entity "*circle*" belongs

to class *geometric_shape* and *left_side* is a subclass of class *side*.

Here, $circle \in O_e, left\_side \sqcup side \in O_c$

$T_{bp} = \{count \sqsubseteq bp,$	$(T_{bp}, 1)$
$geometric\_shape \sqsubseteq bp,$	$(T_{bp}, 2)$
$geometric\_shape\_characteristics \sqsubseteq bp,$	$(T_{bp}, 3)$
$side \sqsubseteq bp,$	$(T_{bp}, 4)$
$size \sqsubseteq bp,$	$(T_{bp}, 5)$
$texture \sqsubseteq bp,$	$(T_{bp}, 6)$
$right\_side \sqsubseteq bp \sqcap side,$	$(T_{bp}, 7)$
$left\_side \sqsubseteq bp \sqcap side,$	$(T_{bp}, 8)$
$left\_side \sqsubseteq \neg right\_side,$	$(T_{bp}, 9)$
$left\_side \sqcup right\_side \sqsubseteq side,$	$(T_{bp}, 10)$
$filled\_texture \sqsubseteq \neg outlined\_texture,$	$(T_{bp}, 11)$
$filled\_texture \sqcup outlined\_texture \sqsubseteq texture,$	$(T_{bp}, 12)\}$

Table 4.1: TBox for solving Bongard Problem.

In RDF (Resource Description Framework) format class assertion can be represented as: <*circle,rdf:type,geometric_shape*>. An example for property assertion $O_{pa} = hassize(x, large)$, where $hassize \in O_p$ and $x \sqcup large \in O_e$, indicating in RDF format as: <*x,hassize,large*>. Class assertion in our approach assumes that every individuals of a class is different from each other (*i.e.* all the geometric shapes are different etc.). This can be represented in DL (Description Logic) syntax as follows:

Axiom: DifferentIndividual($ClassIndividual_1$.....$ClassIndividual_n$)

DL syntax: $\cup_{i \neq j}\ ClassIndividual_i \neq ClassIndividual_j$

*i.e.*DifferentIndividuall(*circle, square*) ::> $circle \neq square$

Annotation is an important feature of an ontology which allows adding "non-logical" comments in the given ontology. Annotation to add a comment "To the Left side of BP" for class *left_side* can be represented as:

ClassAssertion(Annotation(*rdfs:comment* "To the Left set of BP"):*side*:*left_side*))

Using the first-order logic, the above informations can be rendered as (with x and y representing *leftside_1* and *circle* respectively) -

---

Vocabulary $- \forall x(left(x) \Leftrightarrow\ side(x) \wedge\ bp(x) \wedge\ \exists\ y(has(x, y)))$

Assertion - geometric_shape(*circle*)

ABox (assertion components- O_a) of our ontology is represented as follows. (Note: "__" represents the user input from GUI)

$ABox(A_{bp}) = \{1 : count,$ $(A_{bp}, 1)$

.....

$infinite : count,$ $(A_{bp}, 21)$

$circle : geometric\_shape,$ $(A_{bp}, 22)$

.....

$star : geometric\_shape,$ $(A_{bp}, 47)$

$parallel : geometric\_shape\_characteristics,$ $(A_{bp}, 48)$

.....

$elongated\_horizontally : geometric\_shape\_characteristics,$ $(A_{bp}, 88)$

$middle : side,$ $(A_{bp}, 89)$

.....

$to\_left : side,$ $(A_{bp}, 94)$

$left : side \sqcap left\_side,$ $(A_{bp}, 95)$

.....

$left\_6 : side \sqcap left\_side,$ $(A_{bp}, 101)$

$right : side \sqcap right\_side,$ $(A_{bp}, 102)$

.....

$right\_6 : side \sqcap right\_side,$ $(A_{bp}, 108)$

$large : size,$ $(A_{bp}, 109)$

.....

$uneven\_shape\colon size,$ $(A_{bp}, 117)$

.....

$dark\_filling\colon filled\_texture,$ $(A_{bp}, 108)$

.....

$no\_filling\_shape\colon filled\_texture,$ $(A_{bp}, 123)$

$continuous\_outlined\colon outlined\_texture,$ $(A_{bp}, 124)$

.....

$wiggly\_outlined\colon outlined\_texture,$ $(A_{bp}, 134)$

$(leftside\_1, \_\_)\colon has,$ $(A_{bp}, 135)$

$(leftside\_1, \_\_)\colon has,$ $(A_{bp}, 136)$

$(leftside\_1, \_\_)\colon has,$ $(A_{bp}, 137)$

$(leftside\_1, \_\_)\colon hascount,$ $(A_{bp}, 138)$

$(leftside\_1, \_\_)\colon hastexture,$ $(A_{bp}, 139)$

$(leftside\_1, \_\_)\colon alsohastexture,$ $(A_{bp}, 140)$

$(leftside\_1, \_\_)\colon hassize,$ $(A_{bp}, 141)$

$(leftside\_1, \_\_)\colon isonside,$ $(A_{bp}, 142)$

$(leftside\_1, \_\_)\colon hasshapefeature,$ $(A_{bp}, 143)$

.....

$(leftside\_6, \_\_)\colon has,$ $(A_{bp}, 180)$

$(leftside\_6, \_\_)\colon has,$ $(A_{bp}, 181)$

$(leftside\_6, \_\_)\colon has,$ $(A_{bp}, 182)$

$(leftside\_6, \_\_)\colon hascount,$ $(A_{bp}, 183)$

$(leftside\_6, \_\_)\colon hastexture,$ $(A_{bp}, 184)$

$(leftside\_6, \_\_)\colon alsohastexture,$ $(A_{bp}, 185)$

$(leftside\_6, \_\_)\colon hassize,$ $(A_{bp}, 186)$

$(leftside\_6, \_\_)\colon isonside,$ $(A_{bp}, 187)$

$(leftside\_6, \_\_)\colon hasshapefeature,$ $(A_{bp}, 188)$

$(rightside\_1, \_\_)\colon has,$ $(A_{bp}, 189)$

$(rightside\_1, \_\_)\colon has,$ $(A_{bp}, 190)$

$(rightside\_1, \_\_)\colon has,$ $(A_{bp}, 191)$

$(rightside\_1, \_\_)$: $hascount$, $(A_{bp}, 192)$

$(rightside\_1, \_\_)$: $hastexture$, $(A_{bp}, 193)$

$(rightside\_1, \_\_)$: $alsohastexture$, $(A_{bp}, 194)$

$(rightside\_1, \_\_)$: $hassize$, $(A_{bp}, 195)$

$(rightside\_1, \_\_)$: $isonside$, $(A_{bp}, 196)$

$(rightside\_1, \_\_)$: $hasshapefeature$, $(A_{bp}, 197)$

.....

$(rightside\_6, \_\_)$: has, $(A_{bp}, 234)$

$(rightside\_6, \_\_)$: has, $(A_{bp}, 235)$

$(rightside\_6, \_\_)$: has, $(A_{bp}, 236)$

$(rightside\_6, \_\_)$: $hascount$, $(A_{bp}, 237)$

$(rightside\_6, \_\_)$: $hastexture$, $(A_{bp}, 238)$

$(rightside\_6, \_\_)$: $alsohastexture$, $(A_{bp}, 239)$

$(rightside\_6, \_\_)$: $hassize$, $(A_{bp}, 240)$

$(rightside\_6, \_\_)$: $isonside$, $(A_{bp}, 241)$

$(rightside\_6, \_\_)$: $hasshapefeature$, $(A_{bp}, 242)$

$DifferentIndividuals(circle, square, rectangle.....)$, $(A_{bp}, 243)$

$DifferentIndividuals(large, small, ...)$, $(A_{bp}, 244)$

$DifferentIndividuals(dark\_filling, no\_filling, ...)$, $(A_{bp}, 245)$

$DifferentIndividuals(closed\_shape, open\_shape, ...)$, $(A_{bp}, 246)$

$DifferentIndividuals(to\_left, to\_right, ...)$, $(A_{bp}, 247)$

.....

The TBox (terminological components- O_v) (represented in Fig. 4-6) is the meta-data that defines the terms of an ontology vocabulary. The TBox representation of our ontology is as shown in Table 4.1. ABox (assertion components- O_a) of our ontology is as represented in Fig. 4-7 (for *left* side). The combination of both TBox and ABox is called as a Knowledge Base (domain knowledge) in this paper. In this paper, this knowledge base depicts the concept network, which according to Hofstadter [15] in

his book: "*is a kind of semantic net in which all the known nouns, adjectives, etc., are linked in ways which indicate their interrelations*".

SPARQL queries as *Filters:* In this research we employ SPARQL queries (SPARQL Protocol and RDF Query Language) as replica of the concept "Filters" stated by Hofstadter [15]. According to the concept [15], the concept of "Filtering" is "*making a description which concentrates on some particular way of viewing the contents of the box, and deliberately ignoring all other aspects*".

```
String queryString= "PREFIX
relationshipUri2:http://bongardproblem.org/bp/relationship/includes/   "+
"SELECT ?side ?feature1 ?feature2 ?feature3"
+ "?feature4 ?feature5 ?feature6 ?feature7" +
"WHERE { " +
" ?side  relationshipUri2:has  ?feature1 . "+
" ?side   relationshipUri2:hascount   ?feature2 . "+
" ?side  relationshipUri2:hastexture  ?feature3 . "+
" ?side  relationshipUri2:alsohastexture   ?feature4 . "+
" ?side  relationshipUri2:hassize   ?feature5 . "+
" ?side  relationshipUri2:isonside   ?feature6 . "+
" ?side  relationshipUri2:hasshapefeature  ?feature7 . "+
" } ";
```

Using the SPARQL queries, shown above, we try to filter out the important assertions in the ontology O, using the template (as shown below) for each box in the BP.

As a *template* (*i.e.* a description schema) to describe each box in a problem as illustrated in Fig. 4-6, we use-

---

Geometricshapespresent :*like* : *circle* $\cup$ *square...*

Countofnumberofobjectspresent :*like* : 1 $\cup$ 2...

Textureoftheobjects(**filling**) :*like* : *no_filling* $\cup$ *dark_filling...*

Outertexture(**surface**)**ofobjects** :*like* : *wiggly_outline* $\cup$ *dotted_outline...*

Objecthassize :*like* : *small* $\cup$ *large...*

Objectliesonside :*like* : *top* $\cup$ *to_left...*

Characteristicsoftheshapeoftheobjects :*like* : *parallel* $\cup$ *convex_shape..*

This template (with inputs obtained from GUI as shown in Fig. 4-5) for each box in a given BP provides a uniform format for the description. These descriptions are then further expandable into sub-descriptions (TBox and ABox) for the SWRL rules to evaluate the knowledge base.

SWRL rules as *Sam* (*i.e.* "sameness detector"): The semantic web rule language (SWRL) is a standard language for expressing rules over the ontology O. The syntax of the SWRL rule (for $R \geq 1$) is in the form

---

RuleR :$antecedent(body_1 ...., body_n) \rightarrow$ $consequence(head_1 ...., head_m)$

Here antecedent (rule body: $body_x$ *for* $1 \leq x \leq n$) must be satisfied for the consequence (rule head: $head_y$ *for* $1 \leq y \leq m$) to be asserted. Here $body_x$ and $head_y$ are axioms in the form $C(V)$ or $P(O_v, O'_v)$ with $C \in O_c, V \in O_v, P \in O_p$ *and* $(O_v, O'_v) \in O_v$.

SWRL Example 1: To check for the presence of "polygon" in ontology O,

Vocabulary $\boldsymbol{V_{polygon}}$= {*has, isa, hastexture, consists_of_shape*} $\cup$ { *left, closed_shaped, polygon, setoflines, leftside_1, leftside_2, leftside_3, leftside_4, leftside_5, leftside_6, a, b, c, d, e, f* }

Assertion $\boldsymbol{A_{polygon}}$={*has(leftside_1,a), has(leftside_2,b), has(leftside_3,c), has(leftside_4,d), has(leftside_5,e), has(leftside_6,f), isa(a,setoflines), isa(b,setoflines), isa(c,setoflines), isa(d,setoflines), isa(e,setoflines), isa(f,setoflines), hastexture(leftside_1,closed_shaped), hastexture(leftside_2,closed_shaped), hastexture(leftside_3,closed_shaped), hastexture(leftside_4,closed_shaped), hastexture(leftside_5,closed_shaped), hastexture(leftside_6,closed_shaped), consists_of_shape(left,polygon)*}

For checking the presence of *"Polygon"* on *left_side* of a BP, we can use the Vocabulary $V_{polygon}$ with variable symbols- {*p, q, r, s, t, u*}. To check for polygon, the condition that must be satisfied can be written in natural language as: *"any closed shape that is formed by straight lines is a polygon"*. This form of knowledge in natural language can be written as a SWRL rule to check for the presence of polygon on the left and right set of boxes in a BP. Hence, rule $R_{polygon}$ can be written as:

$\boldsymbol{R_{polygon}}$= **Rule 1**: has(leftside_1, *?p*) $\wedge$ has(leftside_2, *?q*) $\wedge$ has(leftside_3, *?r*) $\wedge$ has(leftside_4, *?s*) $\wedge$ has(leftside_5, *?t*) $\wedge$ has(leftside_6, *?u*) $\wedge$ isa(*?p*,setoflines) $\wedge$ isa(*?q*,setoflines) $\wedge$ isa(*?r*,setoflines) $\wedge$ isa(*?s*,setoflines) $\wedge$ isa(*?t*,setoflines) $\wedge$ isa(*?u*,setoflines) $\wedge$ hastexture(leftside_1,closed_shaped) $\wedge$ hastexture(leftside_2,closed_shaped) $\wedge$ hastexture(leftside_3,closed_shaped) $\wedge$ hastexture(leftside_4,closed_shaped) $\wedge$ hastexture(leftside_5,closed_shaped) $\wedge$ hastexture(leftside_6,closed_shaped) $\rightarrow$ consists_of_shape(left,polygon)

This rule $R_{polygon}$ can be written in first-order logic as:

$\forall x\ \exists y_1\ \exists y_2\ \exists y_3\ \exists y_4\ \exists y_5\ \exists y_6\ \exists x_1\ \exists x_2\ \exists x_3\ \exists x_4\ \exists x_5\ \exists x_6$(consists_of_shape($x$, polygon) $\Leftrightarrow x(x_1) \wedge\ x(x_2) \wedge\ x(x_3) \wedge\ x(x_4) \wedge\ x(x_5) \wedge\ x(x_6) \wedge\ (\text{has}(x_1, y_1)) \wedge$ $(\text{has}(x_2, y_2)) \wedge\ (\text{has}(x_3, y_3)) \wedge\ (\text{has}(x_4, y_4)) \wedge\ (\text{has}(x_5, y_5)) \wedge\ (\text{has}(x_6, y_6)) \wedge$ (isa(y_1,setoflines)) $\wedge\ $ (isa(y_2,setoflines)) $\wedge\ $ (isa(y_3,setoflines)) $\wedge\ $ (isa(y_4,setoflines)) $\wedge$ (isa(y_5,setoflines)) $\wedge\ $ (isa(y_6,setoflines)) $\wedge\ $ (hastexture(x_1,closed_shaped)) $\wedge$ (hastexture(x_2,closed_shaped)) $\wedge\ $ (hastexture(x_3,closed_shaped)) $\wedge$ (hastexture(x_4,closed_shaped)) $\wedge\ $ (hastexture(x_5,closed_shaped)) $\wedge$ (hastexture(x_6,closed_shaped)))

In order to evaluate any rule the real entities must be mapped to the variables (*i.e.* replacing the variables {*p, q, r, s, t, u*} by the entities {*a, b, c, d, e, f*}). If the mapping of rule body *(b)* is true then the mapping of rule head *(h)* must be true. Such an SWRL rule for checking for polygons could be employed for solving BP#5.

SWRL Example 2 : To check if a common shape is present on left, which is not common for the right side in BP ("shape common for left set of boxes is different from shape common for right set of boxes"- the solution of BP#97 is: <left,has,triangle> and <right,has,circle>) can be written as:

Rule1 :has(leftside_1, ?a) $\wedge$ has(leftside_2, ?a) $\wedge$ has(leftside_3, ?a) $\wedge$ has(leftside_4, ?a) $\wedge$ has(leftside_5, ?a) $\wedge$ has(leftside_6, ?a) $\wedge$ DifferentIndividuals(?a,null) $\rightarrow$ consists_of_shape(left, ?a)

Rule2 :has(leftside_1, ?a) $\wedge$ has(leftside_2, ?b) $\wedge$ has(leftside_3, ?c) $\wedge$ has(leftside_4, ?d) $\wedge$ has(leftside_5, ?e) $\wedge$ has(leftside_6, ?f) $\wedge$ DifferentIndividuals(?a, ?b) $\wedge$ DifferentIndividuals(?a, ?f) $\wedge$ DifferentIndividuals(?e, ?d) $\rightarrow$ consists_of_shape(left,notempty)

Rule3 :has(rightside_1, ?aa) $\wedge$ has(rightside_2, ?aa) $\wedge$ has(rightside_3, ?aa) $\wedge$

Table 4.2: Algorithm 1

Cross checking dissimilarity to detect possible solution for a BP

Step−1: *Select* $Rule_A$
if *(*$Rule_A$ *satisfies (*L_1,L_2,L_3,L_4,L_5,L_6*))*
if *(*$Rule_A$ *consistent in Left of BP)*
(Inference − > Left, $Predicate_{Left}$*,* $Object_1$*)*

else ***(GOTO*** *Step−1)*

Step−2: *Select* $Rule_B$
$Rule_B$ *satisfies (*R_1,R_2,R_3,R_4,R_5,R_6*)*
if *(*$Rule_B$ *consistent in Right of BP)*
(Inference − > Right, $Predicate_{Right}$*,* $Object_2$*)*

else ***(GOTO*** *Step−2)*

Step−3:*(Left,* $Predicate_{Left}$*,* $Object_1$*), (Right,* $Predicate_{Right}$*,* $Object_2$*)*
if *(*$Object_1$ *isSameAs* $Object_2$*)*
$Rule_A$ *and* $Rule_B$*, not consistent for Left and Right respectively*
else if *(*$Object_1$ *DifferentFrom* $Object_2$*)*
$Rule_A$ *and* $Rule_B$*, consistent for Left and Right respectively*

else ***(GOTO*** *Step−2)*

else ***(GOTO*** *Step−1)*

$\text{has}(\text{rightside\_4}, ?aa) \wedge \text{has}(\text{rightside\_5}, ?aa) \wedge \text{has}(\text{rightside\_6}, ?aa) \wedge$

$\text{DifferentIndividuals}(?aa, null) \rightarrow \text{consists\_of\_shape}(\text{right}, ?aa)$

Rule4 :$\text{has}(\text{rightside\_1}, ?a) \wedge \text{has}(\text{rightside\_2}, ?b) \wedge \text{has}(\text{rightside\_3}, ?c) \wedge$

$\text{has}(\text{rightside\_4}, ?d) \wedge \text{has}(\text{rightside\_5}, ?e) \wedge \text{has}(\text{rightside\_6}, ?f) \wedge$

$\text{DifferentIndividuals}(?a, ?b) \wedge \text{DifferentIndividuals}(?a, ?f) \wedge$

$\text{DifferentIndividuals}(?e, ?d) \rightarrow \text{consists\_of\_shape}(\text{right,notempty})$

Rule5 :$\text{consists\_of\_shape}(\text{right}, ?aa) \wedge \text{consists\_of\_shape}(\text{left}, ?a) \wedge$

$\text{DifferentIndividuals}(?a, ?aa) \rightarrow \text{has\_inferred\_shape}(\text{left}, ?a) \wedge$

$\text{has\_inferred\_shape}(\text{right}, ?aa)$

Rule6 :$\text{consists\_of\_shape}(\text{right}, ?aa) \wedge \text{consists\_of\_shape}(\text{left}, ?a) \wedge$

consists_of_shape(right,notempty) $\wedge$ consists_of_shape(left,notempty) $\wedge$
DifferentIndividuals($?a, ?aa$) $\rightarrow$ has_inferred_shape(left, $?a$) $\wedge$
has_inferred_shape(right, $?aa$)

Here **Rule 1**, **Rule 2**, **Rule 3** and **Rule 4** provides first level of inference (for similarity check), while **Rule 5** and **Rule 6** provides second level of inference (for dissimilarity check) to find solution to a give BP. The solution from the first level of inference is provided as an input for the second level of inference.

In BP#51, the first and second level of inference was derived in the output:

First-level of Inference-

[from **Rule 1** and **Rule 2**:]

Input-

<*left,relationshipUri2:has,circles*>,

Output-

<*left,relationshipUri2:consists_of_shape,circles*>,

<*left,relationshipUri2:consists_of_shape,notempty*>

<*left,relationshipUri2:consists_of_shape,curvilinear*>

[from **Rule 3** and **Rule 4**:]

Input-

<*right,relationshipUri2:has,circles*>,

Output-

<*right,relationshipUri2:consists_of_shape,circles*>,

<*right,relationshipUri2:consists_of_shape,notempty*>,

<*right,relationshipUri2:consists_of_shape,curvilinear*>

Second-level of Inference-

(after mapping real entities to the variables as-{?aa : *circle*,?a : *circle*},{?aa : *curvilinear*,?a : *curvilinear*},{?aa : *circle*,?a : *curvilinear*},{?aa : *curvilinear*,?a :

circle})

[from **Rule 5:** and **Rule 6:**]

Input-

<*left*,*relationshipUri2:consists_of_shape*,*circles*>,

<*left*,*relationshipUri2:consists_of_shape*,*notempty*>,

<*left*,*relationshipUri2:consists_of_shape*,*curvilinear*>,

<*right*,*relationshipUri2:consists_of_shape*,*circles*>,

<*right*,*relationshipUri2:consists_of_shape*,*notempty*>,

<*right*,*relationshipUri2:consists_of_shape*,*curvilinear*>

Output-

No Output (based on geometric shapes; because of DifferentIndividuals(*?a*,*?aa*))

Hence, the above mentioned SWRL rule can be modified, for any properties and entities ($p \cup O_v$), and can be used to detect the sameness and distinct features among the two sides in a given BP. This logical reasoning was computed by embedding in the algorithm as shown in Table 4.2 [26, 27].

In this paper, SWRL rules are used to depicts the idea of "*sam*" (sameness detector). In considering of sameness detector [15], it describes as: "*Sam is a special agent...runs around within individual descriptions and within different descriptions, looking for descriptors or other things which are repeated* (ontology in our case) *or other things which are repeated....Any structure they have in common will make comparing them that much easy*".

ABox and TBox as *Frames :* In considering of Frames [15], it describes as: "*..mental representation of situations involve frames nested within each other. Each of the various ingredients of a situation has its own frame...nested structure of a frame gives you a way of "zooming in" and looking at small details from as close up as you wish: you just zoom in on the proper sub-frame...*" .

According to Fritz Lehmann [25] "*A frame is a named data object with a flexible collection of named slots (attributes or fields) which can have values. The value are*

often pointers to other frames, which permits you to have a network of frames pointing to one another". In our proposed framework, we consider classes (TBox) as "Frames" (O_c).

4.2 Results of Computer Experiments

Our proposed framework was implemented using Jena API to interact with the ontology, and computer experiments were verified using a PC with the Intel Core i7-3770K running at 3.40 GHz. The logical reasoning was demonstrated with a set of 55 SWRL rules to generate 12 new RDF inferred data. Among these 55 SWRL rules, 32 rules were used as first level of inference for similarity check (step 1 and 2 in Table 4.2) and the rest 23 rules were used as second level of inference for dissimilarity check (step 3 in Table 4.2) to find solution to a given BP. The system demonstrated to be a solver of 65 BPs as shown in Figure 4-8.

Foundalis [16] carried out a survey with 31 students as whether or no they can solve 100 BPs and analyzed the difficulty levels according to ratio of solved subject as partially shown in the first column of Table 4.3 and Fig. 4-9(a). In our computer experiments shown in second and third columns in Table 4.3 is not simply correspond to the difficulty levels given by human subjects, while our system provide a hint of reasons why the BP takes time to solve in the number for inferences in Stage I as shown in Table 4.3.

Interestingly, there is an inverse correlation between the ratio of solved subjects and average time to solve in them (Fig. 4-9(a)). It suggests the importance of the re-order of BPs according to the difficulty levels based on the human performance. Indeed, this types of analyses was difficult by Phaeaco's performance due to a limited number of solved BPs (15) [16] and in RF4 [17] which is formulated with the stochastic model in part and they report that the model solved 41 BPs without descriptions of which BPs were solved. Fig. 4-9(b) showed the advantage of our proposed models in the sense of how many BPs were solved.

According to the increase of the difficulty level (Fig. 4-9(c), our proposed model

BP	**Categorization** [16] ($\hat{N}/N$)	**Number of Inferences** Stage I, Stage II, Stage III (SPARQL, SWRL, SWRL)	**Average Time to Solve** [s]
BP#1	Easy (100%)	143, 8, 2	0.42
BP#2	Easy (100%)	120, 14, 4	0.22
BP#3	Easy (100%)	120, 10, 2	0.28
BP#4	Difficult (16.1%)	149, 10, 2	0.22
BP#5	Easy (90.3%)	140, 12, 4	0.21
BP#6	Easy (83.9%)	140, 12, 2	0.24
BP#7	Easy (90%)	156, 8, 2	0.22
BP#8	Easy (77.4%)	149, 12, 4	0.31
BP#9	Easy (100%)	120, 14, 4	0.22
BP#10	Easy (87.1%)	120, 10, 2	0.34
BP#11	Moderate (48.4%)	149, 12, 4	0.22
BP#12	Difficult (23.3%)	98, 12, 2	0.31
BP#13	Easy (82.6%)	149, 12, 2	0.28
BP#14	Easy (96%)	142, 7, 2	0.22
BP#15	Easy (87.1%)	149, 12, 4	0.23
BP #16	Moderate (37.5%)	156, 14, 2	0.31
BP#17	Difficult (26.1%)	156, 12, 2	0.21
BP#18	Moderate (34.8%)	130, 11, 2	0.20
BP#19	Moderate (45.6%)	156, 12, 2	0.21
BP#20	Difficult (22.7%)	-	-
BP#21	Moderate (82.6%)	140, 12, 4	0.23
BP#22	Moderate (36.7%)	196, 14, 2	4.08
BP#23	Easy (96.8%)	149, 12, 2	0.44
BP#24	Easy (66.7%)	156, 13, 2	2.10
BP#25	Easy (84.6%)	-	-
BP#26	Moderate (62.5%)	-	-
BP#27	Moderate (36.4%)	-	-
BP#28	Difficult (0%)	-	-
BP#29	Difficult (12%)	-	-
BP#30	Difficult (28%)	149, 8, 4	0.32

BP	**Categorization** [16] ($\hat{N}/N$)	**Number of Inferences** Stage I, Stage II, Stage III (SPARQL, SWRL, SWRL)	**Average Time to Solve** [s]
BP#31	Easy (75%)	132, 12, 2	0.44
BP#32	Difficult (25%)	196, 12, 4	0.37
BP#33	Difficult (16.7%)	149, 8, 4	0.24
BP#34	Easy (96.8%)	140, 12, 2	5.04
BP#35	Moderate (42.3%)	149, 12, 4	0.37
BP#36	Easy (76.7%)	-	-
BP#37	Difficult (12%)	-	-
BP#38	Easy (80%)	-	-
BP#39	Easy (96.8%)	134, 12, 4	0.25
BP#40	Moderate (50%)	149, 6, 4	0.22
BP#41	Moderate (53.8%)	-	-
BP#42	Moderate (65.5%)	-	-
BP#43	Moderate (63.6%)	149, 12, 4	0.26
BP#44	Difficult (28.6%)	-	-
BP#45	Easy (93.6%)	-	-
BP#46	Moderate (57.7%)	-	-
BP#47	Easy (100%)	-	-
BP#48	Easy (86.7%)	-	-
BP#49	Easy (85.2%)	-	-
BP#50	Difficult (25%)	159, 12, 4	0.36
BP#51	Moderate (63.3%)	98, 12, 2	0.22
BP#52	Easy (72.7%)	149, 12, 4	0.22
BP#53	Difficult (27%)	-	-
BP#54	Difficult (5%)	149, 12, 4	1.07
BP#55	Moderate (33.3%)	-	-
BP#56	Easy (71%)	149, 12, 4	1.43
BP#57	Moderate (48.3%)	149, 12, 4	0.25
BP#58	Difficult (25%)	149, 10, 4	0.72
BP#59	Easy (83.3%)	149, 12, 4	0.24
BP#60	Difficult (31.3%)	149, 12, 4	0.54
BP#61	Easy (83.3%)	-	-
BP#62	Difficult (28.6%)	155, 12, 4	0.22
BP#63	Easy (93.8%)	150, 10, 2	0.237
BP#64	Difficult (6.7%)	-	-
BP#65	(50%)	149, 12, 2	1.09
BP#66	Easy (72.4%)	-	-

BP	**Categorization** [16] ($\hat{N}/N$)	**Number of Inferences** Stage I, Stage II, Stage III (SPARQL, SWRL, SWRL)	**Average Time to Solve** [s]
BP#67	Difficult (31%)	-	-
BP#68	Difficult (0%)	-	-
BP#69	Easy (93.8%)	-	-
BP#70	Moderate (65.5%)	149, 8, 4	0.24
BP#71	Moderate (50%)	140, 12, 4	0.96
BP#72	Difficult (13.3%)	160, 14, 2	0.289
BP#73	Difficult (0%)	-	-
BP#74	Easy (73.3%)	-	-
BP#75	Easy (86.7%)	-	-
BP#76	Moderate (64.2%)	149, 10, 4	0.21
BP#77	Moderate (60%)	98, 12, 4	0.22
BP#78	Difficult (27%)	140, 12, 4	0.22
BP#79	Difficult (6.2%)	-	-
BP#80	Difficult (6.7%)	-	-
BP#81	Moderate (42%)	149, 12, 4	1.04
BP#82	Difficult (0%)	-	-
BP#83	Easy (73.3%)	-	-
BP#84	Easy (100%)	-	-
BP#85	Easy (90%)	146, 12, 4	0.25
BP#86	Difficult (25.8%)	136, 12, 4	0.28
BP#87	Moderate (53.3%)	120, 12, 4	0.22
BP#88	Moderate (53.3%)	144, 12, 4	0.28
BP#89	Difficult (20%)	140, 8, 4	0.27
BP#90	Difficult (14.3%)	102, 12, 4	0.27
BP#91	Moderate (60%)	149, 10, 4	0.32
BP#92	Moderate (40%)	148, 12, 4	8.05
BP#93	Difficult (15%)	-	-
BP#94	Easy (100%)	-	-
BP#95	Easy (96.8%)	149, 12, 4	0.23
BP#96	Easy (83.3%)	149, 12, 4	0.24
BP#97	Easy (93.6%)	149, 12, 4	0.58
BP#98	Moderate (56.2%)	149, 12, 4	2.47
BP#99	Moderate (56.2%)	148, 10, 2	1.093
BP#100	Easy (100%)	149, 12, 4	0.22

Table 4.3: Inference analyses with respect to difficulty levels (for 62 BPs), where $\hat{N}$ and N respectively denote numbers of solved subjects and total subjects. Computation time is extracted only in the inference process from 99 trials.

provided solutions of 65 BPs with a similar level of computation time without an infinite loop of calculation by the assignment of multiple meta-data information, which was highly organized as the framework design with as i) ontology-based description for concept network, ii) DL with TBox and ABox for frames, iii) meta-data template, iv) SPARQL for filtering and v) SWRL rules as sameness detector.

In the logical inference of BP#9, which is categorized in "Easy BP," our model provided the first and second level of inference as output as follows.

Output of First-level of Inference (Stage II)-

<*left*,*relationshipUri2:alsoconsists_of_texture*,*continious_outlined*>,

<*left*,*relationshipUri2:consists_of_character*,*null*>,

<*left*,*relationshipUri2:consists_of_count*,*1*>,

<*left*,*relationshipUri2:consists_of_position*,*middle*>,

<*left*,*relationshipUri2:consists_of_shape*,*notempty*>,

<*left*,*relationshipUri2:consists_of_size*,*large_figure*>,

<*left*,*relationshipUri2:consists_of_texture*,*closed_shaped*>

<*right*,*relationshipUri2:alsoconsists_of_texture*,*wiggly_outlined*>,

<*right*,*relationshipUri2:consists_of_character*,*null*>,

<*right*,*relationshipUri2:consists_of_count*,*1*>,

<*right*,*relationshipUri2:consists_of_position*,*middle*>,

<*right*,*relationshipUri2:consists_of_shape*,*notempty*>,

<*right*,*relationshipUri2:consists_of_size*,*large_figure*>,

<*right*,*relationshipUri2:consists_of_texture*,*closed_shaped*>

Output of Second-level of Inference (Stage III)-

<*left*,*relationshipUri2:has_infered_texture*,*continious_outlined*>,

<*left*,*relationshipUri2:has_infered_doesnothastexture*,*wiggly_outlined*>

<*right*,*relationshipUri2:has_infered_texture*,*wiggly_outlined*>,

<*right*,*relationshipUri2:has_infered_doesnothastexture*,*continious_outlined*>

Our results revealed that the logical inference process and therefore, even in unsolved BPs, this provides a tool of the reversal engineering of the human intelligence to analyze what kind logical components are necessary to solve.

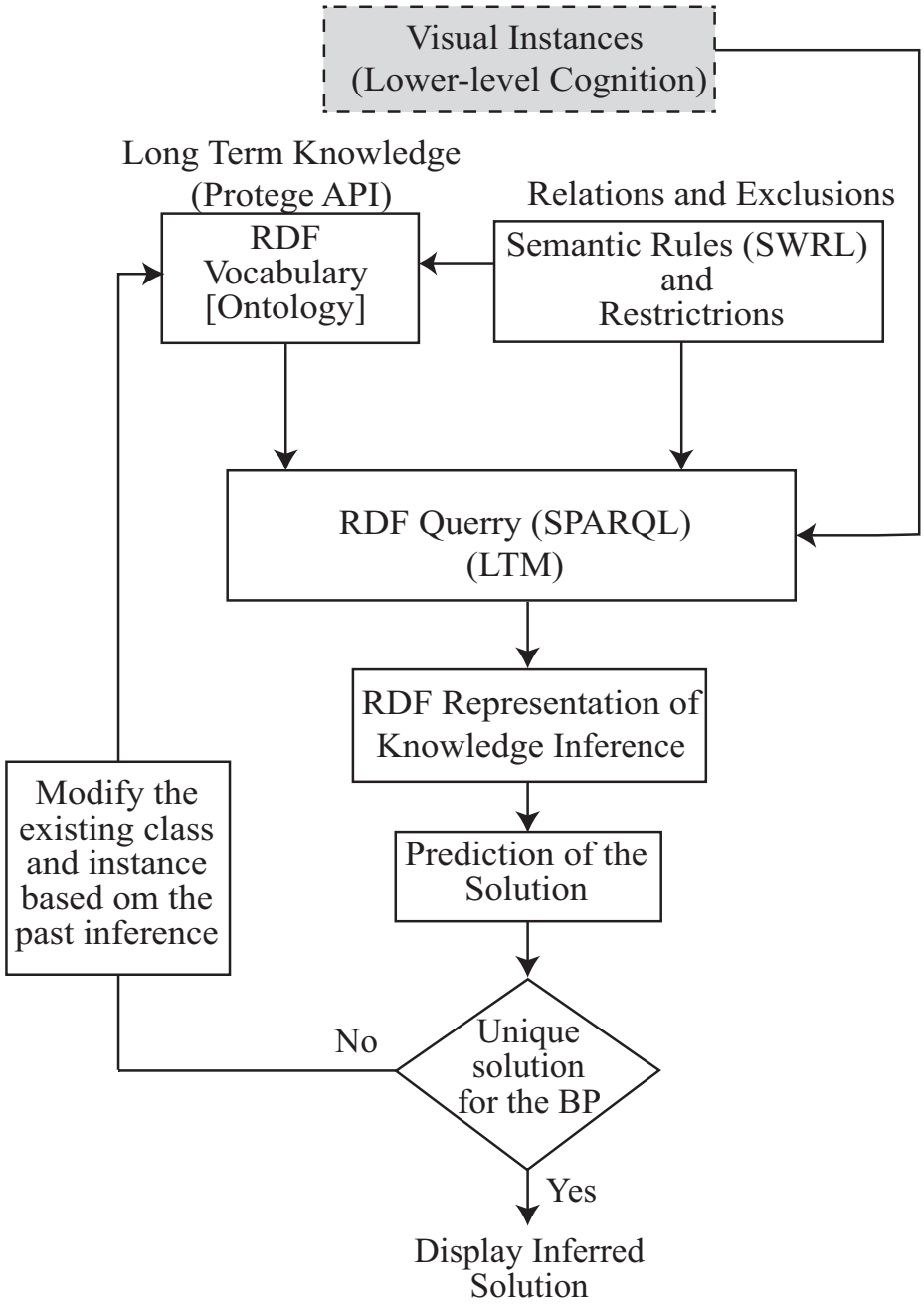

Figure 4-1: Our framework for solving BPs using knowledge tree

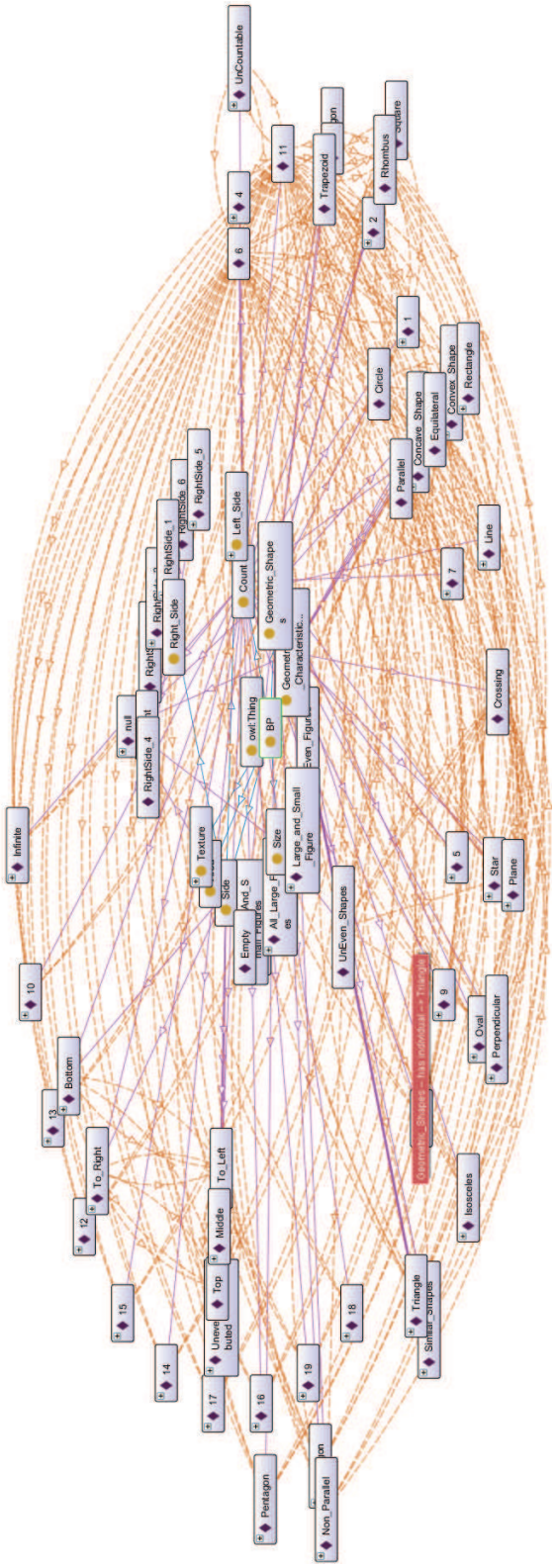

Figure 4-2: Ontology based concept network

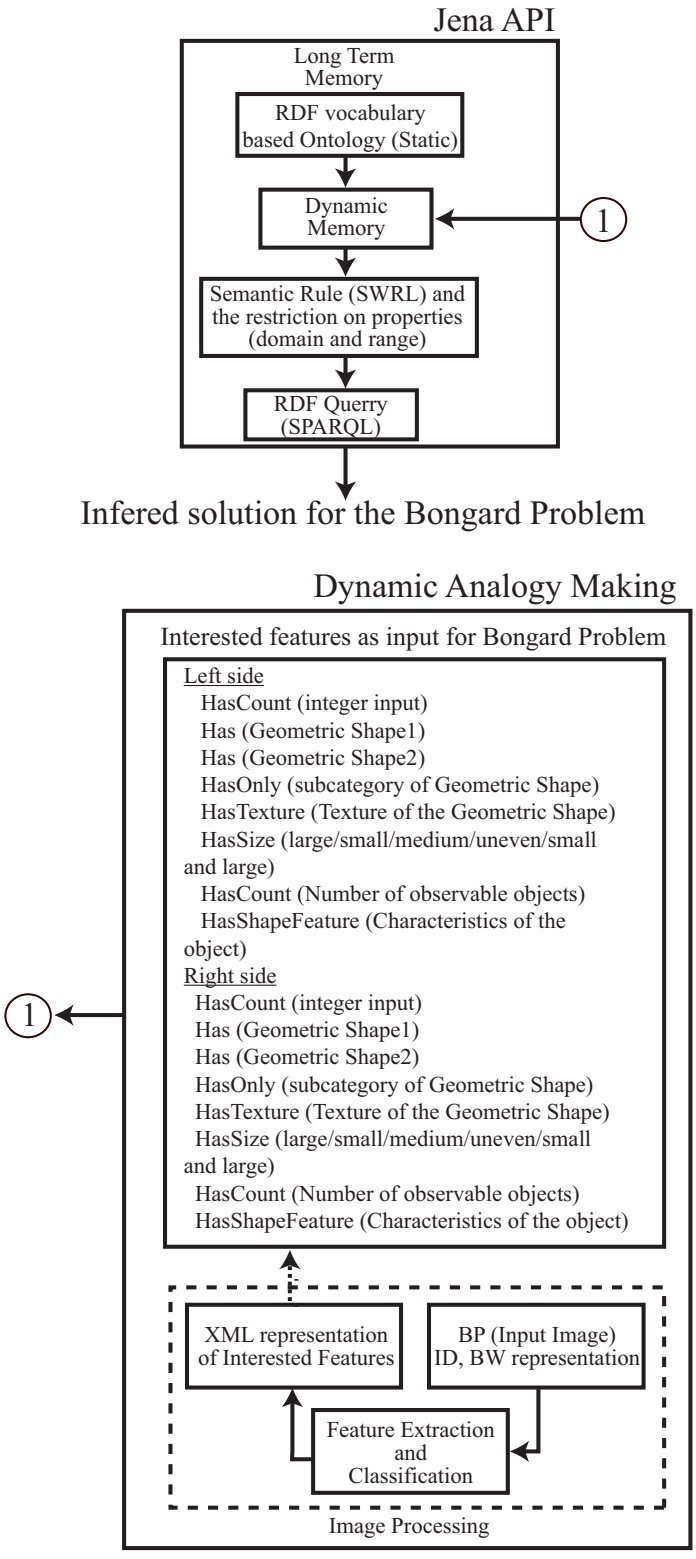

Figure 4-3: Proposed three level hierarchical model as the BP solver.

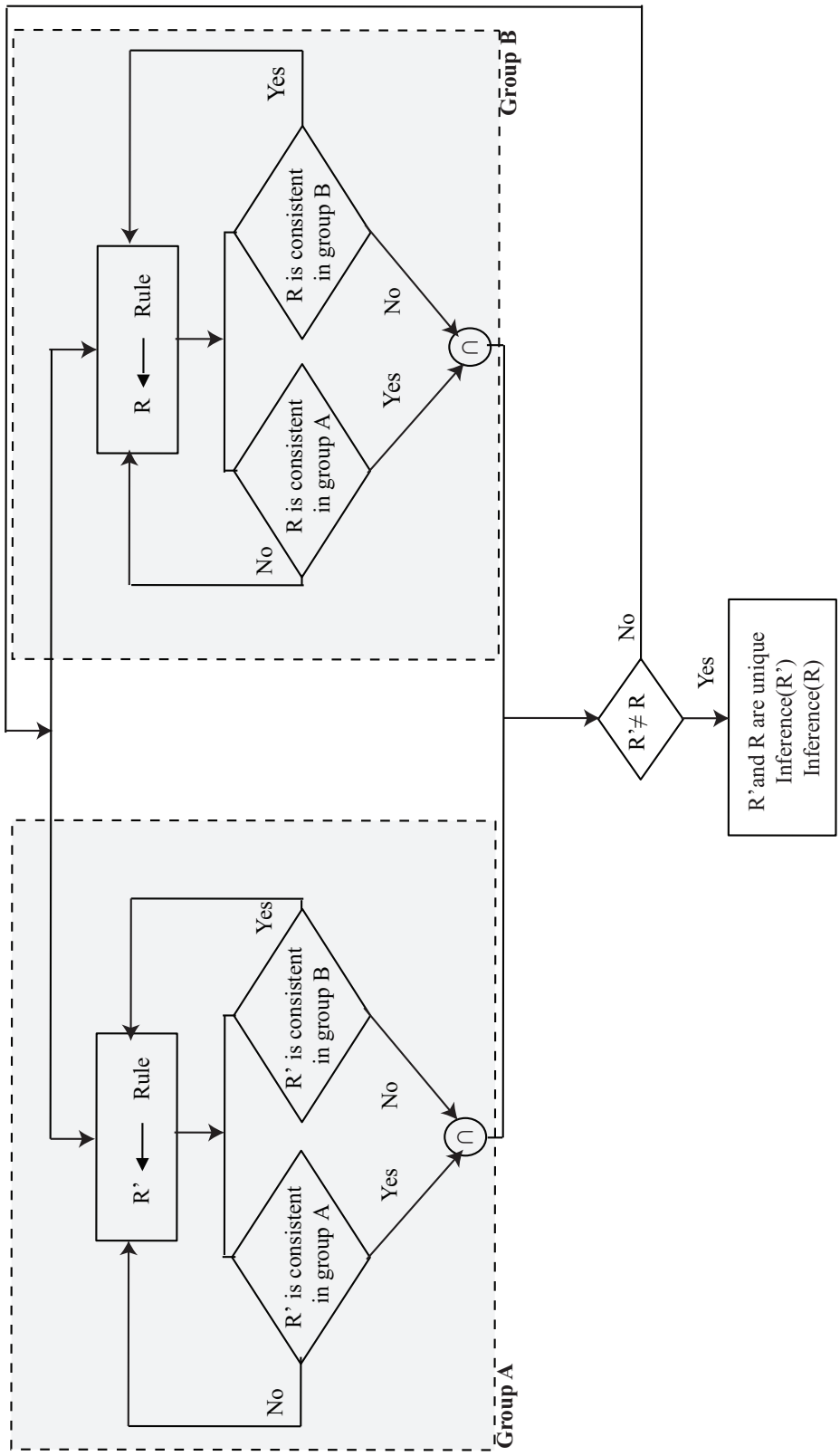

Figure 4-4: Cross checking dissimilarity to detect possible solution for a BP

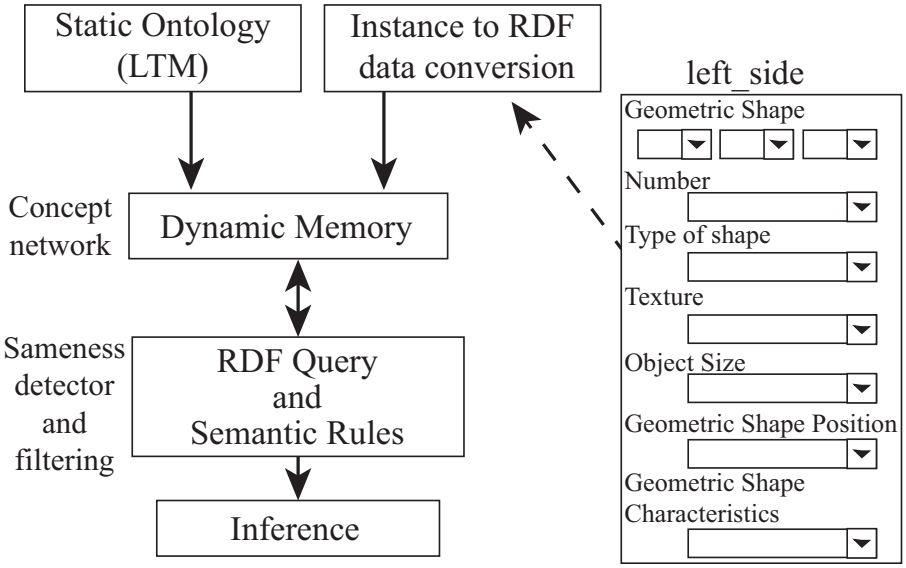

Figure 4-5: Ontology based framework for solving BPs.

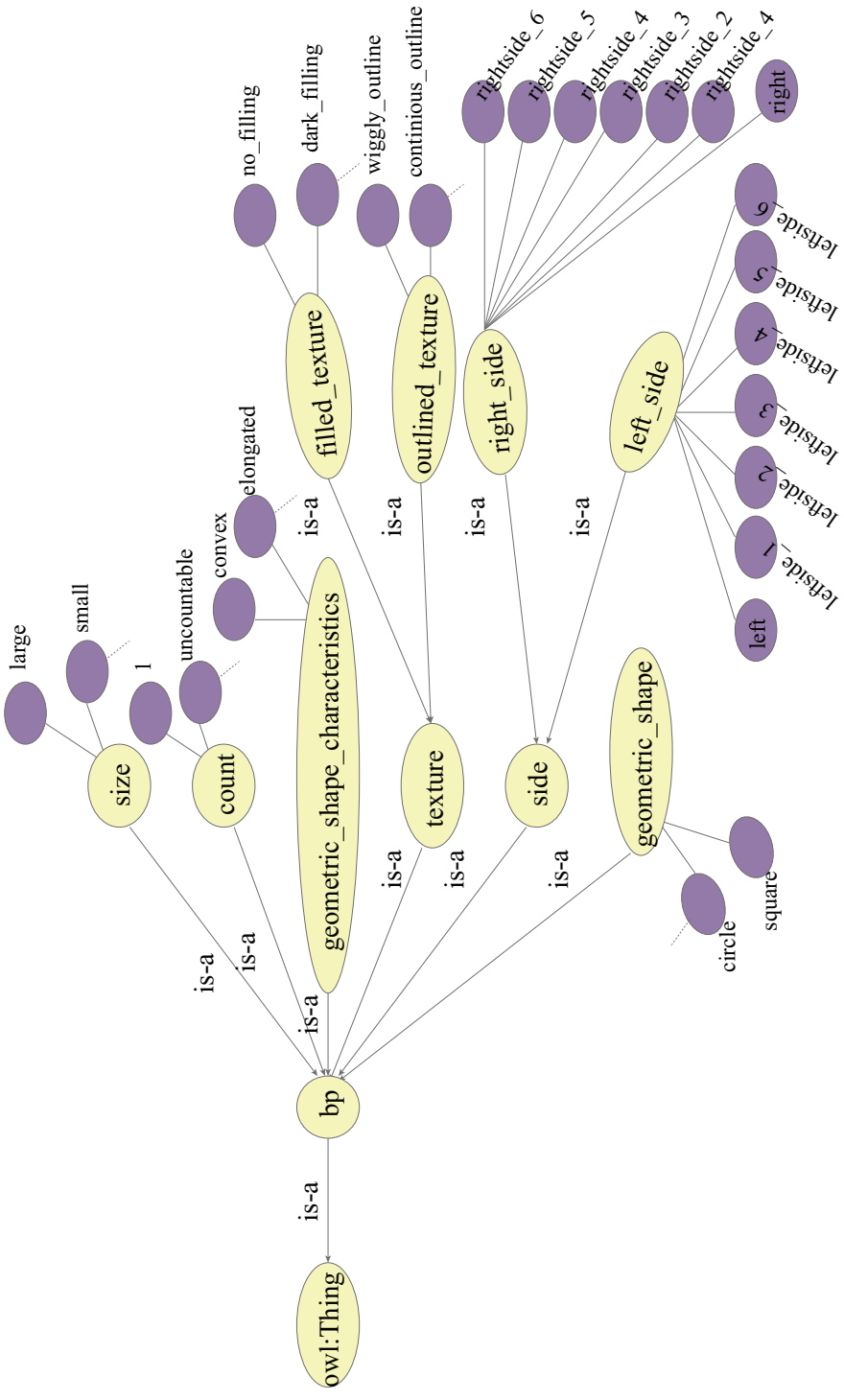

Figure 4-6: TBox and the class categorization used in solving BPs.

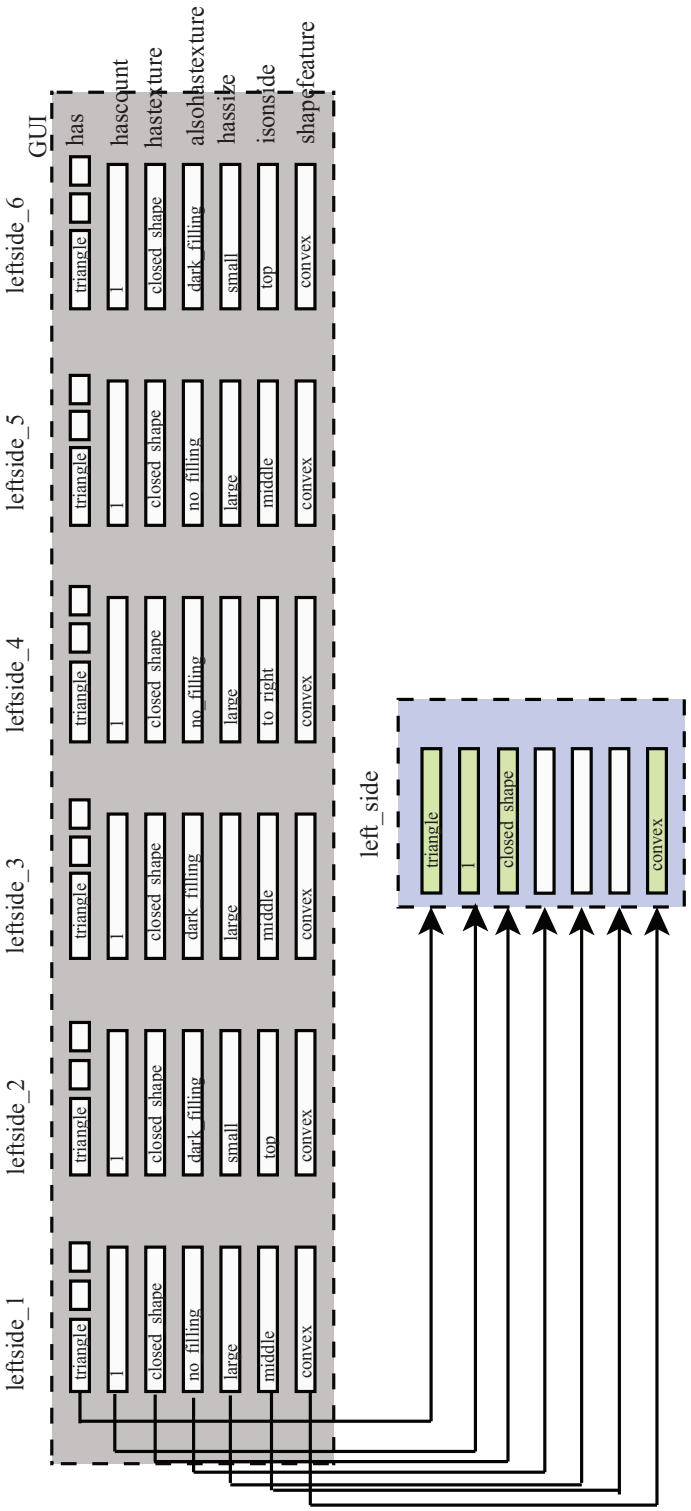

Figure 4-7: ABox framework for left set of boxes- for solving BP#6.

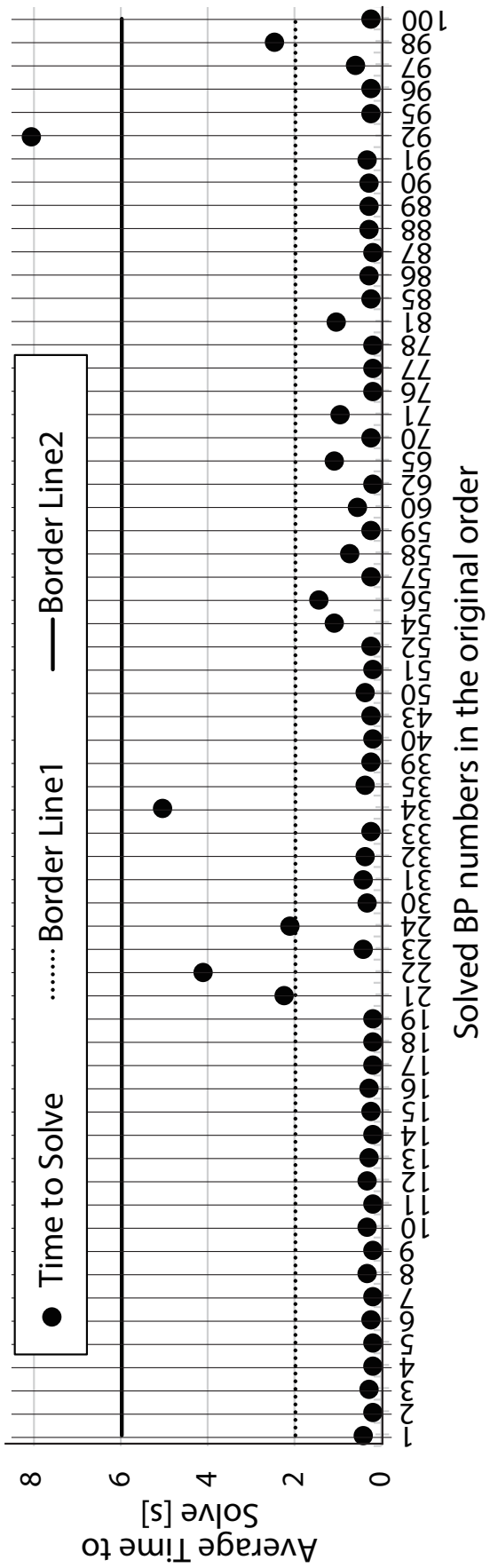

Figure 4-8: Results of our proposed model. Border lines are given as tentative borders to determine "Moderate BP" and "Difficult BP' in our model.

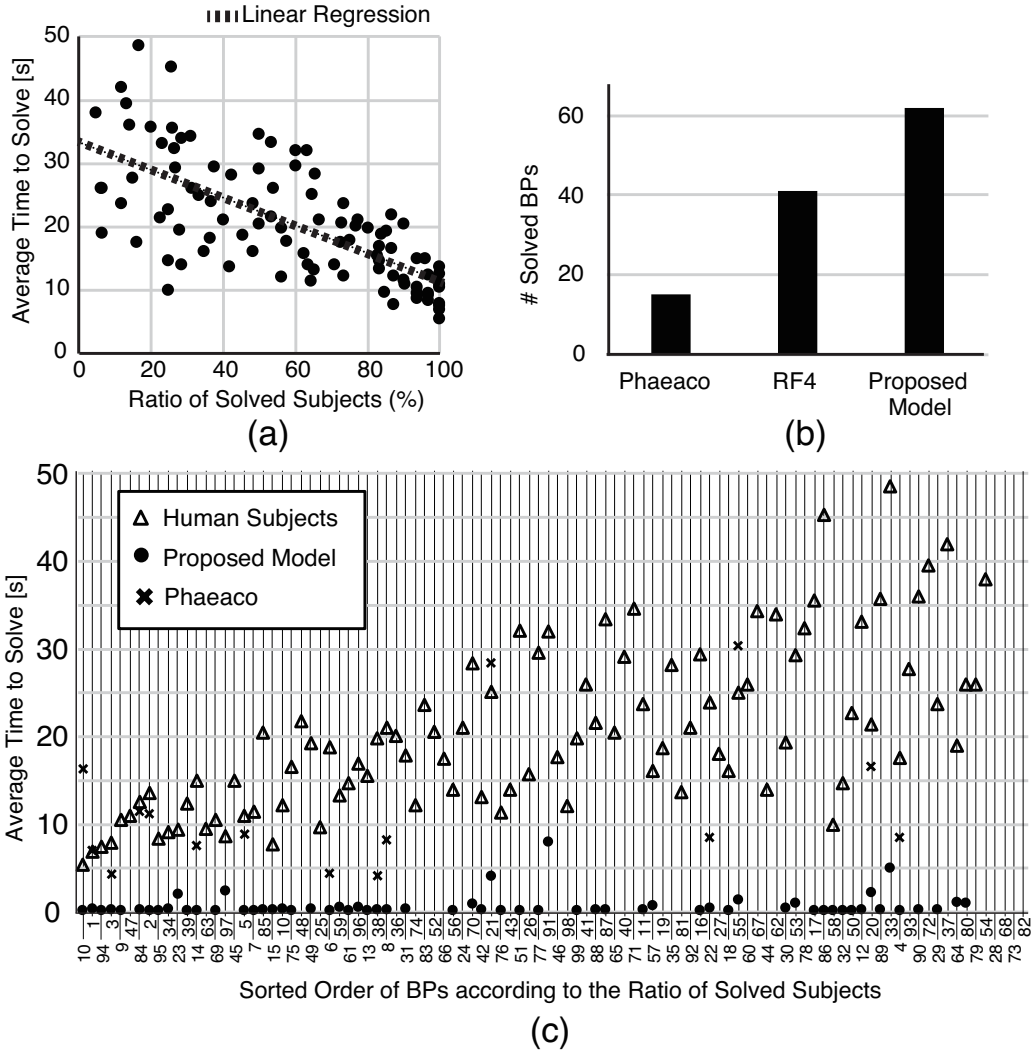

Figure 4-9: Comparison with other proposed models and human subjects. Phaeaco model and human subject data is replotted from data from Foundalis (2006) [16]. There is no description that which BPs can be solved by RF4 [17].

Chapter 5

Solving BP with Dependent Properties

As we have already discussed, solving some BPs (like BP #20, BP#25, BP#26, BP#27, BP#28, BP#29, BP#36, BP#37, BP#38, BP#41, BP#42, BP#44, BP#45, BP#46, BP#47, BP#48, BP#49, BP#53, BP#55, BP#61, BP#63 ... etc.) requires the use of dependent properties.

From the previous chapters and from the Fig. 5-1, $properties = Independentproperties, Dependentl$ Independent properties are the predicates that explain the features of individual objects in a given box, while dependent properties are predicated that helps in establishing relative relations between two objects.

Perceptual features like- "*LargerThan*","*smallerThan*", "*toLeftOf*","*toRightOf*", "*inside*","*outside*","*moreThan*","*lessThan*","*equalTo*","*crossing*" and many more, all pop up as the solutions to fewer problems relying on dependent properties.

An example of the complex hierarchy of dependent properties is as follows-

---

Circle1: *Smaller than* **Triangle1**, *To the bottom of* **Circle2**...;
Triangle1: *Larger than* **Circle1**, *Left of* **Circle2**, *Size is equal to* **Circle2**, ...;
Square1: *Smaller than* **Circle1**, *On the top of* **Circle1**, *Crossing* **Square2**...;

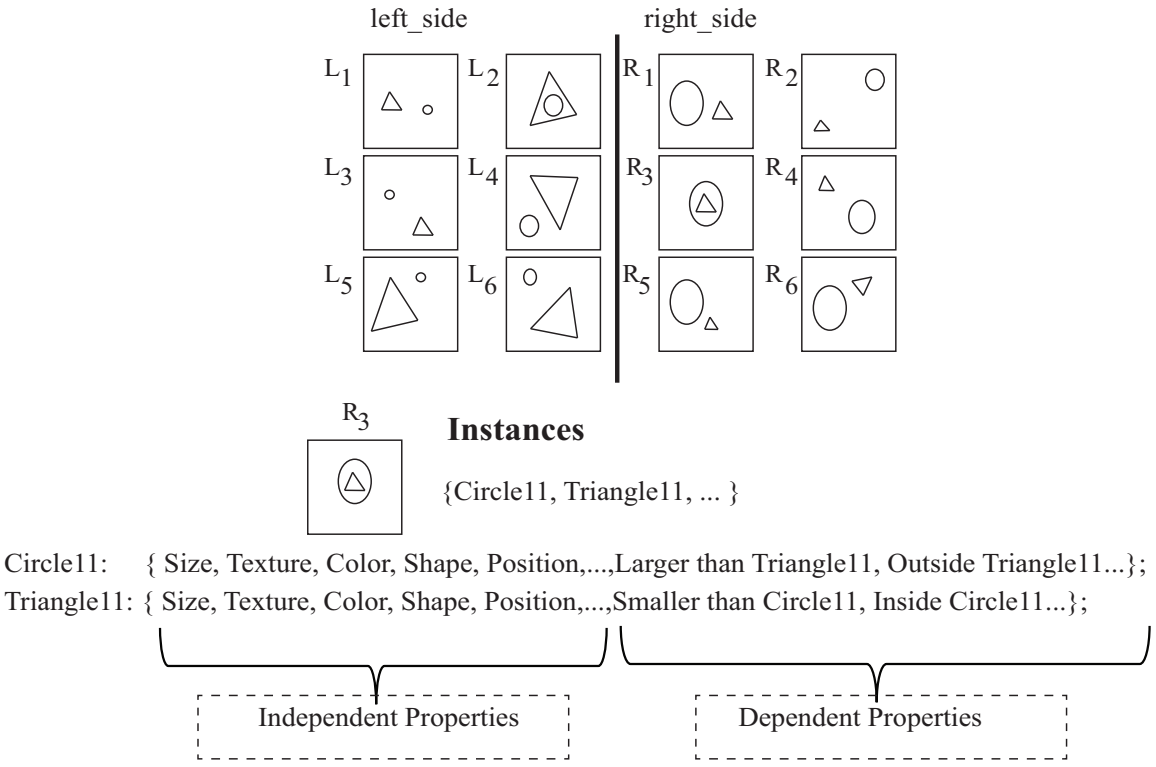

Figure 5-1: Describing a box in BP #38 using independent and dependent Properties.

5.1 Issues faced in solving BPs with dependent properties

Let us consider BP #36 to understand why solving BP employing dependent properties is the boundary from where using ontologies do not lead to any solution-

From Fig. 5-2, the following information can be obtained as ABox-

---

left_side1: <left_side1,has,circle>, <left_side1,has,triangle>,<circle,below,triangle>,<triangle,above,circle>,<circle,hasSize,small>.....

left_side2: <left_side2,has,circle>,<left_side1,has,triangle>,<circle,below,triangle>,<triangle,above,circle>,<circle,hasSize,large>.....

left_side3: <left_side3,has,circle>,<left_side1,has,triangle>,<circle,below,triangle>,<triangle,above,circle>,<circle,hasSize,small>.....

left_side4: <left_side4,has,circle>,<left_side1,has,triangle>,<circle,below,triangle>

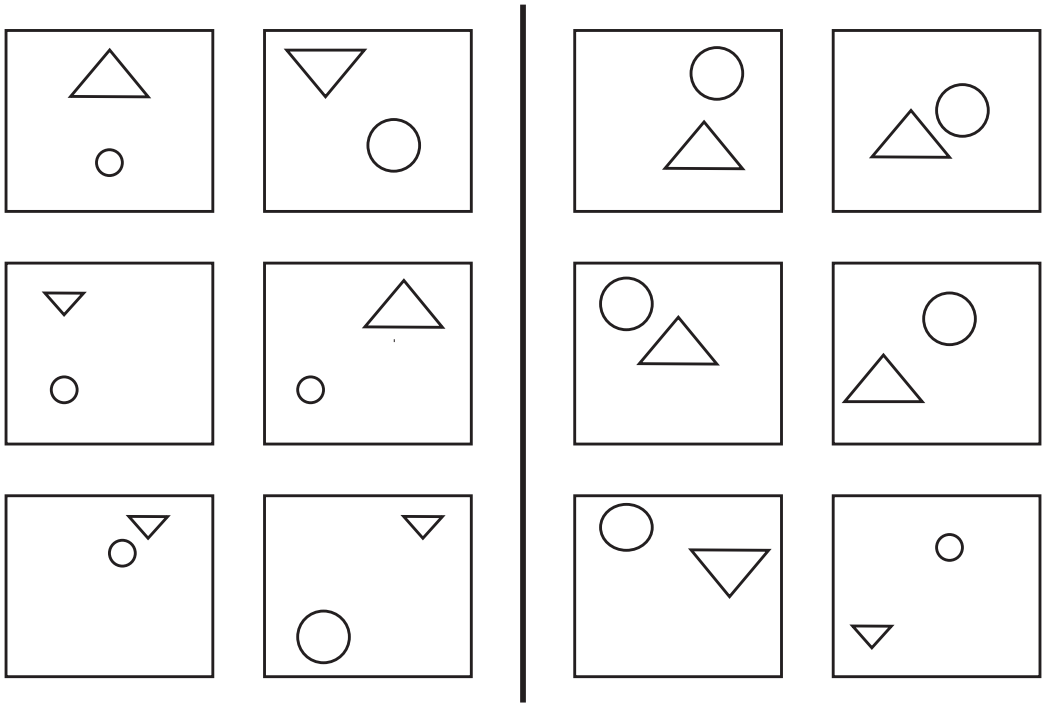

Figure 5-2: BP#36, exemplifying spacial position feature (position of objects) [15].

,<triangle,above,circle>,<circle,hasSize,small>.....

left_side5: <left_side5,has,circle>,<left_side1,has,triangle>,<circle,below,triangle>
,<triangle,above,circle>,<circle,hasSize,small>.....

left_side6: <left_side6,has,circle>,<left_side1,has,triangle>,<circle,below,triangle>
,<triangle,above,circle>,<circle,hasSize,large>.....

right_side1: <right_side1,has,circle>,<right_side1,has,triangle>,<circle,above,triangle>
,<triangle,below,circle>,<circle,hasSize,large>.....

right_side2: <right_side2,has,circle>,<right_side2,has,triangle>,<circle,above,triangle>
,<triangle,below,circle>,<circle,hasSize,large>.....

right_side3: <right_side3,has,circle>,<right_side3,has,triangle>,<circle,above,triangle>
,<triangle,below,circle>,<circle,hasSize,large>.....

right_side4: <right_side4,has,circle>,<right_side4,has,triangle>,<circle,above,triangle>
,<triangle,below,circle>,<circle,hasSize,large>.....

right_side5: <right_side5,has,circle>,<right_side5,has,triangle>,<circle,above,triangle>
,<triangle,below,circle>,<circle,hasSize,large>.....

right_side6: <right_side6,has,circle>,<right_side6,has,triangle>,<circle,above,triangle>

,<triangle,below,circle>,<circle,hasSize,small>.....

From the description-

left_side1: <left_side1,has,circle>, <left_side1,has,triangle>,<circle,below,triangle>, <triangle,above,circle>,<circle,hasSize,small>.....,

It can be understood that one of the left side box (left_side1) has circle and triangle with triangle having position above circle and the circle being small in size. Similarly each of the BP can be described in RDF format. As the number of objects in each boxes increase, the triple relations increases exponentially.

For the Fig. 5-2, the TBox can be represented as,

---

geometricShape(circle)

geometricshape(square)

side(left_side)

side(right_side)

left_side(left_side1).....

right_side(right_side1).....

position(below)

position(above)

To query the objects and their location in the given knowledge base K (where $K=(T, A)$) we use a simple SPARQL query like (query1) -

---

String query1= "PREFIX
relationshipUri2:http://bongardproblem.org/bp/relationship/includes/ "+
"SELECT ?side ?feature1"
"WHERE { " +
" ?side relationshipUri2:has ?feature1 . "+

" } ";

The result of Query1 would yield the following output, as shown in Table 5.1. Table 5.1 shows the objects and their location in the given knowledge base for BP#36.

Table 5.1: SPARQL query1 outcome for BP #36.

left_side1	circle
left_side2	circle
left_side3	circle
left_side4	circle
left_side5	circle
left_side6	circle
right_side1	circle
right_side2	circle
right_side3	circle
right_side4	circle
right_side5	circle
right_side6	circle
left_side1	triangle
left_side2	triangle
left_side3	triangle
left_side4	triangle
left_side5	triangle
left_side6	triangle
right_side1	triangle
right_side2	triangle
right_side3	triangle
right_side4	triangle
right_side5	triangle
right_side6	triangle

As discussed in the previous chapter, we use SWRL rules as sameness detector. Using **Rule 1** and **Rule 3** we can detect common shapes for each side (Left and Right of BP), as stated below-

Rule1 :has(leftside_1, ?a) $\wedge$ has(leftside_2, ?a) $\wedge$ has(leftside_3, ?a) $\wedge$
has(leftside_4, ?a) $\wedge$ has(leftside_5, ?a) $\wedge$ has(leftside_6, ?a) $\wedge$

DifferentIndividuals(?a,null) $\rightarrow$ consists_of_shape(left, ?a)

Rule3 :has(rightside_1, ?aa) $\wedge$ has(rightside_2, ?aa) $\wedge$ has(rightside_3, ?aa) $\wedge$ has(rightside_4, ?aa) $\wedge$ has(rightside_5, ?aa) $\wedge$ has(rightside_6, ?aa) $\wedge$ DifferentIndividuals(?aa, $null$) $\rightarrow$ consists_of_shape(right, ?aa)

Rule5 :consists_of_shape(right, ?aa) $\wedge$ consists_of_shape(left, ?a) $\wedge$ DifferentIndividuals(?a, ?aa) $\rightarrow$ has_inferred_shape(left, ?a) $\wedge$ has_inferred_shape(right, ?aa)

Rule6 :consists_of_shape(right, ?aa) $\wedge$ consists_of_shape(left, ?a) $\wedge$ consists_of_shape(right,notempty) $\wedge$ consists_of_shape(left,notempty) $\wedge$ DifferentIndividuals(?a, ?aa) $\rightarrow$ has_inferred_shape(left, ?a) $\wedge$ has_inferred_shape(right, ?aa)

we obtain an outcome -

<left, consists_of_shape,circle>,<left, consists_of_shape,triangle>,

<right, consists_of_shape,circle>,<right, consists_of_shape,triangle>.

But **Rule 5** and Rule **6**, will not yield an output since circle and triangle are present on both sides.

Rather than using this A_Box, using simple RDF, let us try to understand the outcome of inference and to understand the limitation of this current framework in solving BPs (BPs using dependent properties). If we use a simple SPARQL query like (query2), it will yield the following output as shown in Table 5.2.

String query2= "PREFIX

relationshipUri2:http://bongardproblem.org/bp/relationship/includes/ "+

"SELECT ?feature1 ?p ?feature2"

"WHERE { " +

" ?side relationshipUri2:consists_of_shape ?feature1 . "+

" ?side relationshipUri2:consists_of_shape ?feature2 . "+

“ ?feature1 ?p ?feature2 . ”+

“ } ”;

From Table 5.2, it can be noticed that-

<circle, below,triangle>,<circle, above,triangle>,<triangle, above,circle>,,<triangle, below,circle>,

This doesn't make any sense since a circle which is above a triangle is also below the same triangle (i.e., <circle, below, triangle>,<circle, above, triangle>).

Hence, such an representation of T_Box, as in Table 4.1, would not be sufficient in solving dependent properties. Since the object (*o* from <*s,p,o*>) points towards the same elements in *left_side* and *right_side*, it becomes impossible to use SWRL rules to find the solution (distinct solution between two sides).

Table 5.2: SPARQL query2 outcome for BP #36.

triangle	above	circle
triangle	below	circle
circle	below	triangle
circle	above	triangle

Puzzels like- BP #20, BP#25, BP#26, BP#27, BP#28, BP#29, BP#36, BP#37, BP#38, BP#41, BP#42, BP#44, BP#45, BP#46, BP#47, BP#48, BP#49, BP#53, BP#55, BP#61, BP#64, BP#66, BP#67, BP#68, BP#69, BP#73, BP#74, BP#75, BP#76, BP#79, BP#80, BP#82, BP#84, BP#93, BP#94 are few of the unsolved BPs using our hypothesis.

5.2 Hypothesis for solving BP#38 in Protégé by considering dependent properties

In this section, we propose an hierarchical structure to solve BP#38 by extending the present T_Box used for the 65 BPs discussed in the previous chapter. In addition

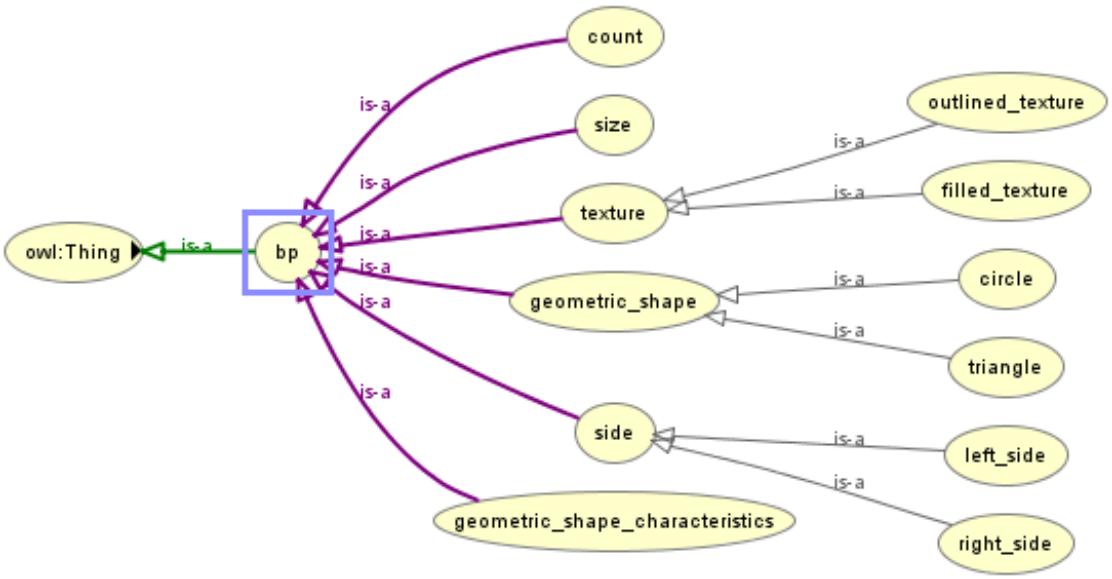

Figure 5-3: Hierarchical structure to solve BP#38.

to the terminologies in Table 4.1; as shown in Fig 5-4 we consider- $circle \sqsubseteq bp \sqcap geometric\_shape$ and $triangle \sqsubseteq bp \sqcap geometric\_shape$ for solving the BPs employing dependent properties.

Here, the concept assertion (i.e.- a: C if a $\in$ C) carried out with instances (from Fig. 5-5) can be represented as-

circle: circle

circle1: circle

circle2: circle

circle3: circle

circle4: circle

circle5: circle

circle6: circle

circle7: circle

circle8: circle

circle9: circle

circle10: circle

circle11: circle

circle12: circle

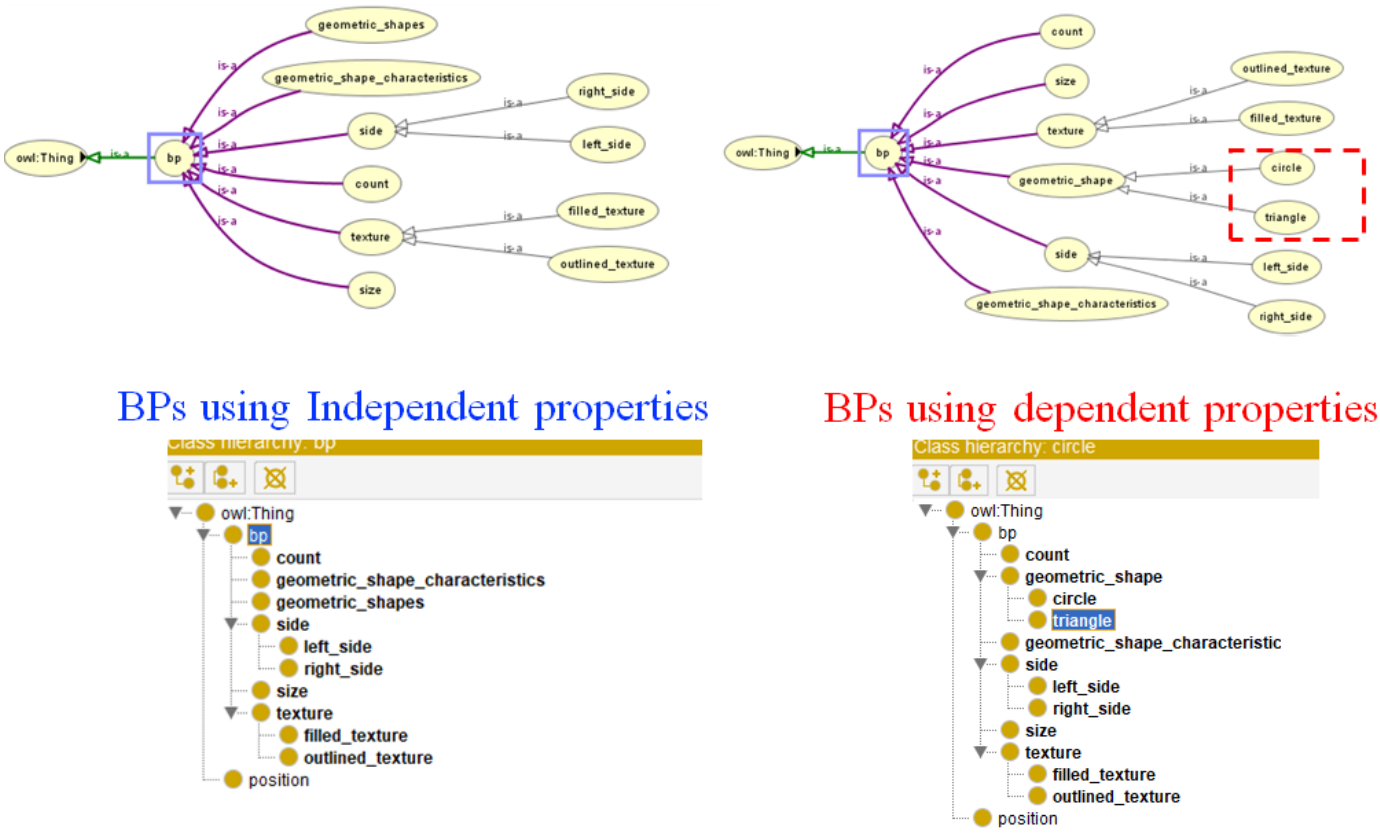

Figure 5-4: Comparison of Hierarchical structure to solve BPs using dependent and Independent Properties

circleLeft: circle

circleRight: circle

[Here the class circle and instant circle are separated from each other by the IRI used, and hence there exists no conflict while reasoning]

Similarly triangle class would have instances- {triangle, triangle1, triangle2, triangle3, triangle4, triangle5, triangle6, triangle7, triangle8, triangle9, triangle10, triangle11, triangle12, triangleLeft, triangleRight}

left_side={left,leftside_1,leftside_2,leftside_3,leftside_4,leftside_5,leftside_6}, and

right_side={right,rightside_1,rightside_2,rightside_3,rightside_4,rightside_5,rightside_6},

In this section we use the following SWRL rules -

Rule1 :has(leftside_1, ?a) $\wedge$ has(leftside_2, ?b) $\wedge$ has(leftside_3, ?c)

$\wedge$ has(leftside_4, ?d) $\wedge$ has(leftside_5, ?e) $\wedge$ has(leftside_6, ?f) $\wedge$

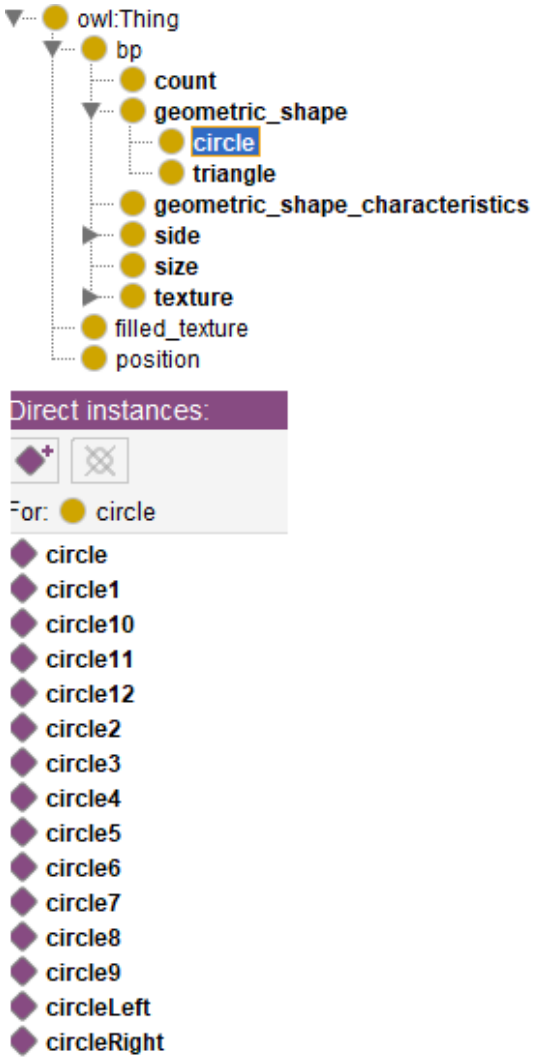

Figure 5-5: Class and instanced employed in solving BP#38.

$circle(?a)$ $\wedge$ circle($?b$) $\wedge$ circle($?c$) $\wedge$ circle($?d$) $\wedge$ circle($?e$) $\wedge$
$circle(?f) \rightarrow$ has_infered_shape($left$, circleLeft)

Rule2 :has(rightside_1, $?a$) $\wedge$ has(rightside_2, $?b$) $\wedge$ has(rightside_3, $?c$)
$\wedge$ has(rightside_4, $?d$) $\wedge$ has(rightside_5, $?e$) $\wedge$ has(rightside_6, $?f$) $\wedge$
$circle(?a)$ $\wedge$ circle($?b$) $\wedge$ circle($?c$) $\wedge$ circle($?d$) $\wedge$ circle($?e$) $\wedge$
$circle(?f) \rightarrow$ has_infered_shape($right$, circleRight)

Rule3 :has(leftside_1, $?aa$) $\wedge$ has(leftside_2, $?ab$) $\wedge$ has(leftside_3, $?ac$)

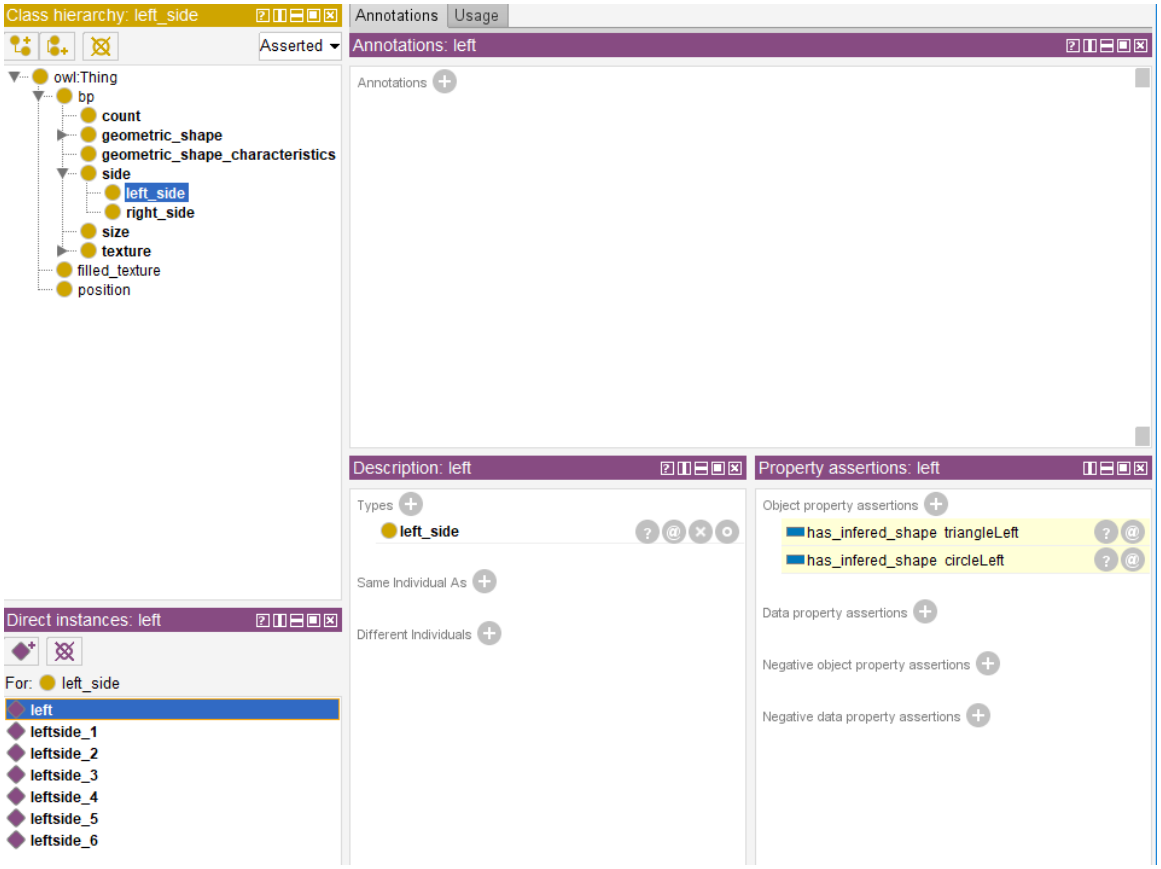

Figure 5-6: Protégé based inference of Left side of BP#38 using dependent properties.

$\wedge$ has(leftside_4, ?ad) $\wedge$ has(leftside_5, ?ae) $\wedge$ has(leftside_6, ?af)
$\wedge$ triangle(?aa) $\wedge$ triangle(?ab) $\wedge$ triangle(?ac) $\wedge$ triangle(?ad) $\wedge$
$triangle$(?ae) $\wedge$ triangle(?af) $\rightarrow$ has_infered_shape($left$, triangleLeft)

Rule4 :has(rightside_1, ?aa) $\wedge$ has(rightside_2, ?ab) $\wedge$ has(rightside_3, ?ac)
$\wedge$ has(rightside_4, ?ad) $\wedge$ has(rightside_5, ?ae) $\wedge$ has(rightside_6, ?af)
$\wedge$ triangle(?aa) $\wedge$ triangle(?ab) $\wedge$ triangle(?ac) $\wedge$ triangle(?ad) $\wedge$
$triangle$(?ae) $\wedge$ triangle(?af) $\rightarrow$ has_infered_shape($right$, triangleRight)

Rule5 :has(leftside_1, ?a) $\wedge$ has(leftside_2, ?b) $\wedge$ has(leftside_3, ?c) $\wedge$
$has(leftside\_4$, ?d) $\wedge$ has(leftside_5, ?e) $\wedge$ has(leftside_6, ?f) $\wedge$ has(leftside_1,
?aa) $\wedge$ has(leftside_2, ?ab) $\wedge$ has(leftside_3, ?ac) $\wedge$ has(leftside_4, ?ad)
$\wedge$ has(leftside_5, ?ae) $\wedge$ has(leftside_6, ?af) $\wedge$ $is\_smaller\_than$(?a, ?aa)

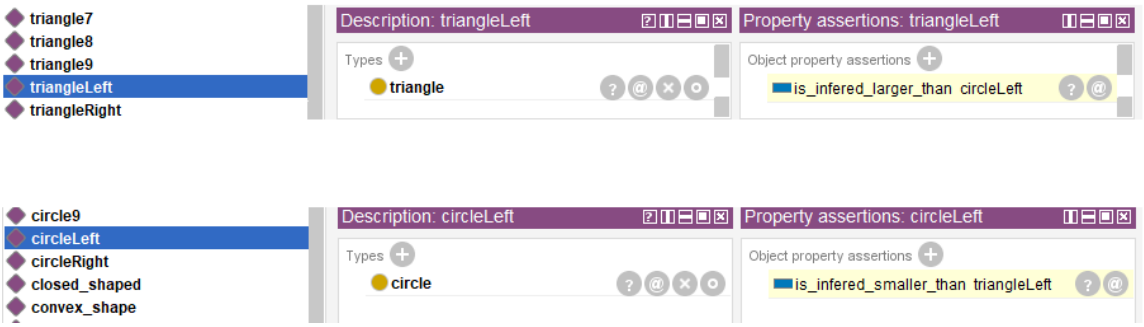

Figure 5-7: Protégé based inference of Left side features of BP#38.

$\wedge$ *is_smaller_than*(?b, ?ab) $\wedge$ *is_smaller_than*(?c, ?ac) $\wedge$ *is_smaller_than*(?d, ?ad)

$\wedge$ *is_smaller_than*(?e, ?ae) $\wedge$ *is_smaller_than*(?f, ?af) $\wedge$ circle(?a) $\wedge$ circle(?b)

$\wedge$ circle(?c) $\wedge$ circle(?d) $\wedge$ circle(?e) $\wedge$ circle(?f) $\wedge$ triangle(?aa) $\wedge$

triangle(?ab) $\wedge$ triangle(?ac) $\wedge$ triangle(?ad) $\wedge$ triangle(?ae) $\wedge$ triangle(?af)

$\rightarrow$ is_infered_smaller_than(circleLeft, triangleLeft)

Rule6 :has(rightside_1, ?a) $\wedge$ has(rightside_2, ?b) $\wedge$ has(rightside_3, ?c)

$\wedge$ has(rightside_4, ?d) $\wedge$ has(rightside_5, ?e) $\wedge$ has(rightside_6, ?f) $\wedge$

has(*rightside*_1, ?aa) $\wedge$ has(rightside_2, ?ab) $\wedge$ has(rightside_3, ?ac) $\wedge$

has(*rightside*_4, ?ad) $\wedge$ has(rightside_5, ?ae) $\wedge$ has(rightside_6, ?af) $\wedge$

is_larger_than(?a, ?aa) $\wedge$ is_larger_than(?b, ?ab) $\wedge$ is_larger_than(?c, ?ac)

$\wedge$ is_larger_than(?d, ?ad) $\wedge$ is_larger_than(?e, ?ae) $\wedge$ is_larger_than(?f, ?af)

$\wedge$ circle(?a) $\wedge$ circle(?b) $\wedge$ circle(?c) $\wedge$ circle(?d) $\wedge$ circle(?e) $\wedge$

circle(?f) $\wedge$ triangle(?aa) $\wedge$ triangle(?ab) $\wedge$ triangle(?ac) $\wedge$ triangle(?ad)

$\wedge$ triangle(?ae) $\wedge$ triangle(?af) $\rightarrow$ is_infered_larger_than(circleRight, triangleRight)

Here SWRL rules **Rule 1**, **Rule 2**, **Rule 3** and **Rule 4** are used to identify common shapes on respective sides. For example, if all the instances of the left side for each box are instances of the circle, then the left side has an inferred shape circleLeft.

SWRL rules **Rule 5** and **Rule 6** are used to compare the relationship between

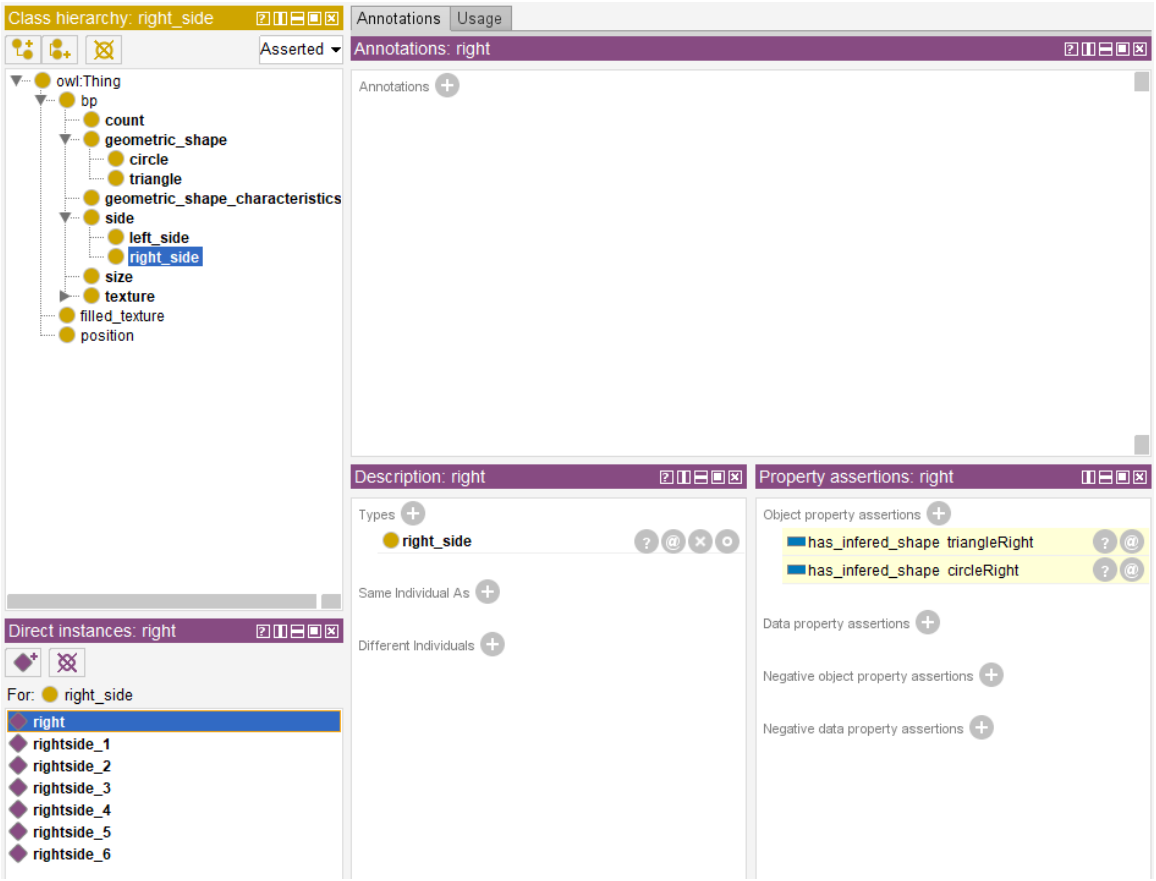

Figure 5-8: Protégé based inference of Right side of BP#38 using dependent properties.

circleLeft and triangleLeft; and circleRight and triangleRight respectively.

Figure 5-6 and Figure 5-7, is the output of the Left side for BP#38, were- left side has triangle and circle, and the circle is smaller than the triangle (or triangle is larger than a circle).

Figure 5-8 and Figure 5-9, is the output of the Right side for BP#38, where- Right side has triangle and circle, and the triangle is smaller than the circle (or circle is larger than triangle).

<left,has_infered_shape,triangleLeft>, <left,has_infered_shape,circleLeft>

<circleLeft,has_infered_smaller_than,triangleLeft>,

<triangleLeft,has_infered_larger_than,circleLeft>

<right,has_infered_shape,triangleRight>, <right,has_infered_shape,circleRight>

<circleRight,has_infered_larger_than,triangleRight>,

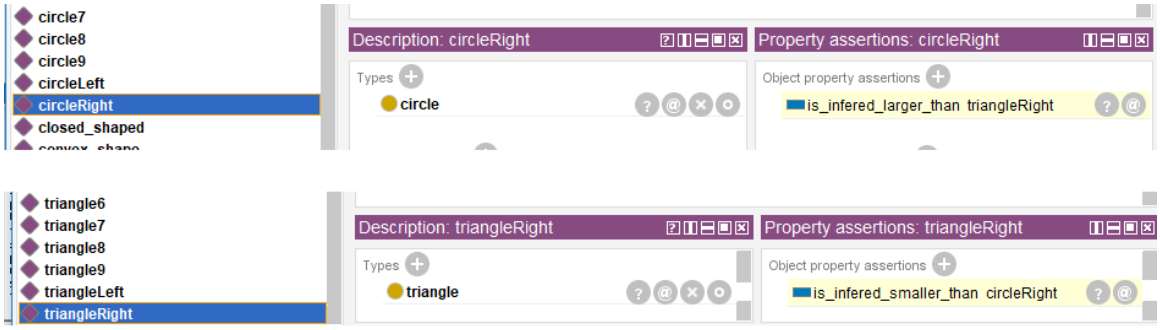

Figure 5-9: Protégé based inference of Right side features of BP#38.

<triangleRight,has_infered_smaller_than,circleRight>

Chapter 6

Discussion and Conclusion

In this chapter of this thesis, we consider the capabilities and limitations of our proposed methodology for solving BPs. W would conclude this chapter with suggestions for future applications.

The main issues that were of our interest are:

1) The scope of a knowledge representation towards solving BPs

2) Understanding the varying difficulties of BPs and understanding Dr. Holfstadter's idea and practically verifying the same using simple logic

Our proposed framework could solve 65 BPs out of the 100 BPs (Fig. 4-8). The inferred knowledge of each BP undergoes three-level of regressive funneling and pruning (SPARQL query, SWRL based the first level of inference and SWRL based the second level of reasoning). Each stage notices a reduction in the predicted outcome of the selected BP, which was the significant extension of preliminary reports [26, 27]. As the novelty, the solver of BPs can be described in Equation 4.1 theoretically and simply; however, no model was presented to realize the correctness. This work proved the equation works well in the realistic implementation with semantics and logic.

This our logical architecture solves BPs from an engineering perspective and has helped us in understanding "why some BPS are difficult to solve" in a theoretical (psychological) perspective. According to the concept by Hofstadter [15], we rebuilt the components based on the theory of sets and tools in the semantic web and proposed the system to solve BPs with-

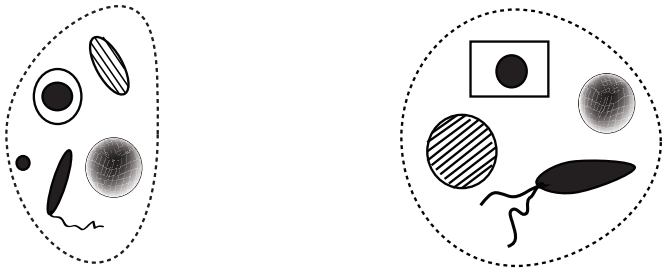

Figure 6-1: Cancer cell (DNC) Vs Normal cell (DNN), redrawn based on the figure of [33].

i) Ontology-based description to represent the necessary concept network,

ii) Description Logic (DL) with assertions on concepts (TBox) and individuals (ABox) to provide minimum frames,

iii) meta-data template,

iv) SPARQL Protocol and RDF Query Language shortly SPARQL for the filtering function and

v) Semantic Web Rule Language (SWRL) rules as sameness detector.

We have proved that our model with an RDF based knowledge base is efficient in solving BPs. The current approach focuses more on independent properties of objects in a box, which was demonstrated with six independent properties as a minimum set. We have also tried in our last chapter of this thesis to solve one BP, which employs dependent property, using the RDF based framework using a fine hierarchy, including upper classes. By solving BP, we believe that deductive reasoning accompanied by expanding the knowledge base, as in Fig. 5-4, is a key towards solving BPs, which matches with Piaget's theory of cognitive development in children. In future work, this framework can be embedded in the hybrid system as an automatic BP solver changing analogies associated with vision-based analyzers for spatial representation. It can open the new horizon of the logical reasoning system to incorporate data-driven models for the decision-making process in the dynamic environment.

This proposed framework for solving BPs works as a step towards-

1) General AI by solving Ill-posed problem

2) Successfully solving Ill-posed problem using Ontology-based knowledge represen-

tation using a simple logic -

$||(L_i \notin P_a) \wedge (R_i \notin P_b) \wedge (L_i \in P_b) \wedge (R_i \in P_a) \wedge (P_a \cap P_b = \emptyset)||$-> $||(L_i has P_b)|| \wedge ||(R_i has P_a)||$,

3) Practically implementing Dr. Holfstadter's idea to solve BPs

BPs can be used as a testbed for the machines to evaluate or study the interaction of computer vision, conceptual knowledge interface, and reasoning. By understanding and generalizing such a top-down method in an attempt to find the best solution, we can relate BPs to real word problems like- understanding the basic cell structure.

$T_{cell} = \{count \sqsubseteq cell,$	$(T_{cell}, 1)$
$geometric\_shape \sqsubseteq cell,$	$(T_{cell}, 2)$
$geometric\_shape\_characteristics \sqsubseteq cell,$	$(T_{cell}, 3)$
$side \sqsubseteq cell,$	$(T_{cell}, 4)$
$size \sqsubseteq cell,$	$(T_{cell}, 5)$
$texture \sqsubseteq cell,$	$(T_{cell}, 6)$
$type\_of\_Protoplasm \sqsubseteq cell,$	$(T_{cell}, 2)$
$right\_side \sqsubseteq cell \sqcap side,$	$(T_{cell}, 7)$
$left\_side \sqsubseteq cell \sqcap side,$	$(T_{cell}, 8)$
$left\_side \sqsubseteq \neg right\_side,$	$(T_{cell}, 9)$
$left\_side \sqcup right\_side \sqsubseteq side,$	$(T_{cell}, 10)$
$filled\_texture \sqsubseteq \neg outlined\_texture,$	$(T_{cell}, 11)$
$filled\_texture \sqcup outlined\_texture \sqsubseteq texture,$	$(T_{cell}, 12)\}$

Table 6.1: TBox for solving cell classification Problem.

A real-world application of this approach can help us in cell classification by understanding the difference between cancerous cells (with cell description-irregular shape, protoplasm shape-circle, stripped texture..and so forth) and non-cancerous cells (with cell description-circular shape, protoplasm shape-square, shaded texture..and so forth). As shown in Fig. 6-1, the DNC cell on the left side is a cancerous cell, and the DNN cell on the right side is non-cancerous [33]. As already discussed, the features used for the Bongard problem, as in Table 4.1, we believe that with small expansion in features(expanding the class structure) used, we can solve the issue of cell classification utilizing the knowledge base. The new T_box for such a cell classification problem can be as shown in Table 6.1. By this, we wish that in the future, many more Ill-posed problems would be tackled using an ontology-based knowledge reasoning along with

a data-driven approach for better visual instances.

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Appendix 1: Ontology for solving 65 BPs

The purpose of this appendix is to give the Ontology for solving 65 BPs. Since the Triple format of the ontology is more understandable we are publishing the “BPOntology” as follows.

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A2

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          </j.1:geometric_shape_characteristics>
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        <owl:differentFrom
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        <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/rightShadowed"/>
      </j.1:geometric_shape_characteristics>
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/kite"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/crossing"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/elongated"/>
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    <owl:differentFrom
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    <owl:differentFrom
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    <owl:differentFrom
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    <owl:differentFrom
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/oval"/>
    <owl:differentFrom
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    <owl:differentFrom
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/star"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/line"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/triangle"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/collinear"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/cluster_formation"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/trapezoid"/>
    <owl:differentFrom
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/bottom"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/endsParallel"/>
    <owl:differentFrom>
      <j.1:geometric_shapes
rdf:about="http://bongardproblem.org/bp/relationship/proprties/waveform">
        <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
      </j.1:geometric_shapes>
    </owl:differentFrom>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/leftShadowed"/>
```

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    <owl:differentFrom
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    <owl:differentFrom
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    <rdf:type rdf:resource="http://bongardproblem.org/bp/outlined_texture"/>
    <owl:differentFrom
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    <rdf:type
rdf:resource="http://bongardproblem.org/bp/geometric_shape_characteristics"/>
    <owl:differentFrom
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/lineset"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/sharpedges"/>
    <owl:differentFrom
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    <rdf:type rdf:resource="http://bongardproblem.org/bp/count"/>
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/rightShadowed"/>
    <owl:differentFrom
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    <rdf:type rdf:resource="http://bongardproblem.org/bp/geometric_shapes"/>
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/parallel"/>
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/squeezed_shape"/>
  </j.1:size>
 </b:hasshapefeature>
 <b:isonside>
  <j.1:side rdf:about="http://bongardproblem.org/bp/relationship/proprties/ "/>
 </b:isonside>
 <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
</j.1:right_side>
<j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/15"/>
<j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_3">
```

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 <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
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 <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
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rdf:about="http://bongardproblem.org/bp/relationship/proprties/not_squeezed_shape"/>
<j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/16"/>
<j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_2">
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 <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
</j.1:left_side>
<j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/13"/>
<j.1:right_side
rdf:about="http://bongardproblem.org/bp/relationship/proprties/rightside_3">
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
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 <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
</j.1:right_side>
<j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_5">
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
 <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
 <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
```

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    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:left_side>
  <j.1:right_side
rdf:about="http://bongardproblem.org/bp/relationship/proprties/rightside_5">
    <b:hasshapefeature
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:right_side>
  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/14"/>
  <j.1:right_side
rdf:about="http://bongardproblem.org/bp/relationship/proprties/rightside_4">
    <b:hasshapefeature
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:right_side>
  <j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_4">
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:left_side>
  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/11"/>
  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/19"/>
```



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  <j.1:right_side
rdf:about="http://bongardproblem.org/bp/relationship/proprties/rightside_1">
    <b:hasshapefeature
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:right_side>
  <owl:AnnotationProperty
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  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/12"/>
  <j.1:right_side
rdf:about="http://bongardproblem.org/bp/relationship/proprties/rightside_2">
    <b:hasshapefeature
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:right_side>
  <j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_6">
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    <b:isonside rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ "/>
    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:left_side>
  <j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/left"/>
  <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/hardlysqueezed_shape"/>
  <j.1:right_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/right"/>
  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/17"/>
  <j.1:left_side rdf:about="http://bongardproblem.org/bp/relationship/proprties/leftside_1">
```



```
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    <b:hassize rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:alsohastexture
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    <b:hastexture rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:hascount rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
    <b:has rdf:resource="http://bongardproblem.org/bp/relationship/proprties/null"/>
  </j.1:left_side>
  <j.1:geometric_shapes
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  <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/softlysqueezed_shape"/>
  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/18"/>
  <j.1:geometric_shapes
rdf:about="http://bongardproblem.org/bp/relationship/proprties/empty"/>
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        <owl:differentFrom>
          <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/4">
            <owl:differentFrom>
              <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/8">
                <owl:differentFrom>
                  <j.1:count rdf:about="http://bongardproblem.org/bp/relationship/proprties/1">
                    <owl:differentFrom
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                  </owl:differentFrom>
                </j.1:count
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                <owl:differentFrom
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              </owl:differentFrom>
            </j.1:count
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            <owl:differentFrom
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          </owl:differentFrom>
        </j.1:count
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        <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/9"/>
```



```
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        <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/uncountable"/>
        <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/4"/>
        <owl:differentFrom>
          <j.1:count
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            <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/9"/>
            <owl:differentFrom
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            <owl:differentFrom
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            <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/6"/>
          </owl:differentFrom>
          <j.1:count
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/uncountable"/>
            <owl:differentFrom
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            <owl:differentFrom
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/6"/>
            <owl:differentFrom
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            <owl:differentFrom
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            <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/7"/>
          </owl:differentFrom>
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            <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/9"/>
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/uncountable"/>
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  <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/no_filling"/>
 </j.1:filled_texture>
 <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/ends_close">
  <owl:differentFrom>
   <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/ends_far">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/ends_close"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
 <j.1:filled_texture
rdf:about="http://bongardproblem.org/bp/relationship/proprties/vertical_lines">
  <owl:differentFrom>
   <j.1:filled_texture
rdf:about="http://bongardproblem.org/bp/relationship/proprties/horizontal_lines">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/vertical_lines"/>
   </j.1:filled_texture>
  </owl:differentFrom>
 </j.1:filled_texture>
 <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/one_level_insideness">
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   <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/two_level_insideness">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/one_level_insideness"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
 <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/horizontal_cluster">
  <owl:differentFrom>
   <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/vertical_cluster">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/horizontal_cluster"/>
```

```
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  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
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  <owl:differentFrom>
   <j.1:size rdf:about="http://bongardproblem.org/bp/relationship/proprties/increasing">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/decreasing"/>
   </j.1:size>
  </owl:differentFrom>
 </j.1:size>
 <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/alphabet_b">
  <owl:differentFrom>
   <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/alphabet_a">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/alphabet_b"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
 <j.1:geometric_shape_characteristics
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  <owl:differentFrom>
   <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/shortconcave_shape">
    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/longconcave_shape"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
 <j.1:geometric_shape_characteristics
rdf:about="http://bongardproblem.org/bp/relationship/proprties/opositedirection">
  <owl:differentFrom>
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rdf:about="http://bongardproblem.org/bp/relationship/proprties/samedirection">
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rdf:resource="http://bongardproblem.org/bp/relationship/proprties/opositedirection"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
 <j.1:geometric_shape_characteristics
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  <owl:differentFrom>
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    <owl:differentFrom
rdf:resource="http://bongardproblem.org/bp/relationship/proprties/one_level_branching"/>
   </j.1:geometric_shape_characteristics>
  </owl:differentFrom>
 </j.1:geometric_shape_characteristics>
</rdf:RDF>
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Appendix 2: Logical Rules for solving 65 BPs

The purpose of this appendix is to give the logical rules to be used on the Ontology for inferring the solution to 65 BPs.

```
//this is for checking shape
        "[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
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bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a),(?a
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a)]"+

        "[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
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http://bongardproblem.org/bp/relationship/proprties/null),(?a
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http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp
/relationship/proprties/leftside_2
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bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a)]"+

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http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org
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http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org
/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org
/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org
/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?a3)-
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http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

//polygon left

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lem.org/bp/relationship/proprties/leftside_3
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http://bongardproblem.org/bp/relationship/proprties/quadrilateral)-
>( http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)]"+

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lem.org/bp/relationship/proprties/leftside_6
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>( http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/curvilinear)]"+

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http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
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http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
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http://bongardproblem.org/bp/relationship/proprties/empty)]"+

//this is for checking shape

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http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa),(?aa
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
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http://bongardproblem.org/bp/relationship/proprties/null),(?aa
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
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/bp/relationship/proprties/rightside_4
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http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa)]"+

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http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://www.w3.org/2002/07/owl#differentFrom ?aa3)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

//polygon right

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http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa3
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http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa6
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http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
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http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
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http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/polygon)]"+

//quadrilateral right

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http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa2
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa3
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa4

http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa5
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa6
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)]"+

//curvilinear left

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa2
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa3
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa4
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa5
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa6
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hastexture

http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/curvilinear)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty)]"+

//this is for checking the difference in shape

"[rule2:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http:/
/bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(http
://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa),(http
://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a)]"+

"[rule2:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http:/
/bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(http
://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa),(http
://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a)]"+
"[rule2:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http:/
/bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a),(http:
//bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa)]"+

//this is for checking the texture

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproble
m.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproble
m.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproble
m.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproble
m.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproble
m.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hastexture ?t)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t)]"+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t1)]"+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t)]"
+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t1)]
"+

//this is for checking the difference in texture

"[rule4:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t1),(?t
http://www.w3.org/2002/07/owl#differentFrom ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t1)]"+

"[rule4:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t),(
http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t1),
(?t http://www.w3.org/2002/07/owl#differentFrom ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t1)]"+

//count left and right

"[rule5:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hascount ?c)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c)]"+

"[rule5:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4

http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hascount ?c1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c1)]"+

//this is for checking difference in count

"[rule6:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c),(http:
//bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c1),(?c1
http://www.w3.org/2002/07/owl#differentFrom ?c)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c),(http:/
/bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c1)]"+

//size of left and right

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?sz)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?sz)]"+

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?sz1)]"+

//uneven size of left and right

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?siz1),(http://bongardproble
m.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?siz3),(http://bongardproble
m.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?siz5),(http://bongardproble
m.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?siz7),(http://bongardproble
m.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?siz9),(http://bongardproble
m.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?siz11),(?siz1
http://www.w3.org/2002/07/owl#differentFrom ?siz5)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size
http://bongardproblem.org/bp/relationship/proprties/uneven_shapes)]"+

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?siz2),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?siz4),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?siz6),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?siz8),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?siz10),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?siz12),(?siz2
http://www.w3.org/2002/07/owl#differentFrom ?siz6)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size
http://bongardproblem.org/bp/relationship/proprties/uneven_shapes)]"+

//this is for checking difference in size

"[rule8:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?siz13),(ht
tp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?siz14),(?si
z13 http://www.w3.org/2002/07/owl#differentFrom ?siz14)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size ?siz13),(htt
p://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size ?siz14)]"+

//side (left and right)

"[rule9:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(?sd1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd1)]"
+

"[rule9:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(?sd
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd)]"+

//this is for checking difference in position(side)

"[rule10:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd1),(
?sd1 http://www.w3.org/2002/07/owl#differentFrom ?sd)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_position ?sd),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_position ?sd1)]"
+

//feature (left and right)

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe)]"
+

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)]
"+

//this is for checking difference in feature

"[rule12:(http://bongardproblem.org/bp/relationship/proprties/left

http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1),(?fe http://www.w3.org/2002/07/owl#differentFrom ?fe1)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?fe1)]"+

//neck and nonempty [no neck]

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/squeezed_shape),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape
http://bongardproblem.org/bp/relationship/proprties/squeezed_shape),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape
http://bongardproblem.org/bp/relationship/proprties/not_squeezed_shape)]"+

//shape and not empty

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(?fet5 http://www.w3.org/2002/07/owl#differentFrom ?fet6)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(?fet5 http://www.w3.org/2002/07/owl#differentFrom ?fet6)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

"[rule12:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshapefeature ?fe1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?fe1)]"+

"[rule12:(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshapefeature ?fe),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?fe)]"+

// feature no. (left - 2 cluster, right- 3 cluster)

"[rule13:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c),(?c http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c1),(?c1 http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp/relationship/proprties/left

http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?c),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?c1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?fe1)]"+

//hardly and softly squeezed

"[rule14:(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/longconcave_shape),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/shortconcave_shape)->(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/hardlysqueezed_shape),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/softlysqueezed_shape)]"+

//damping signal

"[rule15:(?l
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/waveform),(?r
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/waveform),(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size
http://bongardproblem.org/bp/relationship/proprties/increasing),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size
http://bongardproblem.org/bp/relationship/proprties/decreasing)->(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshapefeature http://bongardproblem.org/bp/relationship/proprties/dampingsignal),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/dampingsignal)]"+

//shape feature x and null
//cross check for 13
//cross check

"[rule16:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshape ?shapex),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?shapex)]"+

"[rule16:
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshape ?shapex1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?shapex1)]"+

// cross check independent properties

"[rule16:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2

http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett6),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?aa1),(?a2
http://www.w3.org/2002/07/owl#differentFrom ?aa2),(?a3
http://www.w3.org/2002/07/owl#differentFrom ?aa3),(?fet1
http://www.w3.org/2002/07/owl#differentFrom ?fet2),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?a2),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?a3),(?fet1
http://www.w3.org/2002/07/owl#differentFrom /fet3),(?aa1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(?aa2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?aa1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a2),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?aa2)]"+
"[rule16:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett6),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?aa1),(?a1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(?a2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a2),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a1)]"+

//uneven texture and similar textures
"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex11),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex12),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex13),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex14),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex15),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex16),(?tex11
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex12
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex13
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex14
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex15
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex16
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+
"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex6),(?tex1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex3
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex4
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex5
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex6
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+
"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?texx)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothastexture ?texx),(http://bongardproblem.org/bp/relationship/proprties/left

http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?texx)]"
+
"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?tex
x)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothastext
ure ?texx),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?texx)]"
+

//feature x and no feature
"[rule18:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/line),(http://bongardproblem.org/bp
/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/line),(http://bongardproblem.org/bp
/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]"+
"[rule18:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?Shapex1
),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex2
),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]"+
"[rule18:
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?Shapex1
),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex2
),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]";

Appendix 3: Java Program for solving 65 BPs

The purpose of this appendix is to show the implementation method by using JAVA programming codes as follows.

```
package Applet_ontology_v12_v1_v16;
/**
 * @author Jisha Maniamma
 * Kyushu Institute of Technology
 *
   Here an ontology is created to solve Bongard Problems. BPs are 100 visual puzzels.
   Using an Ontology we have created an Knowledge Base to solve any given BP
(shape puzzle).
   <p>
   Creating Ontology based framework to solve Bongard Problems is a new approach.
   This Shape Ontology considers- geometric shape, position, count, texture, size and
characteristic from each
   box as an input (into place holders).
 *
 * @return new assertion sin the Ontology
 */
import java.io.File;
import java.io.FileOutputStream;
import java.util.Date;

import org.apache.jena.datatypes.xsd.XSDDatatype;
import org.apache.jena.ontology.AnnotationProperty;
import org.apache.jena.ontology.DatatypeProperty;
import org.apache.jena.ontology.Individual;
import org.apache.jena.ontology.ObjectProperty;
import org.apache.jena.ontology.OntClass;
import org.apache.jena.ontology.OntModel;
import org.apache.jena.ontology.OntModelSpec;
import org.apache.jena.query.Query;
import org.apache.jena.query.QueryExecution;
import org.apache.jena.query.QueryExecutionFactory;
import org.apache.jena.query.QueryFactory;
import org.apache.jena.query.ResultSet;
import org.apache.jena.query.ResultSetFormatter;
import org.apache.jena.rdf.model.InfModel;
import org.apache.jena.rdf.model.Model;
import org.apache.jena.rdf.model.ModelFactory;
import org.apache.jena.rdf.model.RDFWriter;
import org.apache.jena.rdf.model.Statement;
import org.apache.jena.rdf.model.impl.StmtIteratorImpl;
import org.apache.jena.reasoner.Reasoner;
import org.apache.jena.reasoner.rulesys.GenericRuleReasoner;
import org.apache.jena.reasoner.rulesys.Rule;
import org.apache.jena.util.iterator.ExtendedIterator;
import org.apache.jena.util.iterator.Filter;
import org.apache.jena.vocabulary.XSD;


public class ontology {

	/**
	 * creating the IRIs for the ontology
	 * creating IRI should be checked correctly as per the rules in creating a URI
	 * After creating an IRI check the SWRL rules for similarity
(IRI+IndividualName)
	 */
	static String LSide="left_side";
	static String RSide="right_side";
	static String F="filled_texture";
	static String O="outlined_texture";
	static String LnSF="large_and_small_figure";
	static String LF="large_figure";
	static String SF="small_figure";
	static String relationshipUri =
"http://bongardproblem.org/bp/relationship/proprties/";
	static String relationshipUri1 =
"http://bongardproblem.org/bp/relationship/includes/";
	static String relationshipUri2 =
"http://bongardproblem.org/bp/relationship/includes/infered/";
	static final String BP = "http://bongardproblem.org/bp/";

	public static void main(String[] args) {
		final long startTime = System.nanoTime();

		/**
		 * creating an empty ontology 'm'
		 */
			final OntModel m =
ModelFactory.createOntologyModel( OntModelSpec.OWL_DL_MEM );

		/**
		 * defining the prefix (which can be used as a shortform for IRIs
		 * in SWRL or in RDF format understanding in the OWL
file/console)
		 */
			Applet2New_prof q=new Applet2New_prof();
			Applet3New_prof p=new Applet3New_prof();
			m.setNsPrefix( "b", relationshipUri1 );
			m.setNsPrefix( "a", relationshipUri );

			/**
			 * creating Ontology class and Sub-class [as per the
requirement /basic information]
			 */
				final OntClass
Side=m.createClass(BP+"side");final OntClass Position=m.createClass(BP+"position");
				final OntClass
GeometricShapes=m.createClass(BP+"geometric_shapes");
				final OntClass
Count=m.createClass(BP+"count");final OntClass Size=m.createClass(BP+"size");final
OntClass Texture=m.createClass(BP+"texture");
				final OntClass
Characteristics=m.createClass(BP+"geometric_shape_characteristics");final OntClass
LeftSide=m.createClass(BP+LSide);final OntClass
RightSide=m.createClass(BP+RSide);
				final OntClass
BP21=m.createClass(BP+"bp");
			///*****///
				BP21.addSubClass(Side);

	BP21.addSubClass(GeometricShapes);BP21.addSubClass(Size);BP21.addSubCl
ass(Count);BP21.addSubClass(Texture);BP21.addSubClass(Characteristics);
				Side.addSubClass(LeftSide);
	Side.addSubClass(RightSide);
				LeftSide.addDisjointWith(RightSide);
				///*****///
				final OntClass
Filled=m.createClass(BP+F);
				final OntClass
OutLined=m.createClass(BP+O);
```

```
///*****///
Texture.addSubClass(Filled);
Texture.addSubClass(OutLined);

/**
 * creating Individuals and assigning them to each class
 */
Individual Large=m.createIndividual( relationshipUri+LF,Size);Individual Uneven=m.createIndividual( relationshipUri+"uneven_figures",Size);
Individual UnevenCharacteristics=m.createIndividual( relationshipUri+"uneven_shapes",Size);Individual AllLarge=m.createIndividual( relationshipUri+"all_large_figures",Size);
Individual Small=m.createIndividual( relationshipUri+SF,Size);Individual LargeAndSmall=m.createIndividual( relationshipUri+LnSF,Size);
Individual AllLargeAndSmall=m.createIndividual( relationshipUri+"all_large_and_small_figures",Size);Individual Increasing=m.createIndividual(relationshipUri+"increasing",Size);Individual Decreasing=m.createIndividual(relationshipUri+"decreasing",Size);

Individual Continious=m.createIndividual( relationshipUri+"continious_outlined",OutLined);Individual Disjoint=m.createIndividual( relationshipUri+"disjoint_outlined",OutLined);
Individual Dotted=m.createIndividual( relationshipUri+"dotted_outline",OutLined);Individual Wiggly=m.createIndividual(relationshipUri+"wiggly_outline",OutLined);

Individual Opened=m.createIndividual( relationshipUri+"open_shaped",OutLined);Individual Closed=m.createIndividual( relationshipUri+"closed_shaped",OutLined);
Individual Thick=m.createIndividual( relationshipUri+"thick_shaped",OutLined);Individual Shadowed=m.createIndividual( relationshipUri+"shadowed_shaped",OutLined);
Individual Branched=m.createIndividual( relationshipUri+"branched_shaped",OutLined);

/**
 * creating the individuals for each sub-class(child of a class) of Side (LSide/RSide)
 */
//SubClassification
Individual Lside1=m.createIndividual(relationshipUri+"leftside_1",LeftSide);
Individual Lside2=m.createIndividual(relationshipUri+"leftside_2",LeftSide);
Individual Lside3=m.createIndividual(relationshipUri+"leftside_3",LeftSide);
Individual Lside4=m.createIndividual(relationshipUri+"leftside_4",LeftSide);
Individual Lside5=m.createIndividual(relationshipUri+"leftside_5",LeftSide);
Individual Lside6=m.createIndividual(relationshipUri+"leftside_6",LeftSide);

Individual Rside1=m.createIndividual(relationshipUri+"rightside_1",RightSide);
Individual Rside2=m.createIndividual(relationshipUri+"rightside_2",RightSide);
Individual Rside3=m.createIndividual(relationshipUri+"rightside_3",RightSide);
Individual Rside4=m.createIndividual(relationshipUri+"rightside_4",RightSide);
Individual Rside5=m.createIndividual(relationshipUri+"rightside_5",RightSide);
Individual Rside6=m.createIndividual(relationshipUri+"rightside_6",RightSide);

/**
 * creating individuals for Count, Side (position),
 * shape characteristics, Shapes
 */
//Count individuals
Individual UnCountable=m.createIndividual( relationshipUri+"uncountable",Count);
Individual Infinite=m.createIndividual( relationshipUri+"infinite",Count);
Individual One=m.createIndividual( relationshipUri+"1",Count);
Individual Two=m.createIndividual( relationshipUri+"2",Count);
Individual Three=m.createIndividual( relationshipUri+"3",Count);
Individual Five=m.createIndividual( relationshipUri+"4",Count);
Individual Four=m.createIndividual( relationshipUri+"5",Count);
Individual Six=m.createIndividual( relationshipUri+"6",Count);
Individual Seven=m.createIndividual( relationshipUri+"7",Count);
Individual Eight=m.createIndividual( relationshipUri+"8",Count);
Individual Nine=m.createIndividual( relationshipUri+"9",Count);
Individual Ten=m.createIndividual( relationshipUri+"10",Count);
Individual Eleven=m.createIndividual( relationshipUri+"11",Count);
Individual Twelve=m.createIndividual( relationshipUri+"12",Count);
Individual Thirteen=m.createIndividual( relationshipUri+"13",Count);
Individual Fourteen=m.createIndividual( relationshipUri+"14",Count);
Individual Fifteen=m.createIndividual( relationshipUri+"15",Count);
Individual Sixteen=m.createIndividual( relationshipUri+"16",Count);
Individual Seventeen=m.createIndividual( relationshipUri+"17",Count);
Individual Eighteen=m.createIndividual( relationshipUri+"18",Count);
Individual Nineteen=m.createIndividual( relationshipUri+"19",Count);
Individual Twenty=m.createIndividual( relationshipUri+"20",Count);

Individual Left=m.createIndividual( relationshipUri+"left",LeftSide);
Individual Right=m.createIndividual(relationshipUri+"right",RightSide);
//Side/possition individulas
Individual ToLeft=m.createIndividual( relationshipUri+"to_left",Position);
```

```
Individual ToRight=m.createIndividual(relationshipUri+"to_right",Position);
Individual Middle=m.createIndividual(relationshipUri+"middle",Position);
Individual Top=m.createIndividual(relationshipUri+"top",Position);
Individual Bottom=m.createIndividual(relationshipUri+"bottom",Position);
Individual Unevenly=m.createIndividual(relationshipUri+"unevenly_distributed",Position);

//

//Shape Characteristics

Individual Similar=m.createIndividual( relationshipUri+"similar_shapes",Characteristics);
Individual Parallel=m.createIndividual(relationshipUri+"parallel",Characteristics);
Individual Perpendicular=m.createIndividual(relationshipUri+"perpendicular",Characteristics);
Individual PlaneLine=m.createIndividual(relationshipUri+"plane",Characteristics);
Individual NonParallel=m.createIndividual(relationshipUri+"non_narallel",Characteristics);
Individual CrossingLine=m.createIndividual(relationshipUri+"crossing",Characteristics);
Individual Equilateral=m.createIndividual(relationshipUri+"equilateral",Characteristics);
Individual Isosceles=m.createIndividual(relationshipUri+"isosceles",Characteristics);
Individual ConcaveShape=m.createIndividual(relationshipUri+"concave_shape",Characteristics);
```

```
Individual ConvexShape=m.createIndividual(relationshipUri+"convex_shape",Characteristics);
Individual Elongated=m.createIndividual(relationshipUri+"elongated",Characteristics);
Individual NonElongated=m.createIndividual(relationshipUri+"nonelongated",Characteristics);
Individual CW=m.createIndividual(relationshipUri+"clockwise",Characteristics);
Individual CCW=m.createIndividual(relationshipUri+"counterclockwise",Characteristics);
Individual Elongated_Verticaly=m.createIndividual(relationshipUri+"elongated_vertically",Characteristics);
Individual Elongated_Horizontal=m.createIndividual(relationshipUri+"elongated_horizontally",Characteristics);
Individual SharpEdges=m.createIndividual(relationshipUri+"sharpedges",Characteristics);
Individual ClusterExists=m.createIndividual(relationshipUri+"cluster_formation",Characteristics);
Individual Collinear=m.createIndividual(relationshipUri+"collinear",Characteristics);
Individual Damping=m.createIndividual(relationshipUri+"dampig_signal",Characteristics);
Individual Sym=m.createIndividual(relationshipUri+"symmetric_feature", Characteristics);
Individual Identical=m.createIndividual(relationshipUri+"identicalshapes",Characteristics);
Individual Bicet=m.createIndividual(relationshipUri+"bicectedangles",Characteristics);
Individual Not_Squeezed_Shape=m.createIndividual(relationshipUri+"not_squeezed_shape",Characteristics);
Individual ShortConcave=m.createIndividual(relationshipUri+"longconcave_shape",Characteristics);
```

```
Individual LongConcave=m.createIndividual(relationshipUri+"shortconcave_shape",Characteristics);
Individual HardlySqueezed_Shape=m.createIndividual(relationshipUri+"hardlysqueezed_shape",Characteristics);
Individual SoftlySqueezed_Shape=m.createIndividual(relationshipUri+"softlysqueezed_shape",Characteristics);
Individual IntersectingLines=m.createIndividual(relationshipUri+"intersectinglines",Characteristics);
Individual HorizontalCluster=m.createIndividual(relationshipUri+"horizontal_cluster",Characteristics);
Individual VerticalCluster=m.createIndividual(relationshipUri+"vertical_cluster",Characteristics);

Individual OpositeDirection=m.createIndividual(relationshipUri+"opositedirection",Characteristics);
Individual SameDirection=m.createIndividual(relationshipUri+"samedirection",Characteristics);

Individual Alphabet_a=m.createIndividual(relationshipUri+"alphabet_a",Characteristics);
Individual Alphabet_b=m.createIndividual(relationshipUri+"alphabet_b",Characteristics);

Individual Left_Shadowed=m.createIndividual(relationshipUri+"leftShadowed",Characteristics);
Individual Ends_Parallel=m.createIndividual(relationshipUri+"endsParallel",Characteristics);
Individual Ends_Perpendicular=m.createIndividual(relationshipUri+"endsPerpendicular",Characteristics);
```

```
Individual Right_Shadowed=m.createIndividual(relationshipUri+"rightShadowed",Characteristics);

Individual OneBranch=m.createIndividual(relationshipUri+"one_level_branching",Characteristics);
Individual TwoBranch=m.createIndividual(relationshipUri+"two_level_branching",Characteristics);
Individual OneObjectInside=m.createIndividual(relationshipUri+"one_level_insideness",Characteristics);
Individual TwoObjectinside=m.createIndividual(relationshipUri+"two_level_insideness",Characteristics);
Individual EndsFar=m.createIndividual(relationshipUri+"ends_far",Characteristics);
Individual EndsClose=m.createIndividual(relationshipUri+"ends_close",Characteristics);

Individual Circle=m.createIndividual( relationshipUri+"circle",GeometricShapes);
Individual Null=m.createIndividual( relationshipUri+"null",GeometricShapes);
Individual lineset=m.createIndividual( relationshipUri+"lineset",GeometricShapes);
//Individual Ellipse=m.createIndividual( relationshipUri+"Ellipse",GeometricShapes);
Individual SetOfLines=m.createIndividual(relationshipUri+"setoflines",GeometricShapes);
Individual Line=m.createIndividual( relationshipUri+"line",GeometricShapes);
```

```
Individual
NoShape=m.createIndividual( relationshipUri+"empty",GeometricShapes);

//Individual
SomeShape=m.createIndividual( relationshipUri+"NotEmpty",GeometricShapes);

Individual
Curves=m.createIndividual( relationshipUri+"curves",GeometricShapes);

Individual
Square=m.createIndividual( relationshipUri+"square",GeometricShapes);

Individual
Dart=m.createIndividual(relationshipUri+"dart",GeometricShapes);

Individual
Rectangle=m.createIndividual( relationshipUri+"rectangle",GeometricShapes);

Individual
Pentagon=m.createIndividual( relationshipUri+"pentagon",GeometricShapes);

Individual
Oval=m.createIndividual( relationshipUri+"oval",GeometricShapes);

Individual
Octagon=m.createIndividual( relationshipUri+"octagon",GeometricShapes);

Individual
Squeezed=m.createIndividual(relationshipUri+"squeezed_shape",GeometricShapes);

Individual
Hexagon=m.createIndividual( relationshipUri+"hexagon",GeometricShapes);

Individual
Triangle=m.createIndividual( relationshipUri+"triangle",GeometricShapes);

Individual
Trapezoid=m.createIndividual( relationshipUri+"trapezoid",GeometricShapes);

Individual
Star=m.createIndividual( relationshipUri+"star",GeometricShapes);

Individual
Rhombus=m.createIndividual( relationshipUri+"rhombus",GeometricShapes);

Individual
Quadrilateral=m.createIndividual( relationshipUri+"quadrilateral",GeometricShapes);

Individual
Polygon=m.createIndividual( relationshipUri+"polygon",GeometricShapes);
```

```
Individual
Curvilinear=m.createIndividual( relationshipUri+"curvilinear",GeometricShapes);


Individual
Heart=m.createIndividual( relationshipUri+"heart",GeometricShapes);

Individual
Spiral=m.createIndividual( relationshipUri+"spiral",GeometricShapes);

Individual
Curve=m.createIndividual( relationshipUri+"curve",GeometricShapes);



Individual
Unkonown=m.createIndividual( relationshipUri+"unknown_shape",GeometricShapes);


Individual
Wave=m.createIndividual( relationshipUri+"waveform",GeometricShapes);


Individual
Kite=m.createIndividual( relationshipUri+"kite",GeometricShapes);

Individual
Alphabet=m.createIndividual( relationshipUri+"alphabet",GeometricShapes);

Individual
Parallelogram=m.createIndividual( relationshipUri+"parallelogram",GeometricShapes);


Individual
Dark=m.createIndividual( relationshipUri+"dark_filling",Filled);

Individual
HorizontalLines=m.createIndividual(relationshipUri+"horizontal_lines",Filled);

Individual
VerticalLines=m.createIndividual(relationshipUri+"vertical_lines",Filled);

Individual
Slanted=m.createIndividual( relationshipUri+"slanted_lines",Filled);

Individual
plane=m.createIndividual( relationshipUri+"no_filling",Filled);
```

```
Individual
UnEvenTexture=m.createIndividual(relationshipUri+"uneven_texture",Filled);


/**

 * creating Object Properties for the
Ontology 'm'

 */

ObjectProperty
hasTexture=m.createObjectProperty(relationshipUri1+"hastexture");

ObjectProperty
AlsohasTexture=m.createObjectProperty(relationshipUri1+"alsohastexture");

ObjectProperty
has=m.createObjectProperty(relationshipUri1+"has"); ObjectProperty
Alsohas=m.createObjectProperty(relationshipUri1+"also_has");

ObjectProperty
Consists=m.createObjectProperty(relationshipUri1+"consists_of");

ObjectProperty
ConsistsOf=m.createObjectProperty(relationshipUri1+"consists");

ObjectProperty
Consists_of_Shape=m.createObjectProperty(relationshipUri2+"consists_of_shape");

ObjectProperty
Consists_of_Count=m.createObjectProperty(relationshipUri2+"consists_of_count");

ObjectProperty
ConsistsTexture=m.createObjectProperty(relationshipUri2+"consists_of_texture");

ObjectProperty
ConsistsTexture1=m.createObjectProperty(relationshipUri2+"alsoconsists_of_texture");

ObjectProperty
ConsistsSize=m.createObjectProperty(relationshipUri2+"consists_of_size");

ObjectProperty
ConsistsPosition=m.createObjectProperty(relationshipUri2+"consists_of_position");

ObjectProperty
ConsistsCharacter=m.createObjectProperty(relationshipUri2+"consists_of_character");
```

```
ObjectProperty
Has_Infered_Shape=m.createObjectProperty(relationshipUri2+"has_infered_shape");

ObjectProperty
Has_Dependent_Infered1=m.createObjectProperty(relationshipUri2+"has_dependent_i
nference1");

ObjectProperty
Has_Dependent_Infered2=m.createObjectProperty(relationshipUri2+"has_dependent_i
nference2");

ObjectProperty
Has_Infered_Count=m.createObjectProperty(relationshipUri2+"has_infered_count");

ObjectProperty
Has_Infered_Feature_Count=m.createObjectProperty(relationshipUri2+"has_infered_fe
ature_count");

ObjectProperty
Has_Infered_Texture=m.createObjectProperty(relationshipUri2+"has_infered_texture")
;

ObjectProperty
Has_Infered_Size=m.createObjectProperty(relationshipUri2+"has_infered_size");

ObjectProperty
Has_Infered_Position=m.createObjectProperty(relationshipUri2+"has_infered_position
");

ObjectProperty
Has_Infered_Charateristics=m.createObjectProperty(relationshipUri2+"has_infered_ch
aracteristics");


ObjectProperty
hasSize=m.createObjectProperty(relationshipUri1+"hassize");

ObjectProperty
hasOnly=m.createObjectProperty(relationshipUri1+"hasonly");

ObjectProperty
hasMore=m.createObjectProperty(relationshipUri1+"hasmore");

ObjectProperty
IsOnSide=m.createObjectProperty(relationshipUri1+"isonside");


/**
```

```
                                        * Creating Data property for the Ontology
'm'
                                        */
                                        DatatypeProperty
hasCount=m.createDatatypeProperty(relationshipUri1+"hascount");
                                        DatatypeProperty
hasLineSlope=m.createDatatypeProperty(relationshipUri1+"haslineslope");
                                        DatatypeProperty
hasArea=m.createDatatypeProperty(relationshipUri1+"hasarea");
                                        DatatypeProperty
EachBoxhasCount=m.createDatatypeProperty(relationshipUri1+"eachboxcount");
                                        ObjectProperty
ShapeFeature=m.createObjectProperty(relationshipUri1+"hasshapefeature");
                                        ObjectProperty
Has_Infered_NoShapeFeature=m.createObjectProperty(relationshipUri2+"has_infered_
doesnothasshapefeature");
                                        ObjectProperty
Has_Infered_DoesNotHasShape=m.createObjectProperty(relationshipUri2+"has_infere
d_doesnothasshape");
                                        ObjectProperty
Has_Infered_DoesNotHasTexture=m.createObjectProperty(relationshipUri2+"has_infer
ed_doesnothastexture");



Has_Infered_NoShapeFeature.addInverseOf(Has_Infered_Charateristics);
                                        DatatypeProperty
IsA=m.createDatatypeProperty(relationshipUri1+"isa");

                                        /**
                                        * creating Annotation Property
                                        */
                                        AnnotationProperty means=
m.createAnnotationProperty(relationshipUri+"means");

                                        /**
                                        * Defining the characteristics of
properties(like- Transitive, Symmetric..etc)
                                        */
                                        ObjectProperty IsDifferentFrom=
m.createObjectProperty(relationshipUri2+"is_different_from")
                                                .convertToTransitiveProperty()

                .convertToSymmetricProperty()
                                                        .asObjectProperty();
                                        ObjectProperty IsSameAs=
m.createObjectProperty(relationshipUri2+"is_same_as")

                .convertToTransitiveProperty()

                .convertToSymmetricProperty()
                                                        .asObjectProperty();


Squeezed.addProperty(Has_Infered_Charateristics,ConcaveShape);



                                        /**
                                        * creating different individuals
                                          i.e. defining that each individual is
distinct <code> DifferentMethod </code>
                                          in RDF for the SWRL to check that
there are two distinct shape/features/count/possition/characteristics/texture
                                          this description of difference is required
                                        *
                                        */

                                        //////////difference////////////

                                        DifferentMethod diff=new
DifferentMethod();
                                        try {
                                                ///shapes
                                                diff.Different(Circle, Square);
                                                diff.Different(Circle, Dart);
                                                diff.Different(Circle, Rectangle);
                                                diff.Different(Circle, Triangle);
                                                diff.Different(Circle, Pentagon);
                                                diff.Different(Circle, Oval);
                                                diff.Different(Circle, Octagon);
                                                diff.Different(Circle, Hexagon);
                                                diff.Different(Circle, Trapezoid);
                                                diff.Different(Circle, Star);
                                                diff.Different(Circle, Rhombus);
                                                diff.Different(Circle,
Quadrilateral);
                                                diff.Different(Circle, Line);
                                                diff.Different(Circle, Null);
                                                diff.Different(Circle, Squeezed);


                                                diff.Different(Square, Rectangle);
                                                diff.Different(Square, Null);
                                                diff.Different(Square, Squeezed);
                                                diff.Different(Square, Dart);
                                                diff.Different(Square, Line);
                                                diff.Different(Square, Triangle);
                                                diff.Different(Square, Pentagon);
                                                diff.Different(Square, Oval);
                                                diff.Different(Square, Octagon);
                                                diff.Different(Square, Hexagon);
                                                diff.Different(Square, Trapezoid);
                                                diff.Different(Square, Star);
                                                diff.Different(Square, Rhombus);

                                                diff.Different(Line, Null);
                                                diff.Different(Line, Squeezed);
                                                diff.Different(Line, Rectangle);
                                                diff.Different(Line, Dart);
                                                diff.Different(Line, Triangle);
                                                diff.Different(Line, Pentagon);
                                                diff.Different(Line, Oval);
                                                diff.Different(Line, Octagon);
                                                diff.Different(Line, Hexagon);
                                                diff.Different(Line, Trapezoid);
                                                diff.Different(Line, Star);
                                                diff.Different(Line, Rhombus);
                                                diff.Different(Line, Quadrilateral);

                                                diff.Different(Rectangle, Null);
                                                diff.Different(Rectangle,
Squeezed);
                                                diff.Different(Rectangle, Dart);
```

```
                                    diff.Different(Rectangle,
Triangle);
                                    diff.Different(Rectangle,
Pentagon);
                                    diff.Different(Rectangle, Oval);
                                    diff.Different(Rectangle,
Octagon);
                                    diff.Different(Rectangle,
Hexagon);
                                    diff.Different(Rectangle,
Trapezoid);
                                    diff.Different(Rectangle, Star);
                                    diff.Different(Rectangle,
Rhombus);
                                    diff.Different(Rectangle,
Quadrilateral);
                                    diff.Different(Triangle, Null);
                                    diff.Different(Triangle, Squeezed);
                                    diff.Different(Triangle, Dart);
                                    diff.Different(Triangle, Pentagon);
                                    diff.Different(Triangle, Oval);
                                    diff.Different(Triangle, Octagon);
                                    diff.Different(Triangle, Hexagon);
                                    diff.Different(Triangle,
Trapezoid);
                                    diff.Different(Triangle, Star);
                                    diff.Different(Triangle, Rhombus);
                                    diff.Different(Triangle,
Quadrilateral);
                                    diff.Different(Pentagon, Null);
                                    diff.Different(Pentagon,
Squeezed);
```

```
                                    diff.Different(Pentagon, Dart);
                                    diff.Different(Pentagon, Oval);
                                    diff.Different(Pentagon, Octagon);
                                    diff.Different(Pentagon, Hexagon);
                                    diff.Different(Pentagon,
Trapezoid);
                                    diff.Different(Pentagon, Star);
                                    diff.Different(Pentagon,
Rhombus);
                                    diff.Different(Pentagon,
Quadrilateral);
                                    diff.Different(Oval, Null);
                                    diff.Different(Oval, Squeezed);
                                    diff.Different(Oval, Dart);
                                    diff.Different(Oval, Octagon);
                                    diff.Different(Oval, Hexagon);
                                    diff.Different(Oval, Trapezoid);
                                    diff.Different(Oval, Star);
                                    diff.Different(Oval, Rhombus);
                                    diff.Different(Oval, Quadrilateral);
                                    diff.Different(Octagon, Null);
                                    diff.Different(Octagon, Squeezed);
                                    diff.Different(Octagon, Dart);
                                    diff.Different(Octagon, Hexagon);
                                    diff.Different(Octagon,
Trapezoid);
                                    diff.Different(Octagon, Star);
                                    diff.Different(Octagon, Rhombus);
                                    diff.Different(Octagon,
Quadrilateral);
```

```
                diff.Different(Hexagon, Dart);
                                    diff.Different(Hexagon, Null);
                                    diff.Different(Hexagon,
Squeezed);
                                    diff.Different(Hexagon,
Trapezoid);
                                    diff.Different(Hexagon, Star);
                                    diff.Different(Hexagon,
Rhombus);
                                    diff.Different(Hexagon,
Quadrilateral);
                                    diff.Different(Trapezoid, Dart);
                                    diff.Different(Trapezoid, Null);
                                    diff.Different(Trapezoid,
Squeezed);
                                    diff.Different(Trapezoid, Star);
                                    diff.Different(Trapezoid,
Rhombus);
                                    diff.Different(Trapezoid,
Pentagon);
                                    diff.Different(Star, Dart);
                                    diff.Different(Star, Null);
                                    diff.Different(Star, Squeezed);
                                    diff.Different(Star, Rhombus);
                                    diff.Different(Star, Quadrilateral);
                                    diff.Different(Rhombus, Dart);
                                    diff.Different(Rhombus, Null);
                                    diff.Different(Rhombus,
Squeezed);
                                    diff.Different(Kite, Null);
                                    diff.Different(Kite, Squeezed);
```

```
                                    diff.Different(Squeezed, Null);
                                    diff.Different(Parallelogram,
Null);
                                    diff.Different(Parallelogram,
Squeezed);
                                diff.Different(Wave, Null);
                                    diff.Different(Polygon,
Curvilinear);
                                    diff.Different(Polygon, Null);
                                    diff.Different(Polygon, Squeezed);
                                    diff.Different(Squeezed,
Quadrilateral);
                                    diff.Different(Squeezed,
Curvilinear);
                                    diff.Different(Quadrilateral, Null);
                                    diff.Different(Curvilinear, Null);

                                    diff.Different(Heart, Line,
Circle,Square,Rectangle,Triangle,Pentagon,Oval,Octagon,Line,Null);
                                    diff.Different(Spiral, Line,
Circle,Square,Rectangle,Triangle,Pentagon,Oval,Octagon,Line,Null);
                                    diff.Different(Curve, Line,
Circle,Square,Rectangle,Triangle,Pentagon,Oval,Octagon,Line,Null);
                                    diff.Different(Heart, Hexagon,
Trapezoid, Star,Rhombus, Kite,Parallelogram,lineset,Squeezed,Dart,Unkonown );
                                    diff.Different(Spiral, Hexagon,
Trapezoid, Star,Rhombus, Kite,Parallelogram,lineset,Squeezed,Dart,Unkonown);
                                    diff.Different(Curve, Hexagon,
Trapezoid, Star,Rhombus, Kite,Parallelogram,lineset,Squeezed,Dart,Unkonown);


        diff.Different(UnCountable,Infinite,One,Two,Three,Four,Five,Six,Seven,Eight,
Nine,Ten);
```

```
                                        ///side
                                    diff.Different(Middle,ToLeft);
                                   //
diff.Different(Middle,ToLeft,ToRight,Top,Bottom,Unevenly);
                                    diff.Different(Middle,ToRight);
                                    diff.Different(Middle,Top);
                                    diff.Different(Middle,Bottom);
                                    diff.Different(Middle,Unevenly);
                                    diff.Different(Middle,Null);

                                    diff.Different(ToLeft,ToRight);
                                    diff.Different(ToLeft,Top);
                                    diff.Different(ToLeft,Bottom);
                                    diff.Different(ToLeft,Unevenly);
                                    diff.Different(ToLeft,Null);

                                    diff.Different(ToRight,Top);
                                    diff.Different(ToRight,Bottom);
                                    diff.Different(ToRight,Unevenly);
                                    diff.Different(ToRight,Null);

                                    diff.Different(Top,Null);
                                    diff.Different(Top,Bottom);
                                    diff.Different(Top,Unevenly);

                                    diff.Different(Bottom,Null);
                                    diff.Different(Bottom,Unevenly);

                                     //size
```

```
diff.Different(Large,Uneven,AllLarge,Small,LargeAndSmall,AllLargeAndSmall);
                                        diff.Different(Increasing,
Decreasing);
                                        diff.Different(Parallel,
Perpendicular);
                                    diff.Different(Parallel, PlaneLine);
                                    diff.Different(Parallel, NonParallel);
                                    diff.Different(Parallel, CrossingLine);
                                    diff.Different(Parallel, ConcaveShape);
                                    diff.Different(Parallel, ConvexShape);
                                    diff.Different(Parallel, Equilateral);
                                    diff.Different(Parallel, Isosceles);
                                    diff.Different(Parallel, Similar);
                                    diff.Different(Parallel,
UnevenCharacteristics);
                                    diff.Different(Parallel, Elongated);
                                    diff.Different(Parallel,
Elongated_Horizontal);
                                    diff.Different(Parallel,
Elongated_Verticaly);
                                    diff.Different(Parallel, CW);
                                    diff.Different(Parallel, CCW);
                                    diff.Different(Parallel, SharpEdges);
                                    diff.Different(Parallel, ClusterExists);
                                diff.Different(Parallel, Collinear);
                                diff.Different(Parallel, Damping);
                                diff.Different(Collinear, Perpendicular);
                            diff.Different(Collinear, PlaneLine);
                                diff.Different(Collinear, NonParallel);
                                diff.Different(Collinear, CrossingLine);
```

```
                                diff.Different(Collinear, ConcaveShape);
                                diff.Different(Collinear, ConvexShape);
                                diff.Different(Collinear, Equilateral);
                                diff.Different(Collinear, Isosceles);
                                diff.Different(Collinear, Similar);
                                diff.Different(Collinear,
UnevenCharacteristics);
                                diff.Different(Collinear, Elongated);
                                diff.Different(Collinear, Elongated_Horizontal);
                                diff.Different(Collinear, Elongated_Verticaly);
                                diff.Different(Collinear, CW);
                                diff.Different(Collinear, CCW);
                                diff.Different(Collinear, SharpEdges);
                                diff.Different(Collinear, ClusterExists);
                                diff.Different(Collinear, Damping);
                            diff.Different(Damping, Perpendicular);
                            diff.Different(Damping, PlaneLine);
                            diff.Different(Damping, NonParallel);
                            diff.Different(Damping, CrossingLine);
                            diff.Different(Damping, ConcaveShape);
                            diff.Different(Damping, ConvexShape);
                            diff.Different(Damping, Equilateral);
                            diff.Different(Damping, Isosceles);
                            diff.Different(Damping, Similar);
                            diff.Different(Damping, UnevenCharacteristics);
                            diff.Different(Damping, Elongated);
                            diff.Different(Damping, Elongated_Horizontal);
                            diff.Different(Damping, Elongated_Verticaly);
                            diff.Different(Damping, CW);
```

```
                                diff.Different(Damping, CCW);
                                diff.Different(Damping, SharpEdges);
                                diff.Different(Damping, ClusterExists);
                                diff.Different(Bicet, Perpendicular);
                                diff.Different(Bicet, PlaneLine);
                                diff.Different(Bicet, NonParallel);
                                diff.Different(Bicet, CrossingLine);
                                diff.Different(Bicet, ConcaveShape);
                                diff.Different(Bicet, ConvexShape);
                                diff.Different(Bicet, Equilateral);
                                diff.Different(Bicet, Isosceles);
                                diff.Different(Bicet, Similar);
                                diff.Different(Bicet, UnevenCharacteristics);
                                diff.Different(Bicet, Elongated);
                                diff.Different(Bicet, Elongated_Horizontal);
                                diff.Different(Bicet, Elongated_Verticaly);
                                diff.Different(Bicet, CW);
                                diff.Different(Bicet, CCW);
                                diff.Different(Bicet, SharpEdges);
                                diff.Different(Bicet, ClusterExists);
                                diff.Different(Bicet, Collinear);
                                diff.Different(Bicet, Damping);
                                diff.Different(Bicet, Parallel);
                                diff.Different(Sym, Perpendicular);
                                diff.Different(Sym, PlaneLine);
                                diff.Different(Sym, NonParallel);
                                diff.Different(Sym, CrossingLine);
                                diff.Different(Sym, ConcaveShape);
                                diff.Different(Sym, ConvexShape);
```

```
diff.Different(Sym, Equilateral);
diff.Different(Sym, Isosceles);
diff.Different(Sym, Similar);
diff.Different(Sym, UnevenCharacteristics);
diff.Different(Sym, Elongated);
diff.Different(Sym, Elongated_Horizontal);
diff.Different(Sym, Elongated_Verticaly);
diff.Different(Sym, CW);
diff.Different(Sym, CCW);
diff.Different(Sym, SharpEdges);
diff.Different(Sym, ClusterExists);
diff.Different(Sym, Collinear);
diff.Different(Sym, Damping);
diff.Different(Sym, Parallel);
diff.Different(Sym, Bicet);
diff.Different(Identical, Perpendicular);
diff.Different(Identical, PlaneLine);
diff.Different(Identical, NonParallel);
diff.Different(Identical, CrossingLine);
diff.Different(Identical, ConcaveShape);
diff.Different(Identical, ConvexShape);
diff.Different(Identical, Equilateral);
diff.Different(Identical, Isosceles);
diff.Different(Identical, UnevenCharacteristics);
diff.Different(Identical, Elongated);
diff.Different(Identical, Elongated_Horizontal);
diff.Different(Identical, Elongated_Verticaly);
diff.Different(Identical, CW);
diff.Different(Identical, CCW);
```

```
diff.Different(Identical, SharpEdges);
diff.Different(Identical, ClusterExists);
diff.Different(Identical, Collinear);
diff.Different(Identical, Damping);
diff.Different(Identical, Parallel);
diff.Different(Identical, Bicet);
diff.Different(Alphabet_a, Alphabet_b);
diff.Different(UnevenCharacteristics,
Perpendicular);
diff.Different(UnevenCharacteristics,
PlaneLine);
diff.Different(UnevenCharacteristics,
NonParallel);
diff.Different(UnevenCharacteristics,
CrossingLine);
diff.Different(UnevenCharacteristics,
ConcaveShape);
diff.Different(UnevenCharacteristics,
ConvexShape);
diff.Different(UnevenCharacteristics,
Equilateral);
diff.Different(UnevenCharacteristics, Isosceles);
diff.Different(UnevenCharacteristics, Similar);
diff.Different(UnevenCharacteristics, Parallel);
diff.Different(UnevenCharacteristics, Elongated);
diff.Different(UnevenCharacteristics,
Elongated_Horizontal);
diff.Different(UnevenCharacteristics,
Elongated_Verticaly);
diff.Different(UnevenCharacteristics, CW);
```

```
diff.Different(UnevenCharacteristics, CCW);
diff.Different(UnevenCharacteristics,
SharpEdges);
diff.Different (Elongated_Horizontal,
SharpEdges);
diff.Different(Elongated_Verticaly, SharpEdges);
diff.Different(Elongated, SharpEdges);
diff.Different(UnevenCharacteristics,
ClusterExists);
diff.Different(UnevenCharacteristics, Large);
diff.Different(UnevenCharacteristics,
LargeAndSmall);
diff.Different(UnevenCharacteristics, Small);
diff.Different(Perpendicular, PlaneLine);
diff.Different(Perpendicular, NonParallel);
diff.Different(Perpendicular, CrossingLine);
diff.Different(Perpendicular, ConcaveShape);
diff.Different(Perpendicular, ConvexShape);
diff.Different(Perpendicular, Equilateral);
diff.Different(Perpendicular, Isosceles);
diff.Different(Perpendicular, Similar);
diff.Different(Perpendicular, Elongated);
diff.Different(Perpendicular,
Elongated_Horizontal);
diff.Different(Perpendicular,
Elongated_Verticaly);
diff.Different(Perpendicular, CW);
diff.Different(Perpendicular, CCW);
diff.Different(Perpendicular, SharpEdges);
diff.Different(Perpendicular, ClusterExists);
diff.Different(LongConcave, ShortConcave);
```

```
diff.Different(HorizontalCluster, VerticalCluster);
diff.Different(SameDirection, Oposite Direction);
diff.Different(PlaneLine, NonParallel);
diff.Different(PlaneLine, CrossingLine);
diff.Different(PlaneLine, ConcaveShape);
diff.Different(PlaneLine, ConvexShape);
diff.Different(PlaneLine, Equilateral);
diff.Different(PlaneLine, Isosceles);
diff.Different(PlaneLine, Similar);
diff.Different(PlaneLine, Elongated);
diff.Different(PlaneLine, Elongated_Horizontal);
diff.Different(PlaneLine, Elongated_Verticaly);
diff.Different(PlaneLine, CW);
diff.Different(PlaneLine, CCW);
diff.Different(PlaneLine, SharpEdges);
diff.Different(PlaneLine, ClusterExists);
diff.Different(CrossingLine, NonParallel);
diff.Different(CrossingLine, ConcaveShape);
diff.Different(CrossingLine, ConvexShape);
diff.Different(CrossingLine, Equilateral);
diff.Different(CrossingLine, Isosceles);
diff.Different(CrossingLine, Similar);
diff.Different(CrossingLine, Elongated);
diff.Different(CrossingLine,
Elongated_Horizontal);
diff.Different(CrossingLine,
Elongated_Verticaly);
diff.Different(CrossingLine, CW);
diff.Different(CrossingLine, CCW);
```

```
diff.Different(CrossingLine, SharpEdges);
diff.Different(CrossingLine, ClusterExists);
diff.Different(ConcaveShape, NonParallel);
diff.Different(ConcaveShape, CrossingLine);
diff.Different(ConcaveShape, ConvexShape);
diff.Different(ConcaveShape, Equilateral);
diff.Different(ConcaveShape, Isosceles);
diff.Different(ConcaveShape, Similar);
diff.Different(ConcaveShape, Elongated);
diff.Different(ConcaveShape,
Elongated_Horizontal);
diff.Different(ConcaveShape,
Elongated_Verticaly);
diff.Different(ConcaveShape, CW);
diff.Different(ConcaveShape, CCW);
diff.Different(ConcaveShape, SharpEdges);
diff.Different(ConcaveShape, ClusterExists);
diff.Different(ConvexShape, NonParallel);
diff.Different(ConvexShape, Equilateral);
diff.Different(ConvexShape, Isosceles);
diff.Different(ConvexShape, Similar);
diff.Different(ConvexShape, Elongated);
diff.Different(ConvexShape,
Elongated_Horizontal);
diff.Different(ConvexShape,
Elongated_Verticaly);
diff.Different(ConvexShape, CW);
diff.Different(ConvexShape, CCW);
diff.Different(ConvexShape, SharpEdges);
diff.Different(ConvexShape, ClusterExists);
```

```
diff.Different(Equilateral, NonParallel);
diff.Different(Equilateral, Isosceles);
diff.Different(Equilateral, Similar);
diff.Different(Equilateral, Elongated);
diff.Different(Equilateral, Elongated_Horizontal);
diff.Different(Equilateral, Elongated_Verticaly);
diff.Different(Equilateral, CW);
diff.Different(Equilateral, CCW);
diff.Different(Equilateral, SharpEdges);
diff.Different(Equilateral, ClusterExists);

diff.Different(Isosceles, NonParallel);
diff.Different(Isosceles, Similar);
diff.Different(Isosceles, Elongated);
diff.Different(Isosceles, Elongated_Horizontal);
diff.Different(Isosceles, Elongated_Verticaly);
diff.Different(Isosceles, CW);
diff.Different(Isosceles, CCW);
diff.Different(Isosceles, SharpEdges);
diff.Different(Isosceles, ClusterExists);

diff.Different(Similar, NonParallel);
diff.Different(Similar, Elongated);
diff.Different(Similar, Elongated_Horizontal);
diff.Different(Similar, Elongated_Verticaly);

diff.Different(Null,Bicet);
diff.Different(Similar, CW, CCW, SharpEdges,
ClusterExists);
```

```
diff.Different(Elongated_Horizontal, CW, CCW,
Elongated_Verticaly, ClusterExists);
diff.Different(ClusterExists, Elongated);



diff.Different(Right_Shadowed,Left_Shadowed,Ends_Parallel,Ends_Perpendicu
lar,Null);
diff.Different(Similar,Null);
diff.Different(Unkonown,Null);
diff.Different(lineset,Null);
diff.Different(Null, SharpEdges);
diff.Different(Identical,Null);
diff.Different(Wiggly, Opened, Closed, Thick, Branched,
Continious,Disjoint, Dotted, Shadowed, Dark, Slanted,plane,UnEvenTexture);
diff.Different(Elongated,NonElongated);
diff.Different(OneBranch,TwoBranch);
diff.Different(OneObjectInside,TwoObjectinside);
diff.Different(EndsClose,EndsFar);
diff.Different(Collinear, Null);
diff.Different(Sym, Null);diff.Different(ConcaveShape, Null);
diff.Different(HorizontalLines,VerticalLines);
diff.Different(CrossingLine,Null);
diff.Different(IntersectingLines,Null,Parallel);
diff.Different(Elongated,Null,ClusterExists);

} catch (Exception e1) {

e1.printStackTrace();
}
```

```
/**
 * Similarity description for each
individuals (excluded in SWRL while checking different Individuals)
 */

Circle.addProperty(IsA, Curves);
Square.addProperty(IsSameAs,
Quadrilateral);
Dart.addProperty(IsSameAs,
Quadrilateral);
Square.addProperty(IsA, SetOfLines);
Line.addProperty(IsA,SetOfLines);
Rectangle.addProperty(IsA, SetOfLines);
Dart.addProperty(IsA, SetOfLines);
Rectangle.addProperty(IsSameAs,
Quadrilateral);
Triangle.addProperty(IsA, SetOfLines);
Pentagon.addProperty(IsA, SetOfLines);
Oval.addProperty(IsA, Curves);
Octagon.addProperty(IsA, SetOfLines);
Hexagon.addProperty(IsA, SetOfLines);

// NoShape.addProperty(IsDifferentFrom,
SomeShape);SomeShape.addProperty(IsDifferentFrom, NoShape);
Hexagon.addProperty(IsA, SetOfLines);
lineset.addProperty(IsA, SetOfLines);
Trapezoid.addProperty(IsSameAs,
Quadrilateral);
Trapezoid.addProperty(IsA, SetOfLines);
// Star.addProperty(IsA, SetOfLines);
```

```
                                        Rhombus.addProperty(IsSameAs,
Quadrilateral);
                                        Rhombus.addProperty(IsA, SetOfLines);

                                        Parallelogram.addProperty(IsSameAs,
Quadrilateral);
                                        Kite.addProperty(IsSameAs,
Quadrilateral);
                                        Kite.addProperty(IsSameAs, Dart);
                                        Dart.addProperty(IsSameAs, Kite);


//Null.addProperty(IsDifferentFrom,Squeezed);
                                         ///testing
                                         Identical.addProperty(IsSameAs, Similar);
                                         Similar.addProperty(IsSameAs, Identical);
            /* NonParallel.addProperty(IsDifferentFrom,Perpendicular);

NonParallel.addProperty(IsDifferentFrom,PlaneLine);

NonParallel.addProperty(IsDifferentFrom,Parallel);

NonParallel.addProperty(IsDifferentFrom,CrossingLine);

NonParallel.addProperty(IsDifferentFrom,ConcaveShape);

NonParallel.addProperty(IsDifferentFrom,ConvexShape);

NonParallel.addProperty(IsDifferentFrom,Equilateral);

NonParallel.addProperty(IsDifferentFrom,Isosceles);

NonParallel.addProperty(IsDifferentFrom,Similar);
```

```
NonParallel.addProperty(IsDifferentFrom,Elongated);

NonParallel.addProperty(IsDifferentFrom,Elongated_Horizontal);

NonParallel.addProperty(IsDifferentFrom,Elongated_Verticaly);

NonParallel.addProperty(IsDifferentFrom,CW);CW.addProperty(IsDifferentFrom,Non
Parallel);

NonParallel.addProperty(IsDifferentFrom,CCW);CCW.addProperty(IsDifferentFrom,N
onParallel);


Elongated.addProperty(IsDifferentFrom,NonParallel);

Elongated_Horizontal.addProperty(IsDifferentFrom,NonParallel);

Elongated_Verticaly.addProperty(IsDifferentFrom,NonParallel);*/

ClusterExists.addProperty(Has_Infered_Feature_Count,Count);


                                        // boolean a=true;

                                         /**
                                          * Creating placeholders for individuals to
be imported (input) form Applet program
                                          * <code> Applet2New_prof </code>
                                          */

                                        Individual Shape1;Individual
Shape2;Individual Shape3;Individual Shape4;Individual Shape5;Individual
```

```
Shape6;Individual Shape7; Individual Shape8;Individual Shape9;Individual
Shape10;Individual Shape11;
                                        Individual Shape12;Individual
Shape13;Individual Shape14;Individual Shape15;Individual Shape16; Individual
Shape17; Individual Shape18;Individual Shape19;Individual Shape20; Individual
Shape21;
                                        Individual Shape22; Individual
Shape23;Individual Shape24; Individual Shape25; Individual Shape26;Individual
Shape27; Individual Shape28; Individual Shape29;Individual Shape30;Individual
Shape31;Individual Shape32;Individual Shape33;Individual Shape34;Individual
Shape35;Individual Shape36;


                                        Individual No1; Individual No2;
Individual No3; Individual No4; Individual No5; Individual No6; Individual No7;
Individual No8; Individual No9; Individual No10; Individual No11;Individual No12;


                                        Individual outline1;Individual
outline2;Individual outline3;Individual outline4;Individual outline5;Individual
outline6;Individual outline7;Individual outline8;Individual outline9;Individual
outline10;Individual outline11;Individual outline12;
                                        Individual outline13;Individual
outline14;Individual outline15;Individual outline16;Individual outline17;Individual
outline18;Individual outline19;Individual outline20;Individual outline21;Individual
outline22;Individual outline23;Individual outline24;


                                        Individual size1; Individual size2;
Individual size3; Individual size4; Individual size5; Individual size6; Individual size7;
Individual size8; Individual size9; Individual size10; Individual size11; Individual
size12;


                                        Individual side1;Individual
side2;Individual side3;Individual side4;Individual side5;Individual side6;Individual
side7;Individual side8;Individual side9;Individual side10;Individual side11;Individual
side12;


                                        Individual Characteristics1; Individual
Characteristics2;Individual Characteristics3;Individual Characteristics4;Individual
```

```
Characteristics5;Individual Characteristics6;Individual Characteristics7;Individual
Characteristics8;Individual Characteristics9;Individual Characteristics10;Individual
Characteristics11;Individual Characteristics12;


                                        ///Input//////


Shape1=m.createIndividual( relationshipUri+p.get_ji(),GeometricShapes);

Shape2=m.createIndividual( relationshipUri+p.get_ji1(),GeometricShapes);

Shape3=m.createIndividual( relationshipUri+p.get_ji2(),GeometricShapes);

Shape4=m.createIndividual( relationshipUri+p.get_ji9(),GeometricShapes);

Shape5=m.createIndividual( relationshipUri+p.get_ji10(),GeometricShapes);

Shape6=m.createIndividual( relationshipUri+p.get_ji11(),GeometricShapes);

Shape7=m.createIndividual( relationshipUri+p.get_ji18(),GeometricShapes);

Shape8=m.createIndividual( relationshipUri+p.get_ji19(),GeometricShapes);

Shape9=m.createIndividual( relationshipUri+p.get_ji20(),GeometricShapes);

Shape10=m.createIndividual( relationshipUri+p.get_ji27(),GeometricShapes);

Shape11=m.createIndividual( relationshipUri+p.get_ji28(),GeometricShapes);

Shape12=m.createIndividual( relationshipUri+p.get_ji29(),GeometricShapes);

Shape13=m.createIndividual( relationshipUri+p.get_ji36(),GeometricShapes);

Shape14=m.createIndividual( relationshipUri+p.get_ji37(),GeometricShapes);
```

```
Shape15=m.createIndividual( relationshipUri+p.get_ji38(),GeometricShapes);
Shape16=m.createIndividual( relationshipUri+p.get_ji45(),GeometricShapes);
Shape17=m.createIndividual( relationshipUri+p.get_ji46(),GeometricShapes);
Shape18=m.createIndividual( relationshipUri+p.get_ji47(),GeometricShapes);

Shape19=m.createIndividual( relationshipUri+p.get_ji54(),GeometricShapes);
Shape20=m.createIndividual( relationshipUri+p.get_ji55(),GeometricShapes);
Shape21=m.createIndividual( relationshipUri+p.get_ji56(),GeometricShapes);
Shape22=m.createIndividual( relationshipUri+p.get_ji63(),GeometricShapes);
Shape23=m.createIndividual( relationshipUri+p.get_ji64(),GeometricShapes);
Shape24=m.createIndividual( relationshipUri+p.get_ji65(),GeometricShapes);
Shape25=m.createIndividual( relationshipUri+p.get_ji72(),GeometricShapes);
Shape26=m.createIndividual( relationshipUri+p.get_ji73(),GeometricShapes);
Shape27=m.createIndividual( relationshipUri+p.get_ji74(),GeometricShapes);
Shape28=m.createIndividual( relationshipUri+p.get_ji81(),GeometricShapes);
Shape29=m.createIndividual( relationshipUri+p.get_ji82(),GeometricShapes);
Shape30=m.createIndividual( relationshipUri+p.get_ji83(),GeometricShapes);
Shape31=m.createIndividual( relationshipUri+p.get_ji90(),GeometricShapes);
Shape32=m.createIndividual( relationshipUri+p.get_ji91(),GeometricShapes);
Shape33=m.createIndividual( relationshipUri+p.get_ji92(),GeometricShapes);
Shape34=m.createIndividual( relationshipUri+p.get_ji99(),GeometricShapes);
Shape35=m.createIndividual( relationshipUri+p.get_ji100(),GeometricShapes);
Shape36=m.createIndividual( relationshipUri+p.get_ji101(),GeometricShapes);

                System.out.println(Shape1);
                System.out.println(Shape2);
                System.out.println(Shape3);
                System.out.println(Shape4);
                System.out.println(Shape5);
                System.out.println(Shape6);
                System.out.println(Shape7);
                System.out.println(Shape8);
                System.out.println(Shape9);
                System.out.println(Shape10);
                System.out.println(Shape11);
                System.out.println(Shape12);
                System.out.println(Shape13);
                System.out.println(Shape14);
                System.out.println(Shape15);
                System.out.println(Shape16);
                System.out.println(Shape17);
                System.out.println(Shape18);
                System.out.println(Shape19);
                System.out.println(Shape20);
                System.out.println(Shape21);
                System.out.println(Shape22);
                System.out.println(Shape23);
                System.out.println(Shape24);
                System.out.println(Shape25);
                System.out.println(Shape26);
                System.out.println(Shape27);
                System.out.println(Shape28);
                System.out.println(Shape29);
                System.out.println(Shape30);
                System.out.println(Shape31);
                System.out.println(Shape32);
                System.out.println(Shape33);
                System.out.println(Shape35);
                System.out.println(Shape36);

No1=m.createIndividual( relationshipUri+p.get_ji3(),Count);
No2=m.createIndividual( relationshipUri+p.get_ji12(),Count);
No3=m.createIndividual( relationshipUri+p.get_ji21(),Count);
No4=m.createIndividual( relationshipUri+p.get_ji30(),Count);
No5=m.createIndividual( relationshipUri+p.get_ji39(),Count);
No6=m.createIndividual( relationshipUri+p.get_ji48(),Count);
No7=m.createIndividual( relationshipUri+p.get_ji57(),Count);
No8=m.createIndividual( relationshipUri+p.get_ji66(),Count);
No9=m.createIndividual( relationshipUri+p.get_ji75(),Count);
No10=m.createIndividual( relationshipUri+p.get_ji84(),Count);
No11=m.createIndividual( relationshipUri+p.get_ji93(),Count);
No12=m.createIndividual( relationshipUri+p.get_ji102(),Count);

                System.out.println(No1);
                System.out.println(No2);
                System.out.println(No3);
                System.out.println(No4);
                System.out.println(No5);
                System.out.println(No6);
                System.out.println(No7);
                System.out.println(No8);
                System.out.println(No9);
                System.out.println(No10);
                System.out.println(No11);
                System.out.println(No12);

outline1=m.createIndividual( relationshipUri+p.get_ji4(),OutLined);
```

```
outline2=m.createIndividual( relationshipUri+p.get_ji13(),OutLined);
outline3=m.createIndividual( relationshipUri+p.get_ji22(),OutLined);
outline4=m.createIndividual( relationshipUri+p.get_ji31(),OutLined);
outline5=m.createIndividual( relationshipUri+p.get_ji40(),OutLined);
outline6=m.createIndividual( relationshipUri+p.get_ji49(),OutLined);
outline7=m.createIndividual( relationshipUri+p.get_ji58(),OutLined);
outline8=m.createIndividual( relationshipUri+p.get_ji67(),OutLined);
outline9=m.createIndividual( relationshipUri+p.get_ji76(),OutLined);
outline10=m.createIndividual( relationshipUri+p.get_ji85(),OutLined);
outline11=m.createIndividual( relationshipUri+p.get_ji94(),OutLined);
outline12=m.createIndividual( relationshipUri+p.get_ji103(),OutLined);

outline13=m.createIndividual( relationshipUri+p.get_ji5(),OutLined);
outline14=m.createIndividual( relationshipUri+p.get_ji14(),OutLined);
outline15=m.createIndividual( relationshipUri+p.get_ji23(),OutLined);
outline16=m.createIndividual( relationshipUri+p.get_ji32(),OutLined);
outline17=m.createIndividual( relationshipUri+p.get_ji41(),OutLined);
outline18=m.createIndividual( relationshipUri+p.get_ji50(),OutLined);
```

```
outline19=m.createIndividual( relationshipUri+p.get_ji59(),OutLined);
outline20=m.createIndividual( relationshipUri+p.get_ji68(),OutLined);
outline21=m.createIndividual( relationshipUri+p.get_ji77(),OutLined);
outline22=m.createIndividual( relationshipUri+p.get_ji86(),OutLined);
outline23=m.createIndividual( relationshipUri+p.get_ji95(),OutLined);
outline24=m.createIndividual( relationshipUri+p.get_ji104(),OutLined);

System.out.println(outline1);
System.out.println(outline2);
System.out.println(outline3);
System.out.println(outline4);
System.out.println(outline5);
System.out.println(outline6);
System.out.println(outline7);
System.out.println(outline8);
System.out.println(outline9);
System.out.println(outline10);
System.out.println(outline11);
System.out.println(outline12);
System.out.println(outline13);
System.out.println(outline14);
System.out.println(outline15);
System.out.println(outline16);
System.out.println(outline17);
System.out.println(outline18);
```

```
System.out.println(outline19);
System.out.println(outline20);
System.out.println(outline21);
System.out.println(outline22);
System.out.println(outline23);
System.out.println(outline24);

size1=m.createIndividual( relationshipUri+p.get_ji6(),Size);
size2=m.createIndividual( relationshipUri+p.get_ji15(),Size);
size3=m.createIndividual( relationshipUri+p.get_ji24(),Size);
size4=m.createIndividual( relationshipUri+p.get_ji33(),Size);
size5=m.createIndividual( relationshipUri+p.get_ji42(),Size);
size6=m.createIndividual( relationshipUri+p.get_ji51(),Size);
size7=m.createIndividual( relationshipUri+p.get_ji60(),Size);
size8=m.createIndividual( relationshipUri+p.get_ji69(),Size);
size9=m.createIndividual( relationshipUri+p.get_ji78(),Size);
size10=m.createIndividual( relationshipUri+p.get_ji87(),Size);
size11=m.createIndividual( relationshipUri+p.get_ji96(),Size);
size12=m.createIndividual( relationshipUri+p.get_ji105(),Size);
```

```
side1=m.createIndividual( relationshipUri+p.get_ji7(),Side);
side2=m.createIndividual( relationshipUri+p.get_ji16(),Side);
side3=m.createIndividual( relationshipUri+p.get_ji25(),Side);
side4=m.createIndividual( relationshipUri+p.get_ji34(),Side);
side5=m.createIndividual( relationshipUri+p.get_ji43(),Side);
side6=m.createIndividual( relationshipUri+p.get_ji52(),Side);
side7=m.createIndividual( relationshipUri+p.get_ji61(),Side);
side8=m.createIndividual( relationshipUri+p.get_ji70(),Side);
side9=m.createIndividual( relationshipUri+p.get_ji79(),Side);
side10=m.createIndividual( relationshipUri+p.get_ji88(),Side);
side11=m.createIndividual( relationshipUri+p.get_ji97(),Side);
side12=m.createIndividual( relationshipUri+p.get_ji106(),Side);

System.out.println(size1);
System.out.println(size2);
System.out.println(size3);
System.out.println(size4);
System.out.println(size5);
System.out.println(size6);
System.out.println(size7);
System.out.println(size8);
```

```
                                        System.out.println(size9);
                                        System.out.println(size10);
                                        System.out.println(size11);
                                        System.out.println(size12);

                                        System.out.println(side1);
                                        System.out.println(side2);
                                        System.out.println(side3);
                                        System.out.println(side4);
                                        System.out.println(side5);
                                        System.out.println(side6);
                                        System.out.println(side7);
                                        System.out.println(side8);
                                        System.out.println(side9);
                                        System.out.println(side10);
                                        System.out.println(side11);
                                        System.out.println(side12);


Characteristics1=m.createIndividual( relationshipUri+p.get_ji8(),Characteristics);

Characteristics2=m.createIndividual( relationshipUri+p.get_ji17(),Characteristics);

Characteristics3=m.createIndividual( relationshipUri+p.get_ji26(),Characteristics);

Characteristics4=m.createIndividual( relationshipUri+p.get_ji35(),Characteristics);

Characteristics5=m.createIndividual( relationshipUri+p.get_ji44(),Characteristics);

Characteristics6=m.createIndividual( relationshipUri+p.get_ji53(),Characteristics);

Characteristics7=m.createIndividual( relationshipUri+p.get_ji62(),Characteristics);

Characteristics8=m.createIndividual( relationshipUri+p.get_ji71(),Characteristics);

Characteristics9=m.createIndividual( relationshipUri+p.get_ji80(),Characteristics);

Characteristics10=m.createIndividual( relationshipUri+p.get_ji89(),Characteristics);

Characteristics11=m.createIndividual( relationshipUri+p.get_ji98(),Characteristics);

Characteristics12=m.createIndividual( relationshipUri+p.get_ji107(),Characteristics);


                                        System.out.println(Characteristics1);
                                        System.out.println(Characteristics2);
                                        System.out.println(Characteristics3);
                                        System.out.println(Characteristics4);
                                        System.out.println(Characteristics5);
                                        System.out.println(Characteristics6);
                                        System.out.println(Characteristics7);
                                        System.out.println(Characteristics8);
                                        System.out.println(Characteristics9);
                                        System.out.println(Characteristics10);
                                        System.out.println(Characteristics11);
                                        System.out.println(Characteristics12);

                                        /**
                                         * Assigning the Individuals to each place
holders Lside (left Side Individuals)
                                         * and Rside (Right Side Individuals)
                                                in the RDF form-

<left(box1)><property(different)><input(Individuals)>
/<Right(box7)><property(different)><input(Individuals)>
                                        */

                                        Lside1.addProperty(has, Shape1);
                                        Lside1.addProperty(has, Shape2);
                                        Lside1.addProperty(has, Shape3);
                                        Lside1.addProperty(hasCount, No1);
                                        Lside1.addProperty(hasTexture,
outline1);
                                        Lside1.addProperty(AlsohasTexture,
outline13);
                                        Lside1.addProperty(hasSize, size1);
                                        Lside1.addProperty(IsOnSide, side1);
                                        Lside1.addProperty(ShapeFeature,
Characteristics1);

                                        Lside2.addProperty(has, Shape4);
                                        Lside2.addProperty(has, Shape5);
                                        Lside2.addProperty(has, Shape6);
                                        Lside2.addProperty(hasCount, No2);
                                        Lside2.addProperty(hasTexture,
outline2);
                                        Lside2.addProperty(AlsohasTexture,
outline14);
                                        Lside2.addProperty(hasSize, size2);
                                        Lside2.addProperty(IsOnSide, side2);
                                        Lside2.addProperty(ShapeFeature,
Characteristics2);

                                        Lside3.addProperty(has, Shape7);
                                        Lside3.addProperty(has, Shape8);
                                        Lside3.addProperty(has, Shape9);
                                        Lside3.addProperty(hasCount, No3);
                                        Lside3.addProperty(hasTexture,
outline3);
                                        Lside3.addProperty(AlsohasTexture,
outline15);
                                        Lside3.addProperty(hasSize, size3);
                                        Lside3.addProperty(IsOnSide, side3);
                                        Lside3.addProperty(ShapeFeature,
Characteristics3);

                                        Lside4.addProperty(has, Shape10);
                                        Lside4.addProperty(has, Shape11);
                                        Lside4.addProperty(has, Shape12);
                                        Lside4.addProperty(hasCount, No4);
                                        Lside4.addProperty(hasTexture,
outline4);
                                        Lside4.addProperty(AlsohasTexture,
outline16);
                                        Lside4.addProperty(hasSize, size4);
                                        Lside4.addProperty(IsOnSide, side4);
                                        Lside4.addProperty(ShapeFeature,
Characteristics4);

                                        Lside5.addProperty(has, Shape13);
                                        Lside5.addProperty(has, Shape14);
                                        Lside5.addProperty(has, Shape15);
                                        Lside5.addProperty(hasCount, No5);
```

```
                                        Lside5.addProperty(hasTexture,
outline5);
                                        Lside5.addProperty(AlsohasTexture,
outline17);
                                        Lside5.addProperty(hasSize, size5);
                                        Lside5.addProperty(IsOnSide, side5);
                                        Lside5.addProperty(ShapeFeature,
Characteristics5);

                                        Lside6.addProperty(has, Shape16);
                                        Lside6.addProperty(has, Shape17);
                                        Lside6.addProperty(has, Shape18);
                                        Lside6.addProperty(hasCount, No6);
                                        Lside6.addProperty(hasTexture,
outline6);
                                        Lside6.addProperty(AlsohasTexture,
outline18);
                                        Lside6.addProperty(hasSize, size6);
                                        Lside6.addProperty(IsOnSide, side6);
                                        Lside6.addProperty(ShapeFeature,
Characteristics6);

                                            /////


                                        Rside1.addProperty(has, Shape19);
                                        Rside1.addProperty(has, Shape20);
                                        Rside1.addProperty(has, Shape21);
                                        Rside1.addProperty(hasCount, No7);
                                        Rside1.addProperty(hasTexture,
outline7);
```

```
                                        Rside1.addProperty(AlsohasTexture,
outline19);
                                        Rside1.addProperty(hasSize, size7);
                                        Rside1.addProperty(IsOnSide, side7);
                                        Rside1.addProperty(ShapeFeature,
Characteristics7);

                                        Rside2.addProperty(has, Shape22);
                                        Rside2.addProperty(has, Shape23);
                                        Rside2.addProperty(has, Shape24);
                                        Rside2.addProperty(hasCount, No8);
                                        Rside2.addProperty(hasTexture,
outline8);
                                        Rside2.addProperty(AlsohasTexture,
outline20);
                                        Rside2.addProperty(hasSize, size8);
                                        Rside2.addProperty(IsOnSide, side8);
                                        Rside2.addProperty(ShapeFeature,
Characteristics8);

                                        Rside3.addProperty(has, Shape25);
                                        Rside3.addProperty(has, Shape26);
                                        Rside3.addProperty(has, Shape27);
                                        Rside3.addProperty(hasCount, No9);
                                        Rside3.addProperty(hasTexture,
outline9);
                                        Rside3.addProperty(AlsohasTexture,
outline21);
                                        Rside3.addProperty(hasSize, size9);
                                        Rside3.addProperty(IsOnSide, side9);
```

```
                                        Rside3.addProperty(ShapeFeature,
Characteristics9);

                                        Rside4.addProperty(has, Shape28);
                                        Rside4.addProperty(has, Shape29);
                                        Rside4.addProperty(has, Shape30);
                                        Rside4.addProperty(hasCount, No10);
                                        Rside4.addProperty(hasTexture,
outline10);
                                        Rside4.addProperty(AlsohasTexture,
outline22);
                                        Rside4.addProperty(hasSize, size10);
                                        Rside4.addProperty(IsOnSide, side10);
                                        Rside4.addProperty(ShapeFeature,
Characteristics10);

                                        Rside5.addProperty(has, Shape31);
                                        Rside5.addProperty(has, Shape32);
                                        Rside5.addProperty(has, Shape33);
                                        Rside5.addProperty(hasCount, No11);
                                        Rside5.addProperty(hasTexture,
outline11);
                                        Rside5.addProperty(AlsohasTexture,
outline23);
                                        Rside5.addProperty(hasSize, size11);
                                        Rside5.addProperty(IsOnSide, side11);
                                        Rside5.addProperty(ShapeFeature,
Characteristics11);

                                        Rside6.addProperty(has, Shape34);
                                        Rside6.addProperty(has, Shape35);
```

```
                                        Rside6.addProperty(has, Shape36);
                                        Rside6.addProperty(hasCount, No12);
                                        Rside6.addProperty(hasTexture,
outline12);
                                        Rside6.addProperty(AlsohasTexture,
outline24);
                                        Rside6.addProperty(hasSize, size12);
                                        Rside6.addProperty(IsOnSide, side12);
                                        Rside6.addProperty(ShapeFeature,
Characteristics12);



                                    LeftSide.addProperty(means,"To the Left
set of bp", XSDDatatype.XSDstring ) ;
                                    RightSide.addProperty(means,"To the
Right set of bp", XSDDatatype.XSDstring ) ;


                                    /**
                                      Saving an Ontology model 'm' into OWL
file format (in RDF format)
                                      you can save it in multiple format like-
RDF, N-triple, OWl, Turtle
                                      the Turtle format is easily understandable
to check for errors  (or for no output after executions SWRL rules)
                                    <p>
                                      The Owl file is saved at location-
"WagaLabData4T\\New2_Research_Projects\\D3_Jisha\\Research\\BP\\BP_v18.owl"
                                      using try catch for catching any error
while saving the file
                                    */
```

```
try{
File file=new
File("\\\\172.17.117.38\\WagaLabData4T\\New2_Research_Projects\\D3_Jisha\\Researc
h\\BP\\BP_v18.owl");
FileOutputStream f1=new
FileOutputStream(file);
RDFWriter d =
m.getWriter("RDF/XML-ABBREV");

d.write(m,f1,null);
}catch(Exception e) {}


////////////////////////////////////////////////////////////////////////////////////////////////////
////
/**
*
* creating the SWRL rule
Each section of the SWRL rule for
checking difference in each properties is written by providing comment
used for solving 62 BPs
<p>
To correct the redundant output
<><><>+<><><>
*
*/

String rule=
//this is for checking shape

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a),(?a
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a)]"+


"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/null),(?a
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp
/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a),(http://bongardproblem.org/
bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a)]"+


"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org
/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org
/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org
/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org
/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org
/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(?a1
http://bongardproblem.org/bp/relationship/includes/has ?a2),(?a2
http://bongardproblem.org/bp/relationship/includes/has ?a3),(?a3
http://bongardproblem.org/bp/relationship/includes/has ?a4),(?a4
http://bongardproblem.org/bp/relationship/includes/has ?a5),(?a5
http://bongardproblem.org/bp/relationship/includes/has ?a6),(?a6
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/setoflines),(http://bongardproblem.
org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/polygon)]"+
//quad_left

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org
/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org
/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),
(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),
(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),
(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(?a1
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?a2
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?a3
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?a4
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?a5
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?a6
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)-
>( http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)]"+
//curvilinear_left
```

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org
/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),
(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),
(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),
(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),
(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(?a1
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?a2
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?a3
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?a4
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?a5
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?a6
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(http://bongardproblem.org/
bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/curvilinear)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/
bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty)]"+

//this is for checking shape

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa),(?aa
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/null),(?aa
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp
/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa),(http://bongardproblem.org
/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://www.w3.org/2002/07/owl#differentFrom ?aa3)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

//polygon_right

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa2
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa3
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa4
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa5
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(?aa6
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/setoflines),(http://bongardproblem.
org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardprob
lem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/polygon)]"+

//quad_right

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),
(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),
(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),
(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa2
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa3
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa4
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa5
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral),(?aa6
http://bongardproblem.org/bp/relationship/includes/infered/is_same_as
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/quadrilateral)]"+

//curvilinear_left

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),
(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),
(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),
(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),
(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(?aa1
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa2
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa3
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa4
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa5
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(?aa6
http://bongardproblem.org/bp/relationship/includes/isa
http://bongardproblem.org/bp/relationship/proprties/curves),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hastexture
http://bongardproblem.org/bp/relationship/proprties/closed_shaped)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/curvilinear)]"+

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/rightside_4

http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has
http://bongardproblem.org/bp/relationship/proprties/empty)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty)]"+

//this is for checking the difference in shape

"[rule2:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a)]"+

"[rule2:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/empty),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a)]"+

"[rule2:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?a),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?aa),(?a
http://www.w3.org/2002/07/owl#differentFrom ?aa)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?a),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?aa)]"+

//this is for checking the texture

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hastexture ?t),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hastexture ?t)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t)]"+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hastexture ?t1),(http://bongardproblem.org/bp/relationship/proprties/rightside_6

http://bongardproblem.org/bp/relationship/includes/hastexture ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t1)]"+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t),(http://bongardpro
blem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t)]"
+

"[rule3:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1),(http://bongardpr
oblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t1)]
"+

//this is for checking the
difference in texture

"[rule4:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_texture ?t1),(?t
http://www.w3.org/2002/07/owl#differentFrom ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t1)]"+

"[rule4:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t),(
http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?t1),
(?t http://www.w3.org/2002/07/owl#differentFrom ?t1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t),(http
://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?t1)]"+

//count_left and right

"[rule5:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hascount ?c),(http://bongardproblem
.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hascount ?c)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c)]"+

"[rule5:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hascount ?c1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hascount ?c1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c1)]"+

//this is for checking
difference in count

"[rule6:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c),(http:
//bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_count ?c1),(?c1
http://www.w3.org/2002/07/owl#differentFrom ?c)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c),(http:/
/bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c1)]"+

//size of left and right

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?sz),(http://bongardproblem.
org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?sz)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?sz)]"+

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?sz1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?sz1)]"+

//unevensize of left and
right

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?siz1),(http://bongardproble
m.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?siz3),(http://bongardproble
m.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?siz5),(http://bongardproble
m.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?siz7),(http://bongardproble
m.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?siz9),(http://bongardproble
m.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?siz11),(?siz1
http://www.w3.org/2002/07/owl#differentFrom ?siz5)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size
http://bongardproblem.org/bp/relationship/proprties/uneven_shapes)]"+

"[rule7:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hassize ?siz2),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hassize ?siz4),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hassize ?siz6),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hassize ?siz8),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hassize ?siz10),(http://bongardprobl
em.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hassize ?siz12),(?siz2
http://www.w3.org/2002/07/owl#differentFrom ?siz6)-
>(http://bongardproblem.org/bp/relationship/proprties/right

http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size
http://bongardproblem.org/bp/relationship/proprties/uneven_shapes)]"+

//this is for checking
difference in size

"[rule8:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?siz13),(ht
tp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_size ?siz14),(?si
z13 http://www.w3.org/2002/07/owl#differentFrom ?siz14)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size ?siz13),(htt
p://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size ?siz14)]"+

//side (left and right)

"[rule9:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(http://bongardproble
m.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/isonside ?sd1),(?sd1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd1)]"
+

"[rule9:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(http://bongardproble
m.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/isonside ?sd),(?sd
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd)]"+

//pro//////////this is for
checking difference in position(side)

"[rule10:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_position ?sd1),(
?sd1 http://www.w3.org/2002/07/owl#differentFrom ?sd)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_position ?sd),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_position ?sd1)]"
+

//feature (left and right)

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe),(http://bongard
problem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe)]"
+

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)]
"+

//this is for checking
difference in feature

"[rule12:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1),(
?fe http://www.w3.org/2002/07/owl#differentFrom ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
fe1)]"+

//neck and non_empty
[no_neck]

"[rule1:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/squeezed_shape),(http://bongardpro
blem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape
http://bongardproblem.org/bp/relationship/proprties/squeezed_shape),(http://bongardpro
blem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape
http://bongardproblem.org/bp/relationship/proprties/not_squeezed_shape)]"+

//shape and notempty

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(?fet5
http://www.w3.org/2002/07/owl#differentFrom ?fet6)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

//
"[rule11:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)]
"+

"[rule11:(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_4

```
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(?fet5
http://www.w3.org/2002/07/owl#differentFrom ?fet6)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+
                                                        //
"[rule11:(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1),(http://bongar
dproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)]
"+
                                                        //this is for checking
difference in feature [x shape and no x shape]


        "[rule12:(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?fe1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
fe1)]"+


        "[rule12:(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?fe),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
fe)]"+
                                                        // feature no. (left - 2
cluster, right- 3 cluster)
                                                        "[rule13:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c),(?c
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp
/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count ?c1),(?c1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(http://bongardproblem.org/bp
/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe),(h
ttp://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?fe1)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?
c),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?
c1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?
fe),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_feature_count ?
fe1)]"+
                                                        //hardly and softly squeezed
                                                        "[rule14:(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/longconcave_shape),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/shortconcave_shape)->(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/hardlysqueezed_shape),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/softlysqueezed_shape)]"+
```

```
                                                        //damping signal
                                                        "[rule15:(?l
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/waveform),(?r
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/waveform),(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size
http://bongardproblem.org/bp/relationship/proprties/increasing),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size
http://bongardproblem.org/bp/relationship/proprties/decreasing)->(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature http://bongardproblem.org/bp/relationship/proprties/dampingsignal),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
http://bongardproblem.org/bp/relationship/proprties/dampingsignal )]"+
                                                        //shape feature x and null
                                                        //   "[rule16:(?l
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?ftu1),
(?r http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null)->(?l
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
ftu1),(?r
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?ftu1)]";
                                                        //cross check  for 13
//                                                              "[rule16: (),(),()]"+
                                                        //cross check
                                                        "[rule16:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex),
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
e ?shapex),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?shapex)
]"+
                                                        "[rule16:
(http://bongardproblem.org/bp/relationship/proprties/right
```

```
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex),
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/notempty)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
e ?shapex1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape ?shapex1
)]"+
                                                        // cross check independent
properties
                                                        "[rule16:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org
/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org
/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org
/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org
/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org
/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(http://bongardproblem.org
/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bonga
rdproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(http://bonga
rdproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?aa1),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?aa2),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?aa3),(http://bongardproblem.or
g/bp/relationship/proprties/rightside_4
```

http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett6),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?aa1),(?a2
http://www.w3.org/2002/07/owl#differentFrom ?aa2),(?a3
http://www.w3.org/2002/07/owl#differentFrom ?aa3),(?fet1
http://www.w3.org/2002/07/owl#differentFrom ?fet2),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?a2),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?a3),(?fet1
http://www.w3.org/2002/07/owl#differentFrom /fet3),(?aa1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(?aa2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?aa1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a2),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?aa2)]"+

"[rule16:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/has ?a3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/has ?a4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/has ?a5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/has ?a6),(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/has ?a2),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/has ?a1),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/has ?aa4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/has ?aa5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/has ?aa6),(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet1),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet2),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fet3),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett4),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett5),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/hasshapefeature ?fett6),(?a1
http://www.w3.org/2002/07/owl#differentFrom ?aa1),(?a1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null),(?a2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?a2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference1 ?fet1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a2),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?fet2),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_dependent_inference2 ?a1)]"+

//uneven texture and similar textures

"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/rightside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex11),(http://bongardproblem.org/bp/relationship/proprties/rightside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex12),(http://bongardproblem.org/bp/relationship/proprties/rightside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex13),(http://bongardproblem.org/bp/relationship/proprties/rightside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex14),(http://bongardproblem.org/bp/relationship/proprties/rightside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex15),(http://bongardproblem.org/bp/relationship/proprties/rightside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex16),(?tex11
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex12
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex13
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex14
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex15
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex16
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

"[rule17:
(http://bongardproblem.org/bp/relationship/proprties/leftside_1
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex1),(http://bongardproblem.org/bp/relationship/proprties/leftside_2
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex2),(http://bongardproblem.org/bp/relationship/proprties/leftside_3
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex3),(http://bongardproblem.org/bp/relationship/proprties/leftside_4
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex4),(http://bongardproblem.org/bp/relationship/proprties/leftside_5
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex5),(http://bongardproblem.org/bp/relationship/proprties/leftside_6
http://bongardproblem.org/bp/relationship/includes/alsohastexture ?tex6),(?tex1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex2
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex3
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex4
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex5
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture),(?tex6
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/uneven_texture)-
>(http://bongardproblem.org/bp/relationship/proprties/left

```
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty)]"+

                                                "[rule17:
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?tex
x)->(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothastext
ure ?texx),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?texx)]"
+

                                                "[rule17:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture
http://bongardproblem.org/bp/relationship/proprties/notempty),(http://bongardproblem.o
rg/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/alsoconsists_of_texture ?tex
x)->(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothastext
ure ?texx),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture ?texx)]"
+

                                                //featurex and no feature

                                                "[rule18:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/line),(http://bongardproblem.org/bp
/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape
http://bongardproblem.org/bp/relationship/proprties/line),(http://bongardproblem.org/bp
/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]"+

                                                "[rule18:
(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?Shapex1
),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex2
),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]"+

                                                "[rule18:
(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?Shapex1
),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_shape ?shapex2
),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character ?chara
cter1),(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/consists_of_character
http://bongardproblem.org/bp/relationship/proprties/null),(?character1
http://www.w3.org/2002/07/owl#differentFrom
http://bongardproblem.org/bp/relationship/proprties/null)-
>(http://bongardproblem.org/bp/relationship/proprties/left
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothasshap
efeature ?character1),(http://bongardproblem.org/bp/relationship/proprties/right
http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics ?
character1)]";


////////////////////////////////////////////////////////////////////////////////////////////////////

                                                /**
```

```
                                                * The SPARQL Queries for displaying all
the relations

                                                * depending on properties like-

                                                *
has,hascount,hastexture,hastexture,hassize,isonside,feature

                                                */


                                                String queryString=//"PREFIX
Relation:<http://www.somerelation.com/relation> "+

                                                "PREFIX
relationshipUri2:<http://BongardProblem.org/BP_21/relationship/includes/infered/> "+

"SELECT ?side ?obj ?obj1 ?obj2 ?obj3 ?obj4 ?obj5 ?obj6 " +

                                                "WHERE { " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/has> ?obj . "+

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/hascount> ?obj1 . " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/hastexture> ?obj2 . " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/hastexture> ?obj3 . " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/hassize> ?obj4 . " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/isonside> ?obj5 . " +

                                                "     ?side
<http://bongardproblem.org/bp/relationship/includes/hasshapefeature> ?obj6 . " +

                                                "     } ";



                                                String queryString1=//"PREFIX
Relation:<http://www.somerelation.com/relation> "+
```

```
                                                "PREFIX
relationshipUri2:<http://bongardproblem.org/bp/relationship/includes/infered/> "+

                                                "PREFIX
rela:<http://bongardproblem.org/bp/relationship/includes/infered/> "+


"SELECT ?a ?b ?c ?d ?e ?f ?g ?h ?i ?j " +

                                                "WHERE { " +

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_shape> ?b . "+

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_count> ?c . "
+

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_texture> ?d . "
+

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_size> ?e . " +

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_position> ?f .
" +

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_characteristics
> ?g . " +

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothassha
pe> ?h . "+

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothastex
ture> ?i . "+

                                                "     ?a
<http://bongardproblem.org/bp/relationship/includes/infered/has_infered_doesnothassha
pefeature> ?j . "+

                                                "     } ";


////////////////////////////////////////////////////////////////////////////////////////////////////
```

```
                                        /**
                                         * To output- (SPARQL output)
                                         */


                                        ////
                                        Query query1 =
QueryFactory.create(queryString);
                                         QueryExecution qe1 =
QueryExecutionFactory.create(query1, m);
                                         ResultSet results1 =
qe1.execSelect();

ResultSetFormatter.out(System.out, results1, query1);

        ////////////////////////////////////////////////////////////////////////////////////////////////
                                        /**
                                         * To output the SWRL based new
assertion (excluding any other form of assertion-i.e excluding the existing assertions)
                                         */


                                         System.out.printf("The
Infererence/ Output of solving BP is... ");
                                        Reasoner reasoner = new
GenericRuleReasoner(Rule.parseRules(rule));
                                        InfModel inf =
ModelFactory.createInfModel(reasoner, m);



        @SuppressWarnings("deprecation")

        ExtendedIterator<Statement> stmts = inf.listStatements().filterDrop( new
Filter<Statement>() {
                                                @Override
```

```
                                                public boolean
accept(Statement o) {
                                                    return m.contains( o );
                                                }
                                                });
                                                Model deductions =
ModelFactory.createDefaultModel().add( new StmtIteratorImpl( stmts ));
                                                deductions.write( System.out,
"TTL" );
                                                qe1.close();

////////////////////////////////////////////////////////////////////////////////////////////////
                                                /**
                                                 * To check if new SPRAQL
query can be obtained (failed)
                                                 *
                                                 */


                                                Query query =
QueryFactory.create(queryString1);
                                                    // Execute the query and
obtain results
                                                    QueryExecution qe =
QueryExecutionFactory.create(query, m);
                                                    // QueryExecution qe1 =
QueryExecutionFactory.create(query, m);
                                                    // ResultSet resultss =
qe1.execSelect();
                                                    ResultSet results =
qe.execSelect();
                                                    // Output query results

ResultSetFormatter.out(System.out, results, query);
```

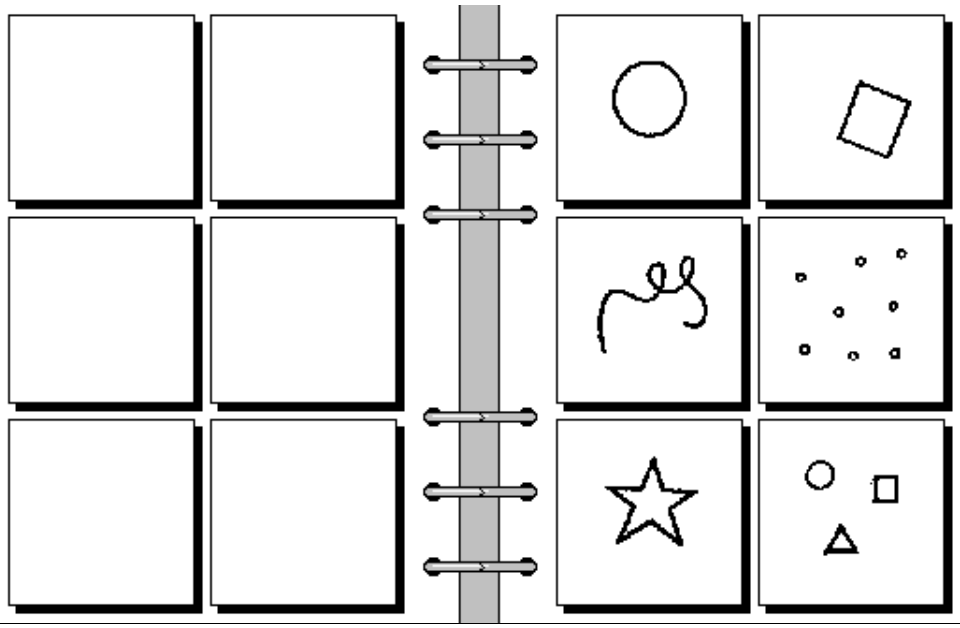
```
                                                    // Important - free up
resources used running the query
                                                //
ResultSetFormatter.out(System.out, resultss, query); qe1.close();
                                                    qe.close();



                                                    final long duration =
System.nanoTime() - startTime;
                                                    double seconds= (double)
duration/1000000000.0;System.out.println(seconds);Date myTime = new Date(duration
/ 1000);          System.out.println(myTime);
                                                }}
```

Appendix 4: Simplified output obtained for 65 BPs

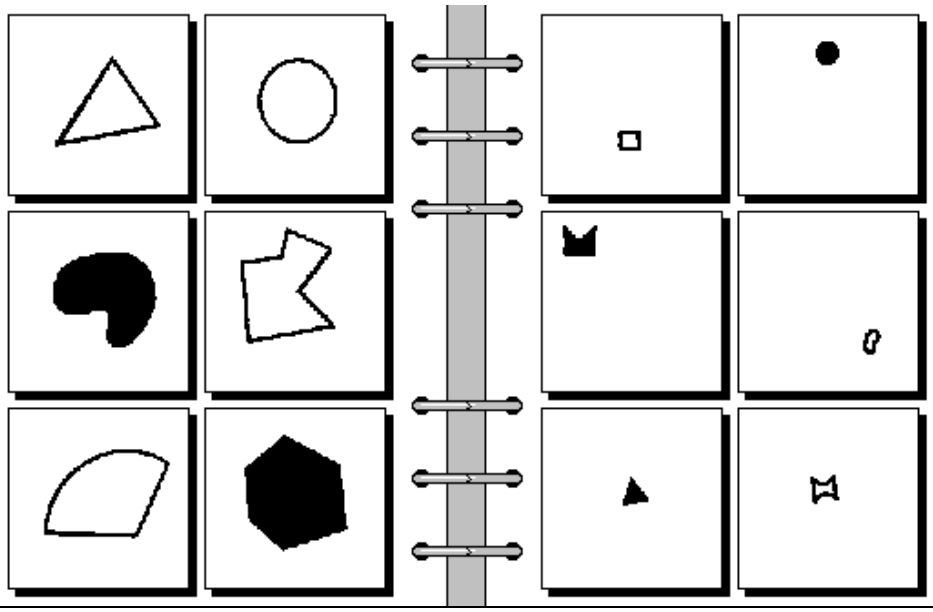
BP1



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/null> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/null> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/null> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/null> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**empty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/null> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/null> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/empty> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/has_infered_doesnothasshape>
<http://.../proprties/empty> ;

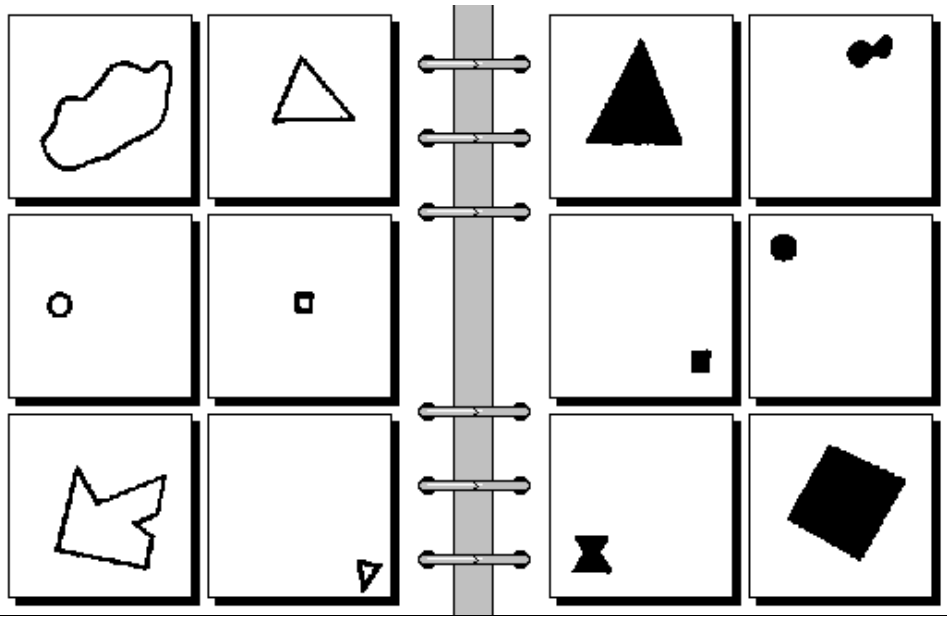
BP2



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_size>
<http://.../proprties/large_figure> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_size>
<http://.../proprties/small_figure> ;

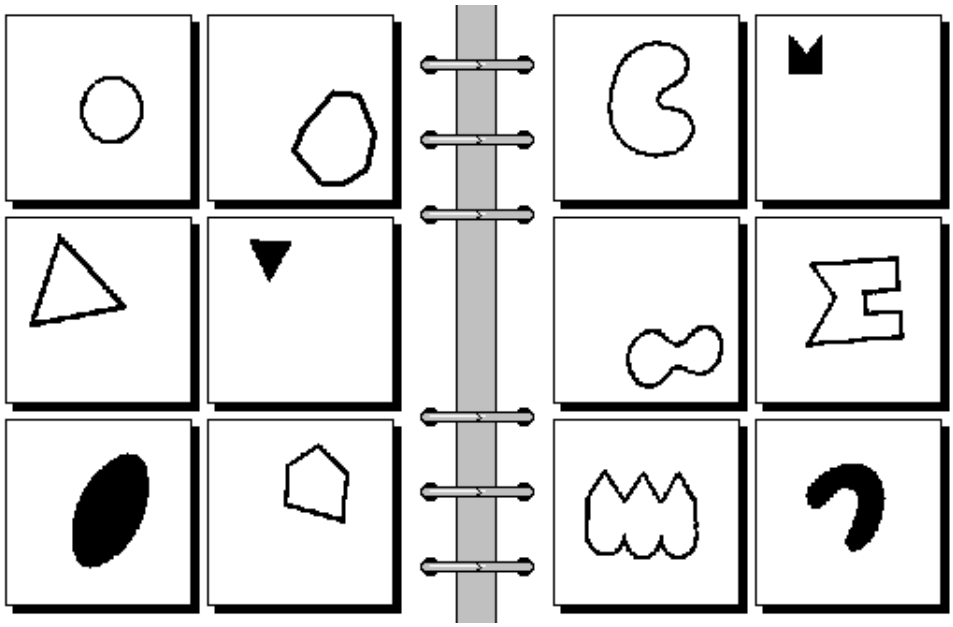
BP3



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**no_filling**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_texture>
<http://.../proprties/no_filling> .

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**dark_filling**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_texture>
<http://.../proprties/dark_filling>.

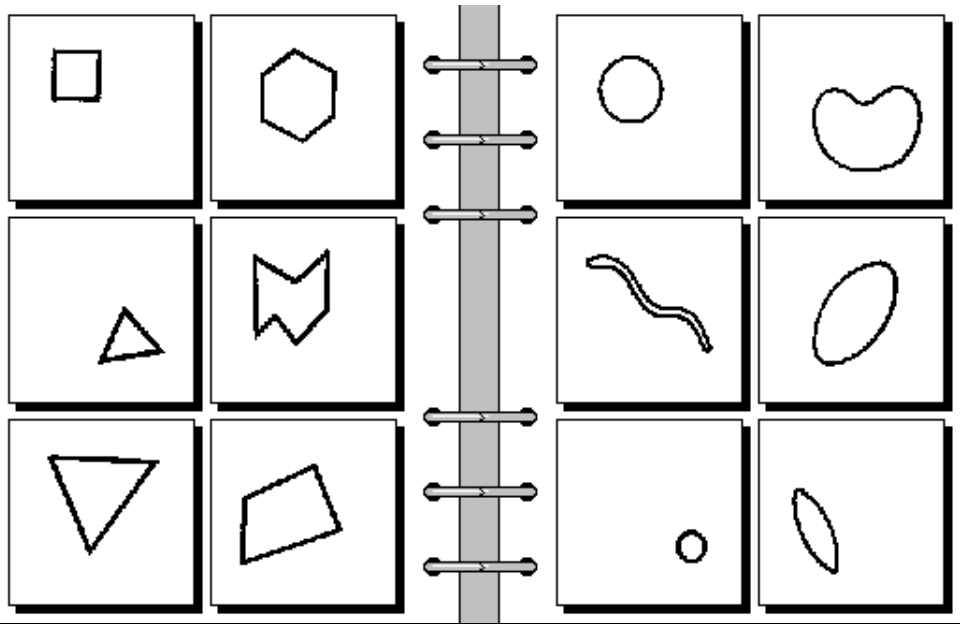
BP4



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**convex_shape**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/convex_shape> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**concave_shape**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/concave_shape> ;

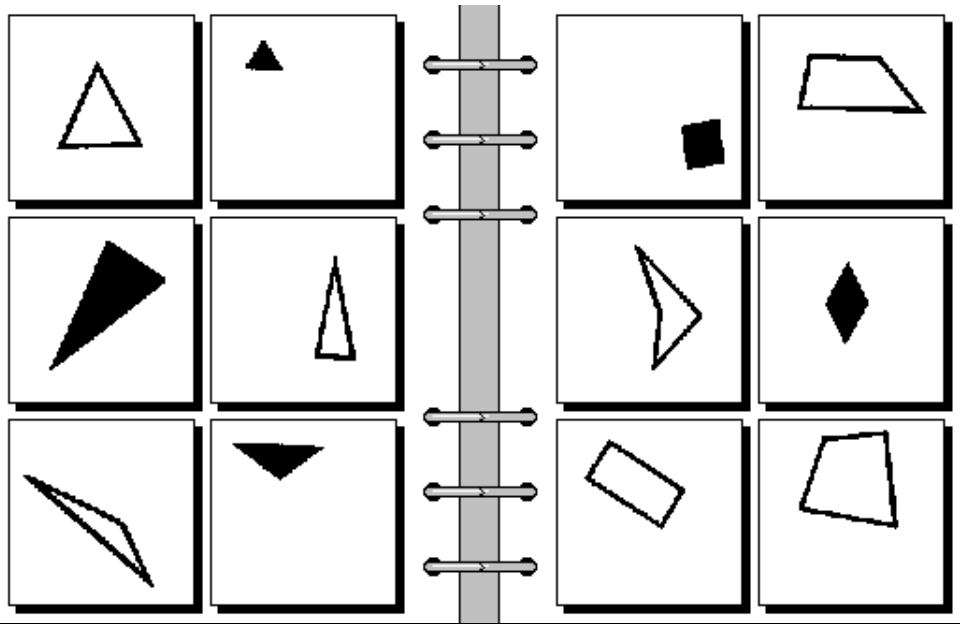
BP5



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**no_filling**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**sharpedges**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/notempty> , <http://.../proprties/**polygon**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/polygon>.

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**no_filling**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**null**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**curvilinear**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/curvilinear> ;

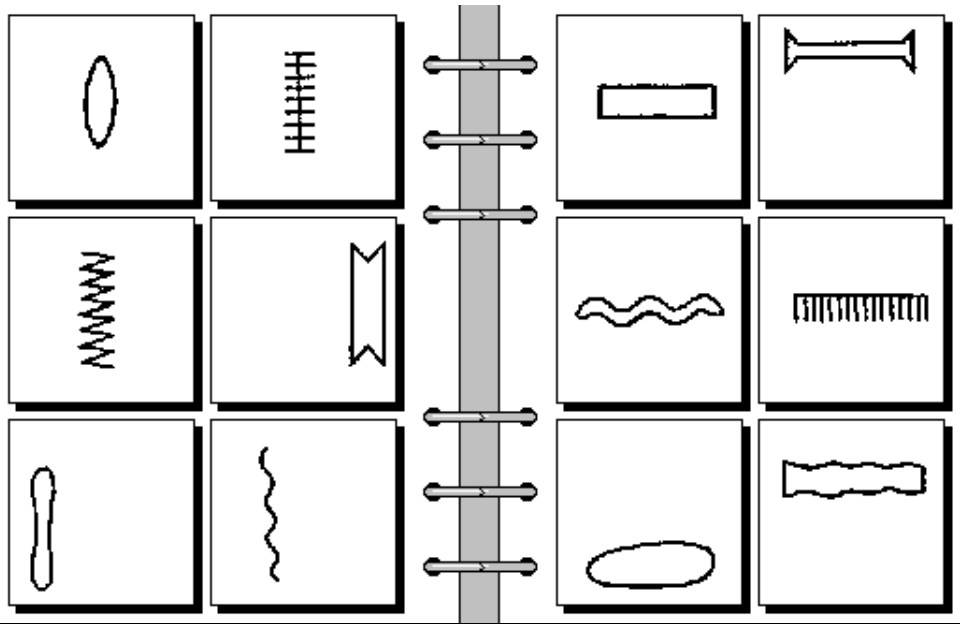
BP6



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**convex_shape**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> , <http://.../proprties/**polygon**> , <http://.../proprties/**triangle**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/triangle> , <http://.../proprties/polygon> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**convex_shape**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**quadrilateral**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/quadrilateral> ;

BP7



<http://.../proprties/left>
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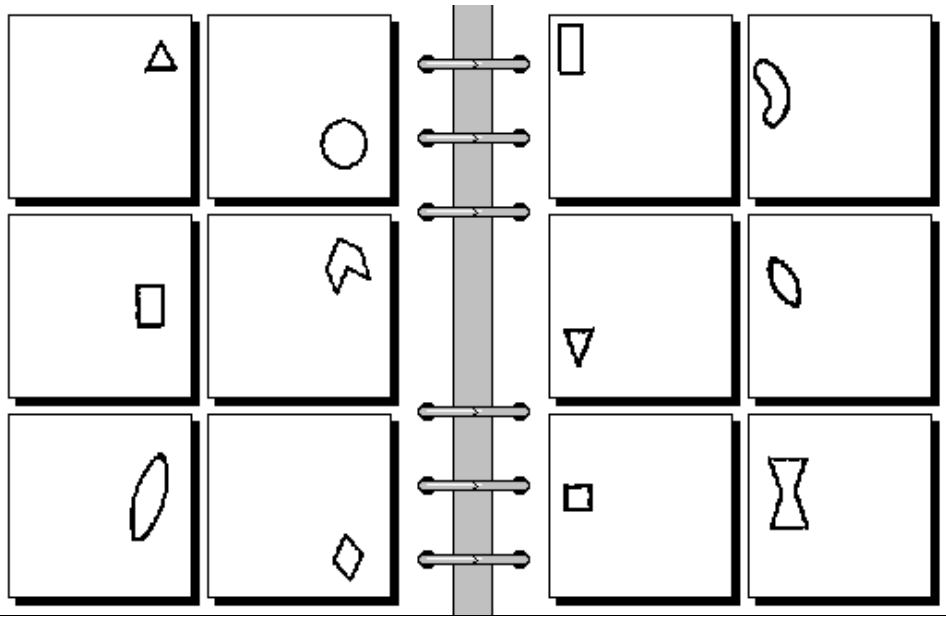
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/elongated_vertically> ;

http://.../proprties/right>
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**elongated_horizontally**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/elongated_horizontally> ;

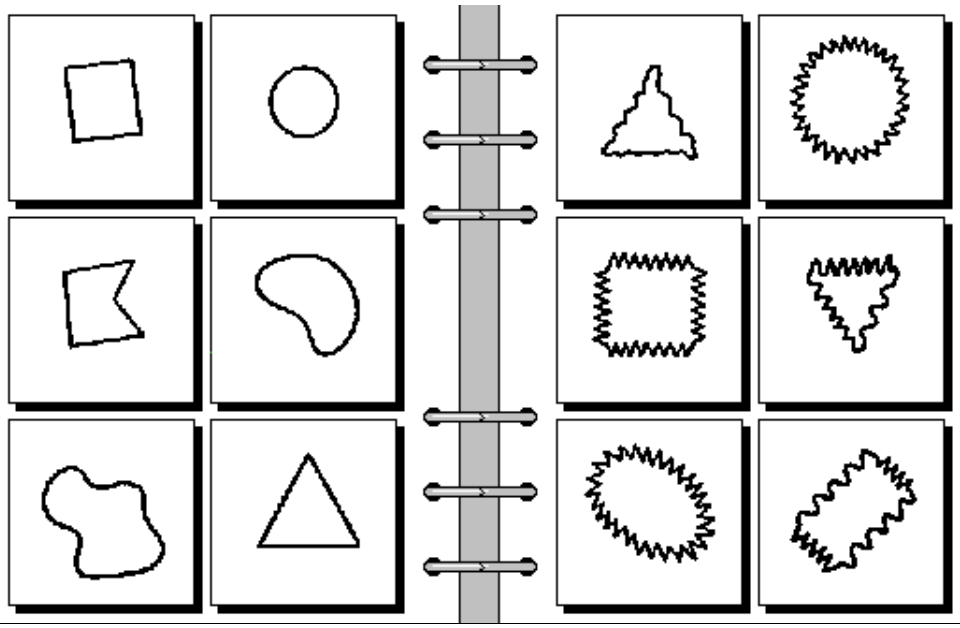
BP8



<http://.../proprties/left>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**no_filling**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**to_right**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_position>
<http://.../proprties/to_right> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**no_filling**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**to_left**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_position>
<http://.../proprties/to_left> ;

BP9



<http://.../proprties/left>
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<http://.../proprties/**notempty**> ;
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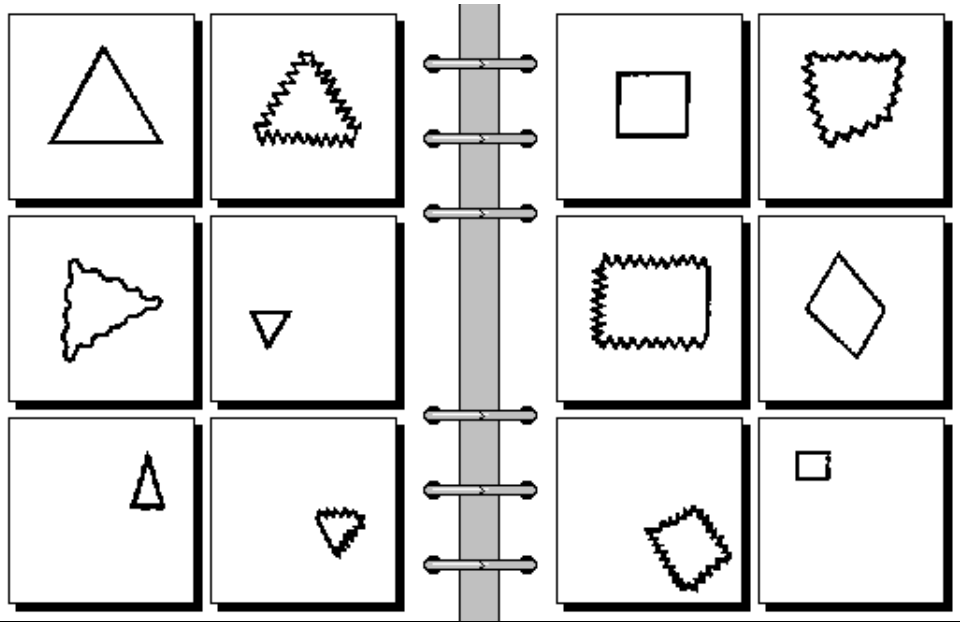
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_doesnothastexture>
<http://.../proprties/wiggly_outline>
<http://.../includes/infered/has_infered_texture>
<http://.../proprties/continious_outlined> .

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**wiggly_outline**> , <http://.../proprties/notempty> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**null**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>

<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_doesnothastexture>
<http://.../proprties/continious_outlined>
<http://.../includes/infered/has_infered_texture>
<http://.../proprties/wiggly_outline>

BP10



<http://.../proprties/left>
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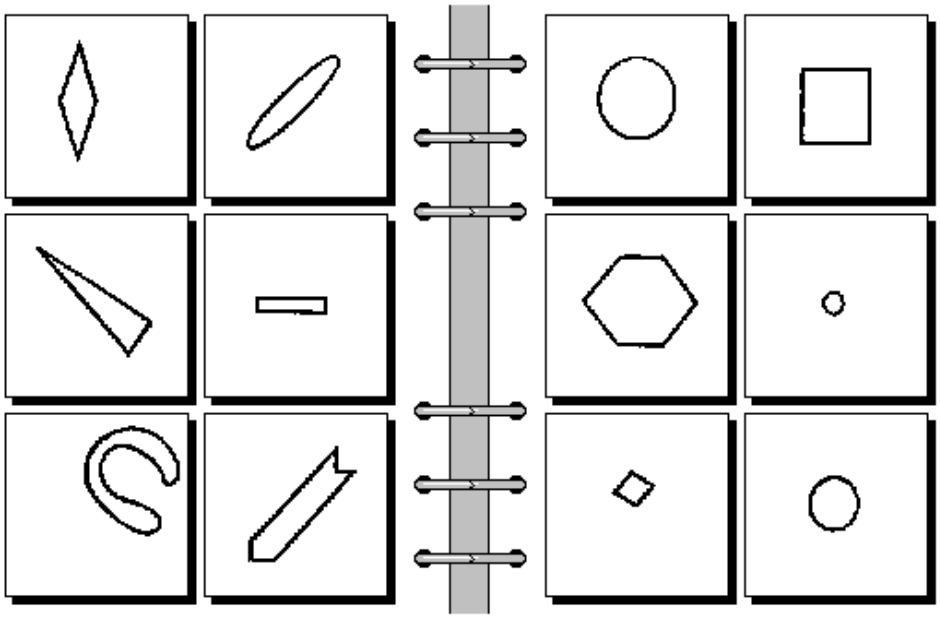
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> , <http://.../proprties/**polygon**> , <http://.../proprties/**triangle**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/triangle> , <http://.../proprties/polygon> .

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>

<http://.../proprties/**quadrilateral**> , <http://.../proprties/**square**> , <http://.../proprties/**polygon**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/quadrilateral> , <http://.../proprties/square> ;

BP11



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<http://.../proprties/**elongated**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
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<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/elongated> ;

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**continious_outlined**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
<http://.../proprties/**null**> ;

<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
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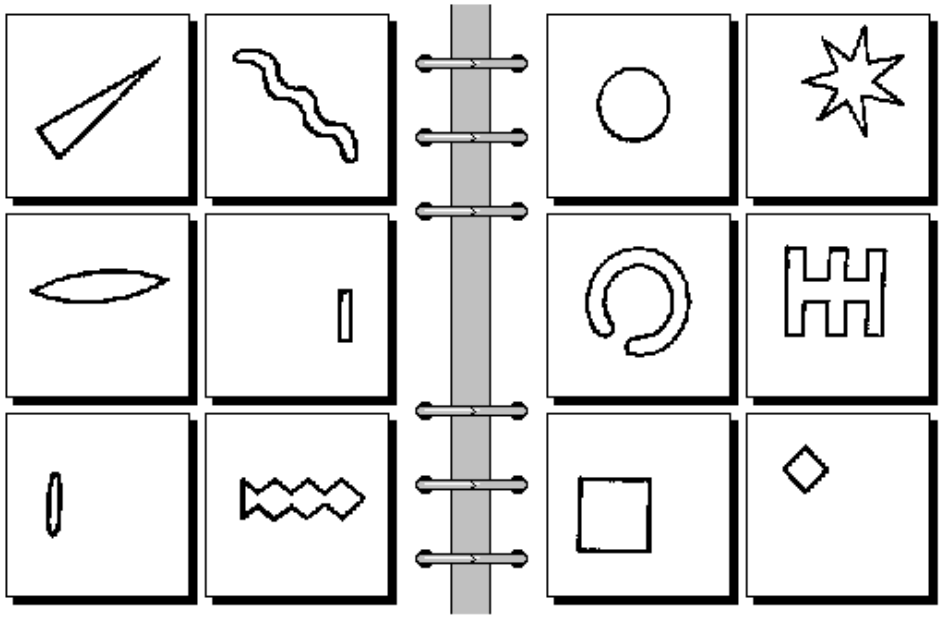
<http://.../proprties/elongated> ;

BP12



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<http://.../proprties/**no_filling**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
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<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/elongated> ;

<http://.../proprties/right>
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<http://.../proprties/**no_filling**> , <http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_character>
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<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
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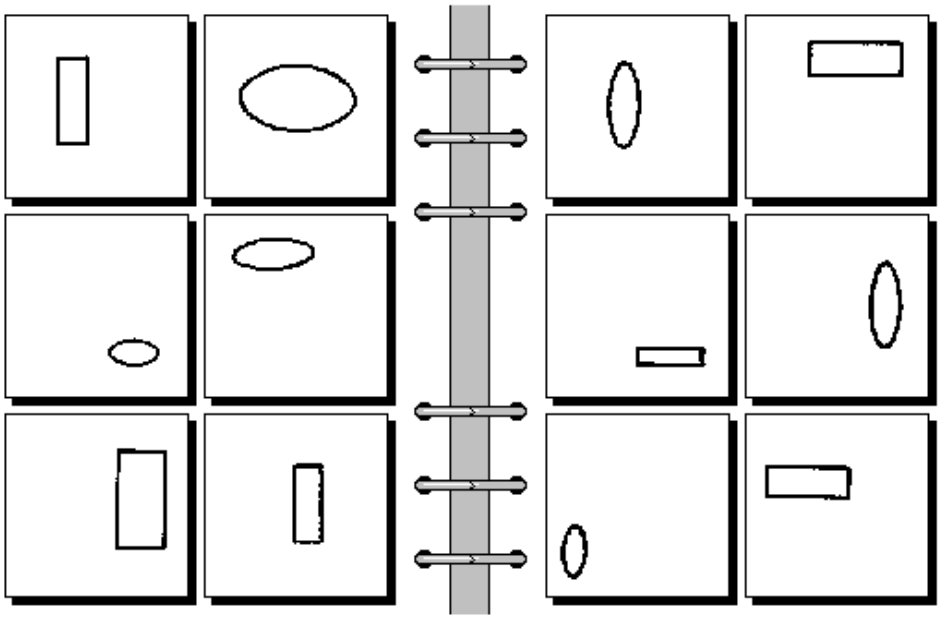
BP13



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<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
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<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_dependent_inference1>
<http://.../proprties/rectangle> ,
<http://.../proprties/elongated_vertically> ;
<http://.../includes/infered/has_dependent_inference2>

<http://.../proprties/oval> **,**
<http://.../proprties/elongated_horizontally> ;

<http://.../proprties/right>
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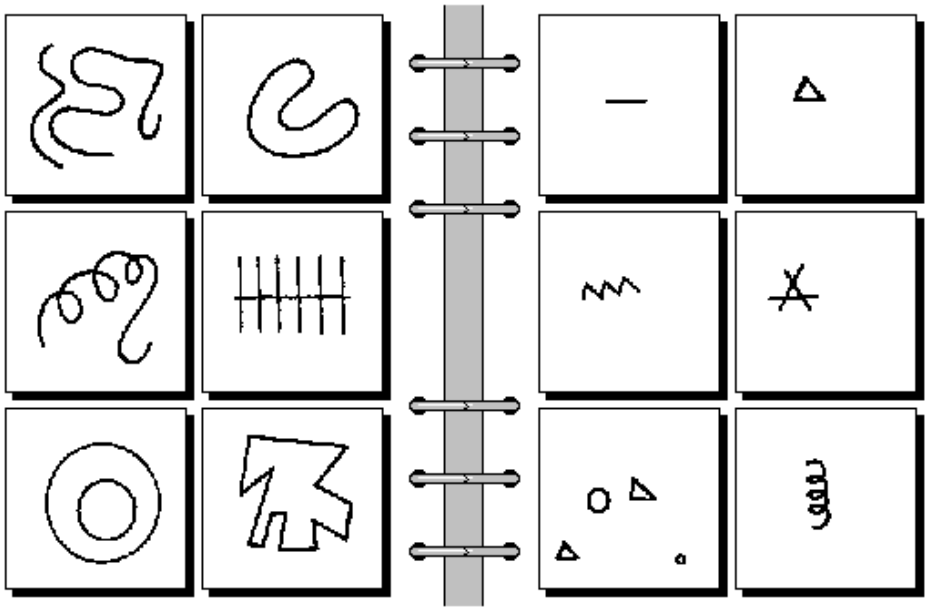
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/has_dependent_inference1>
<http://.../proprties/oval> , <http://.../proprties/elongated_vertically> ;
<http://.../includes/infered/has_dependent_inference2>
<http://.../proprties/rectangle> **,**
<http://.../proprties/elongated_horizontally> ;

BP14



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<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;

<http://.../includes/infered/has_infered_size>
<http://.../proprties/large_figure>

<http://.../proprties/right>
<http://.../includes/infered/alsoconsists_of_texture>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
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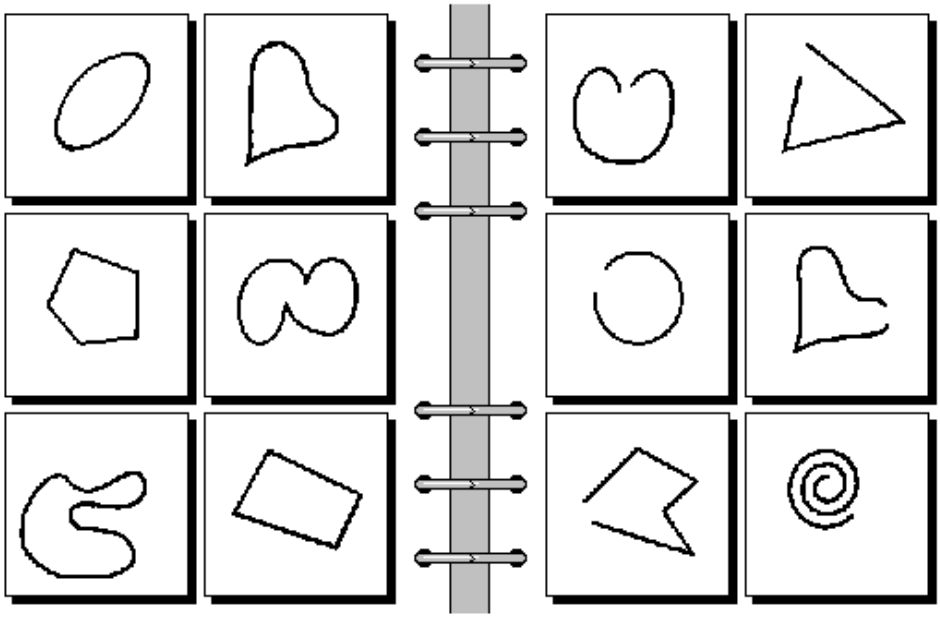
BP15



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<http://.../proprties/**middle**> ;
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<http://.../proprties/**notempty**> ;
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<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_texture>
<http://.../proprties/closed_shaped>

<http://.../proprties/right>
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<http://.../includes/infered/consists_of_character>

<http://.../proprties/**null**> ;
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<http://.../proprties/**1**> ;
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<http://.../proprties/**large_figure**> ;
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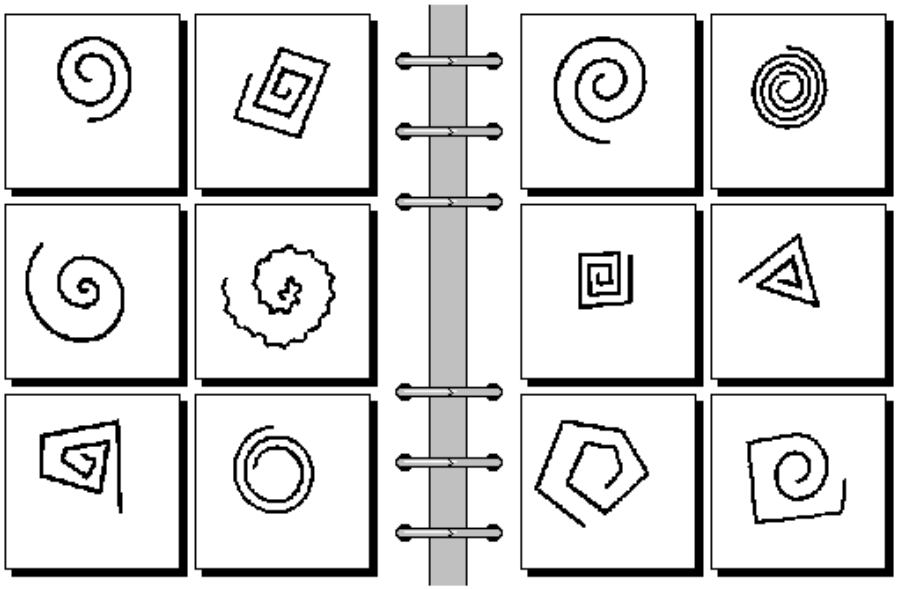
BP16



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<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/counterclockwise> ;

<http://.../proprties/right>
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<http://.../proprties/**clockwise**> ;
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<http://.../proprties/**1**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
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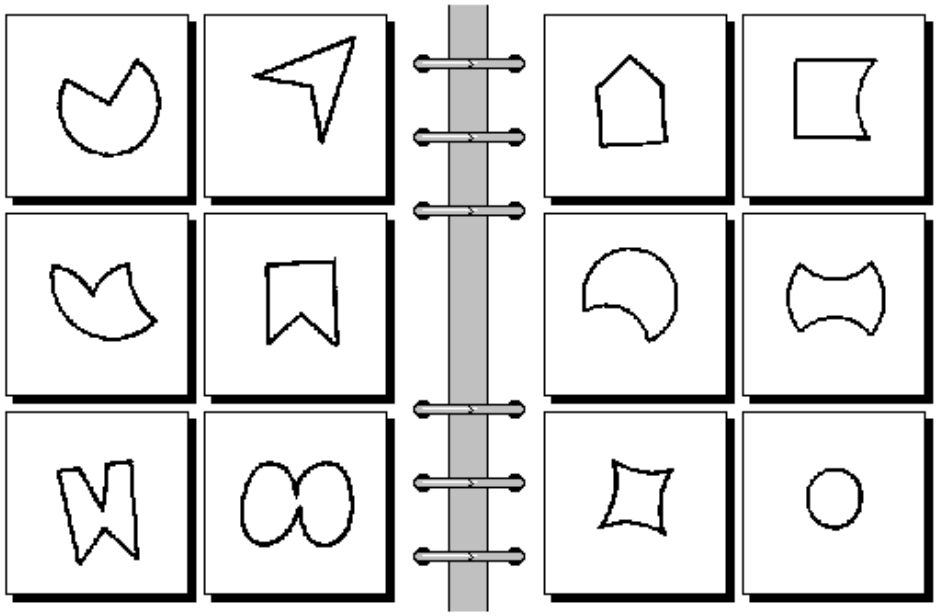
BP17



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<http://.../proprties/**middle**> ;
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<http://.../proprties/**large_figure**> ;
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<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/concave_shape> ;

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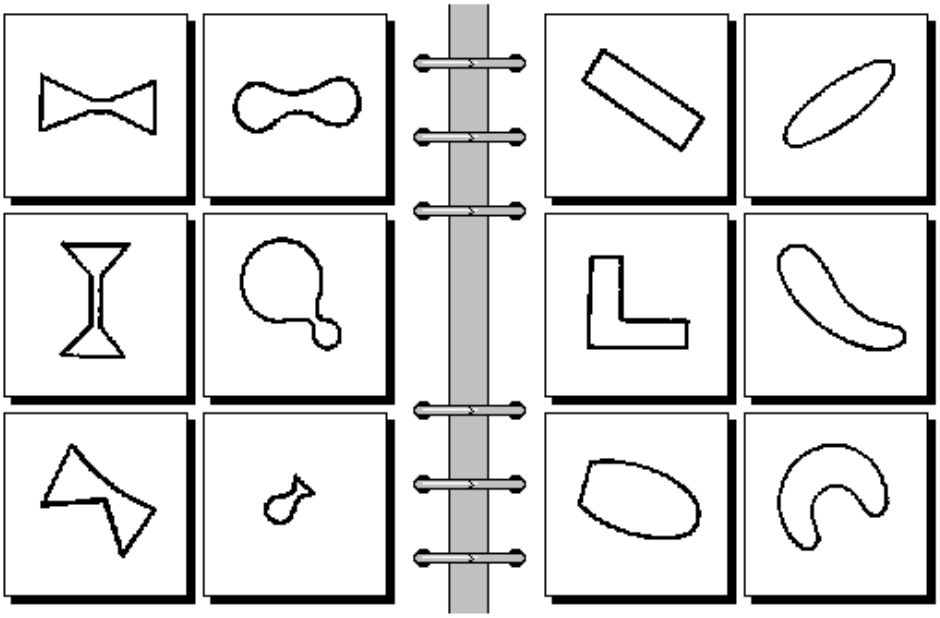
BP18



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<http://.../proprties/**middle**> ;
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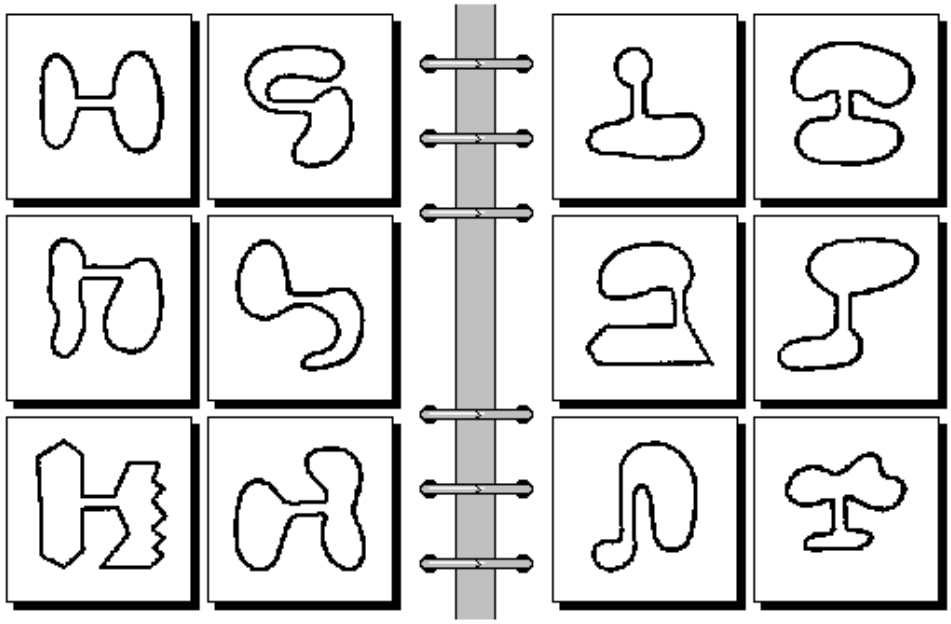
BP19



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<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/**elongated_vertically**> ;
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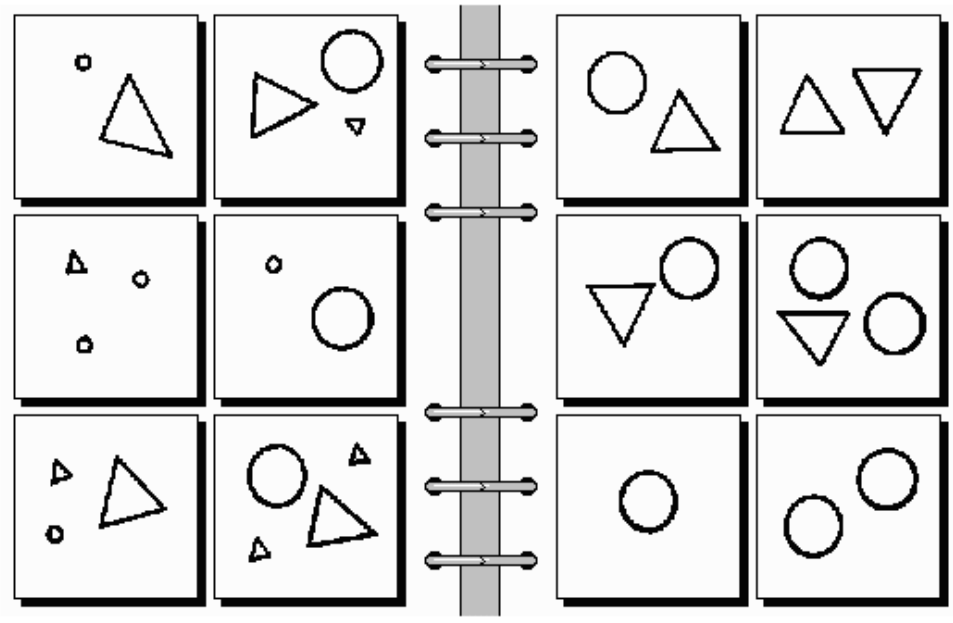
BP21



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<http://.../proprties/**convex_shape**> ;
<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
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<http://.../proprties/**large_and_small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/large_and_small_figure> ;

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<http://.../proprties/**large_figure**> ;
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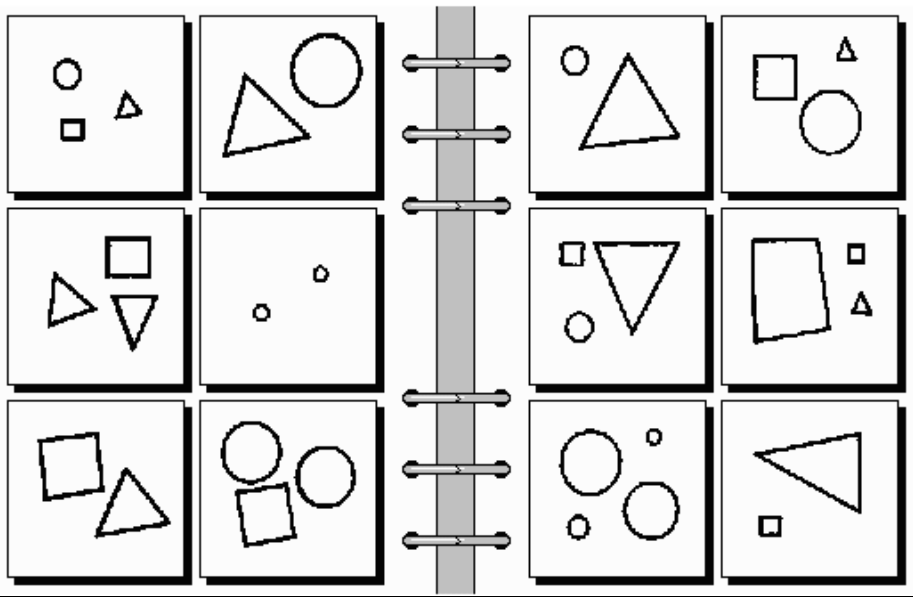
BP22



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<http://.../proprties/**large_and_small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_size>
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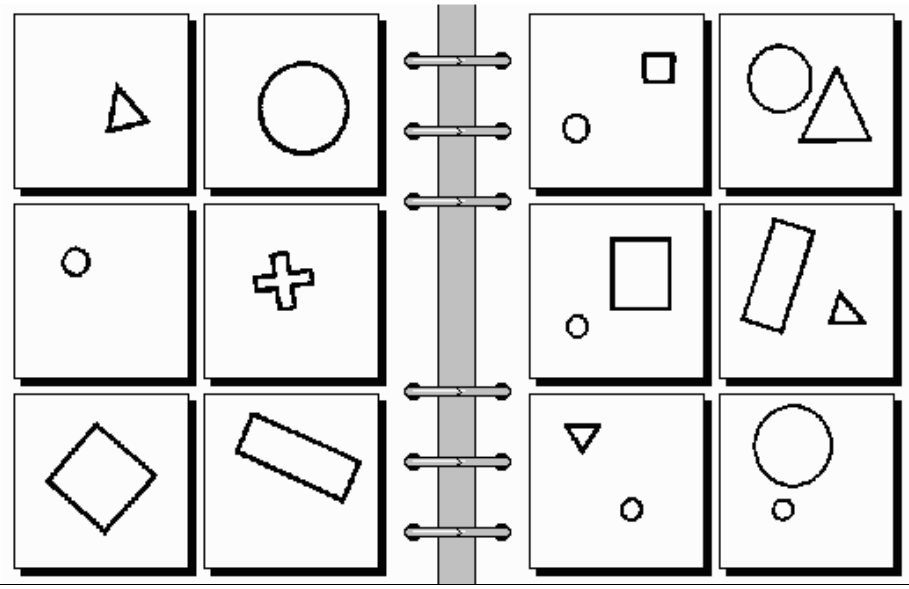
BP23



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<http://.../proprties/**convex_shape**> ;
<http://.../includes/infered/consists_of_count>
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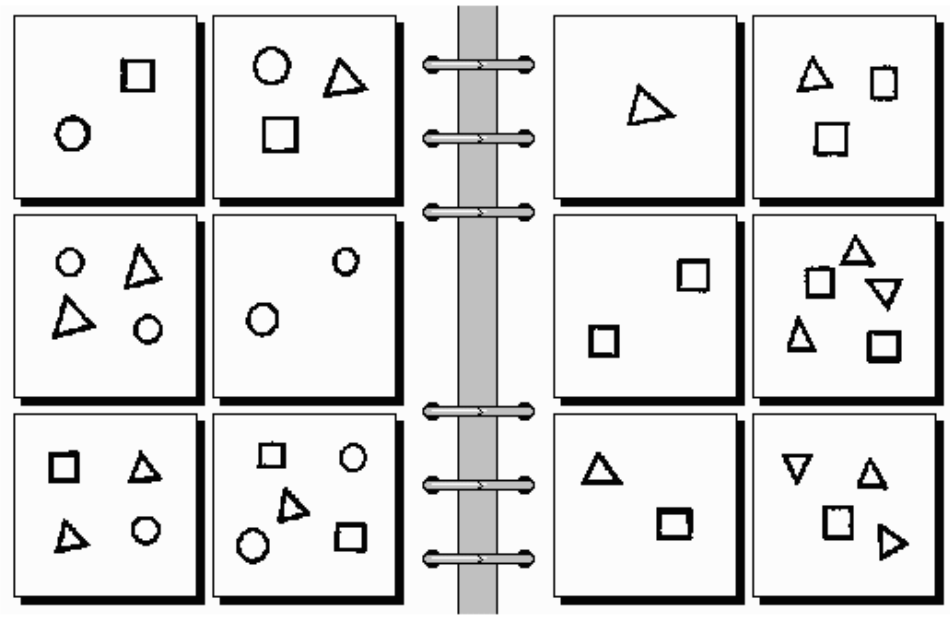
BP24



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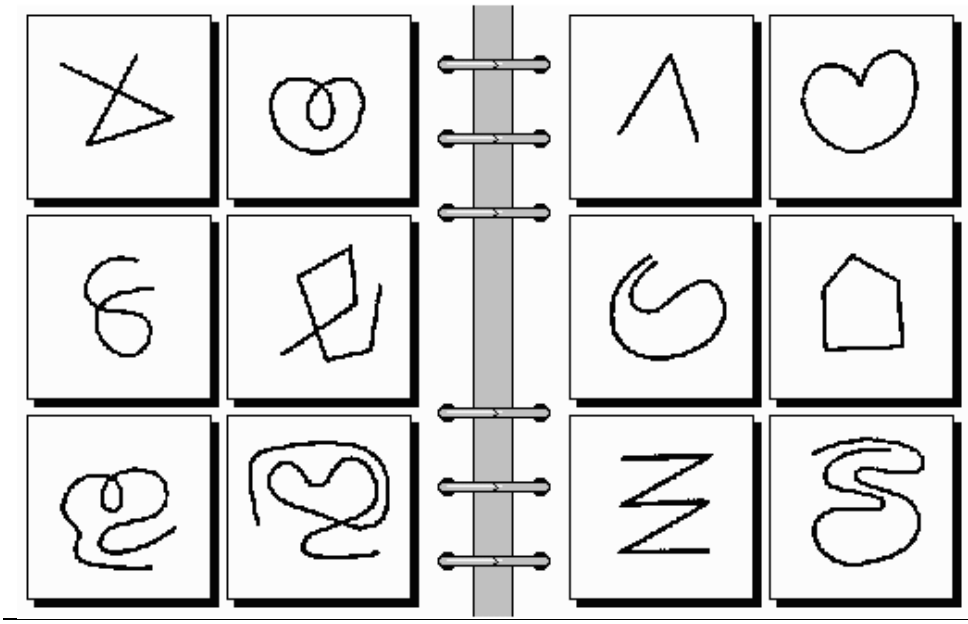
BP30



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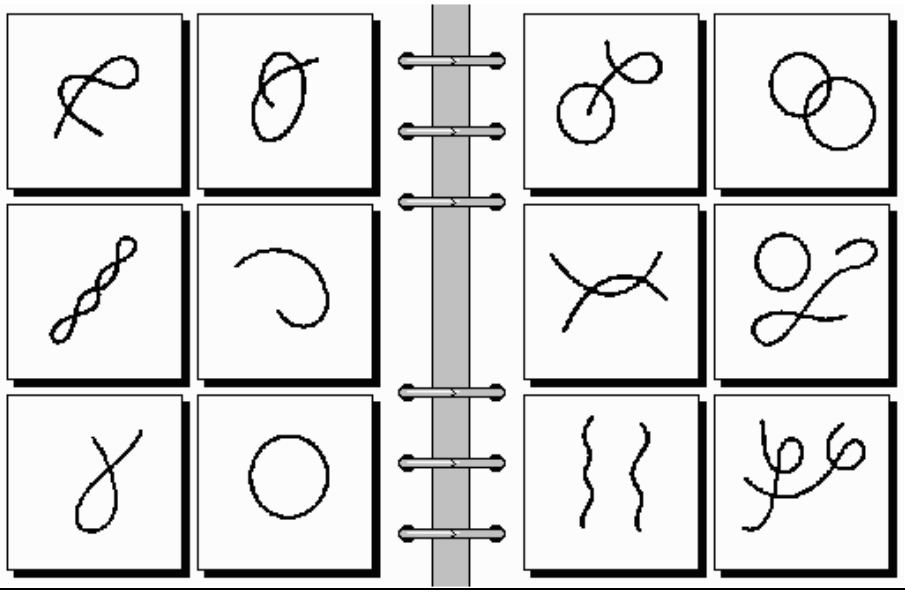
BP31



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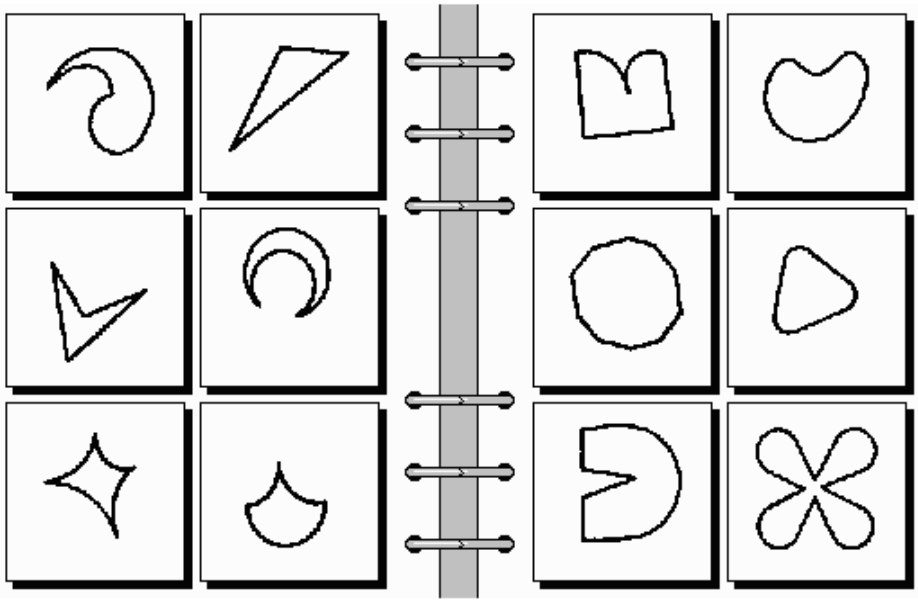
BP32



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<http://.../proprties/**large_figure**> ;
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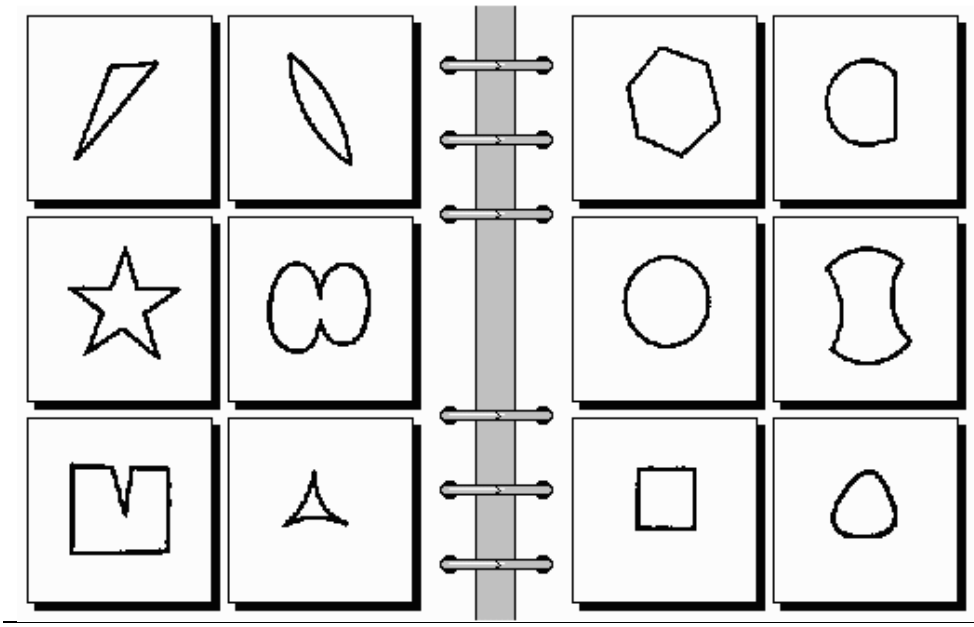
BP33



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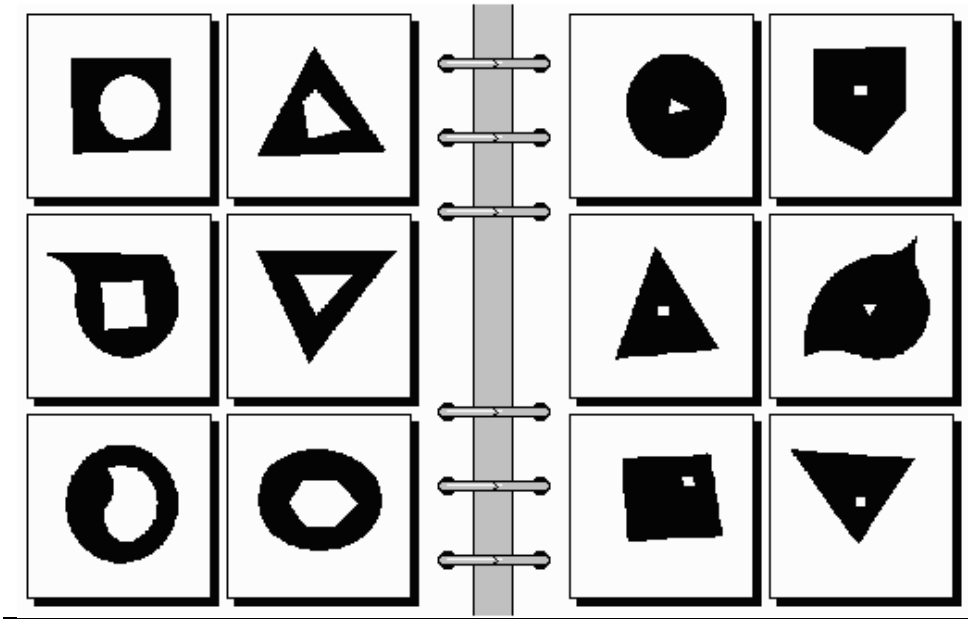
BP34



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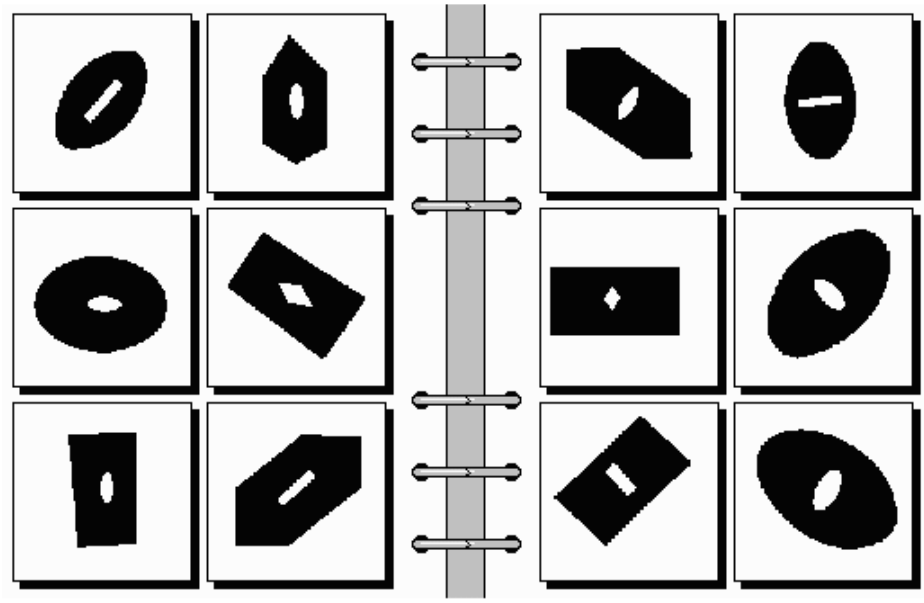
BP35



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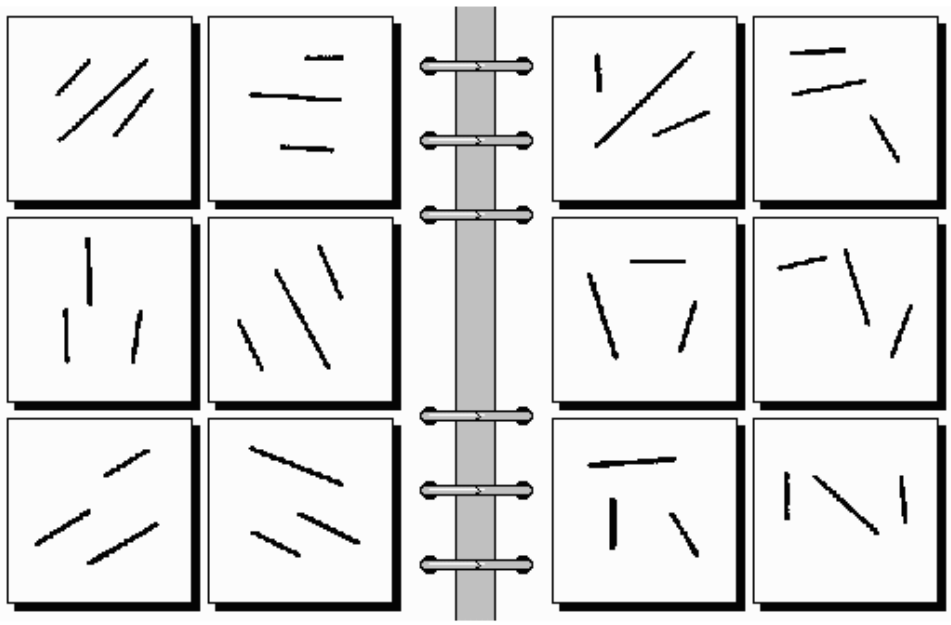
BP39



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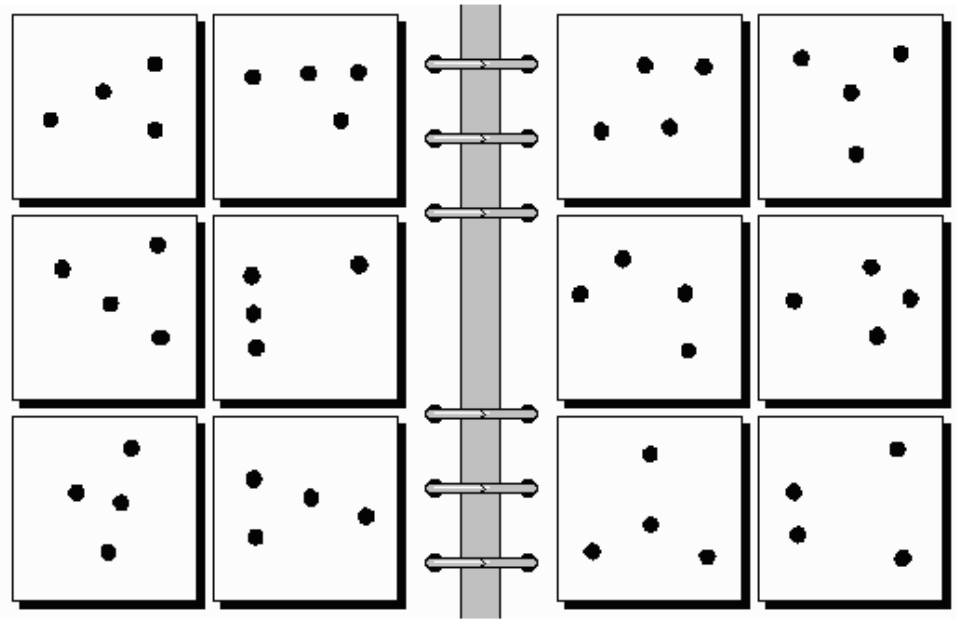
BP40



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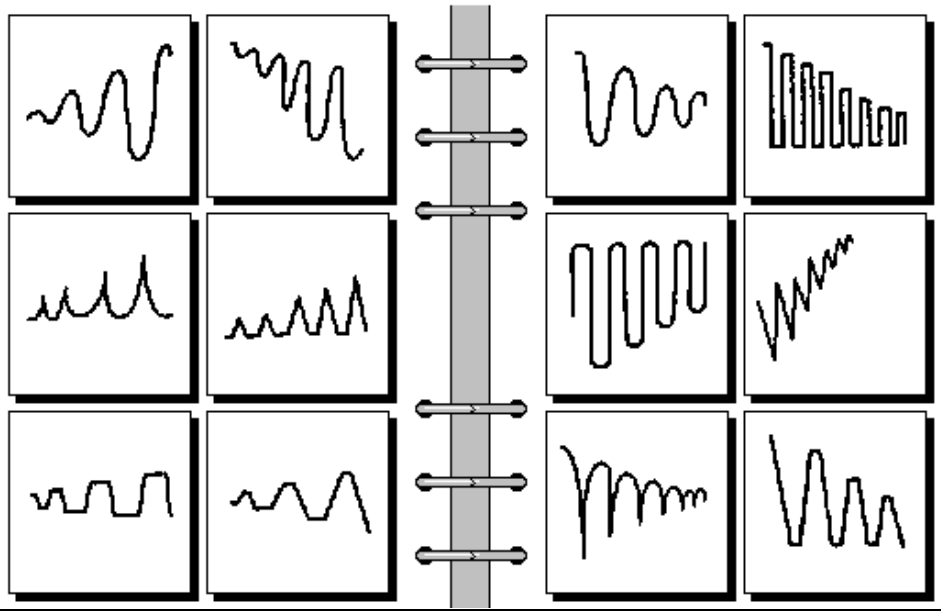
BP43



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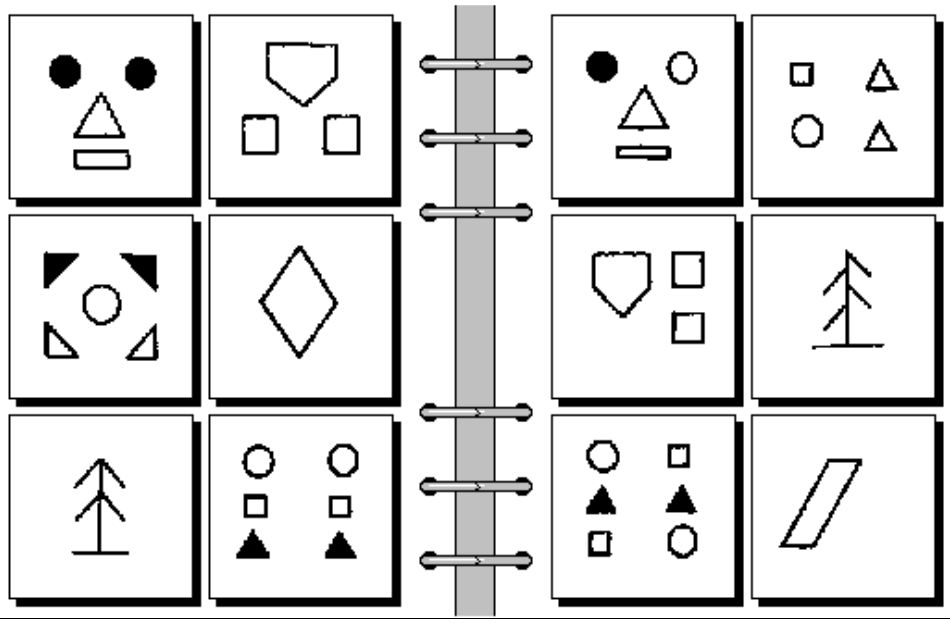
BP50



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<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**uneven_shapes**> ;
<http://.../includes/infered/has_infered_characteristics>
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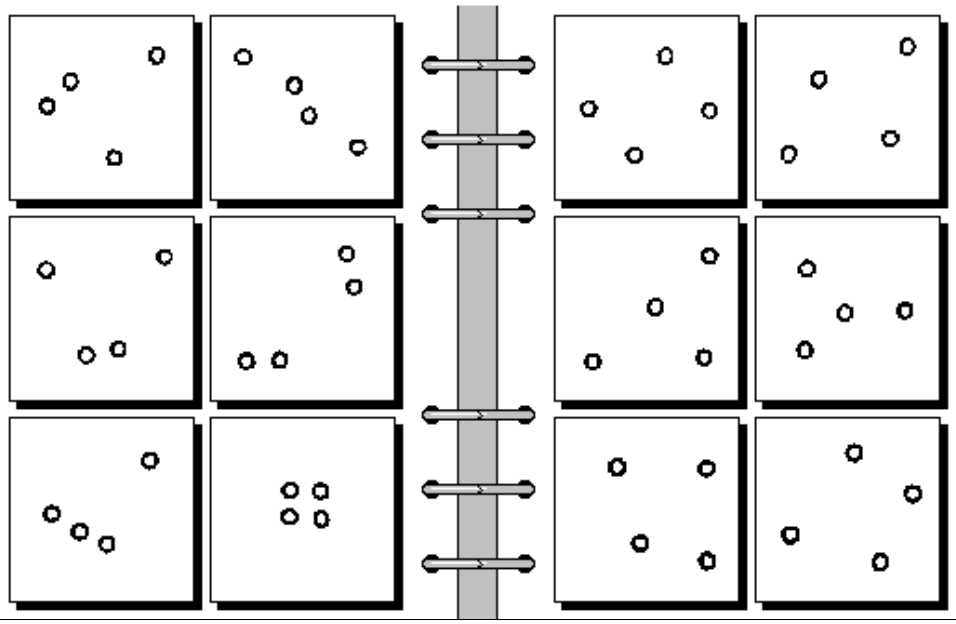
BP51



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<http://.../proprties/**4**> ;
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<http://.../proprties/**small_figure**> ;
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<http://.../proprties/**null**> ;
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<http://.../proprties/**small_figure**> ;
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<http://.../proprties/**closed_shaped**> ;
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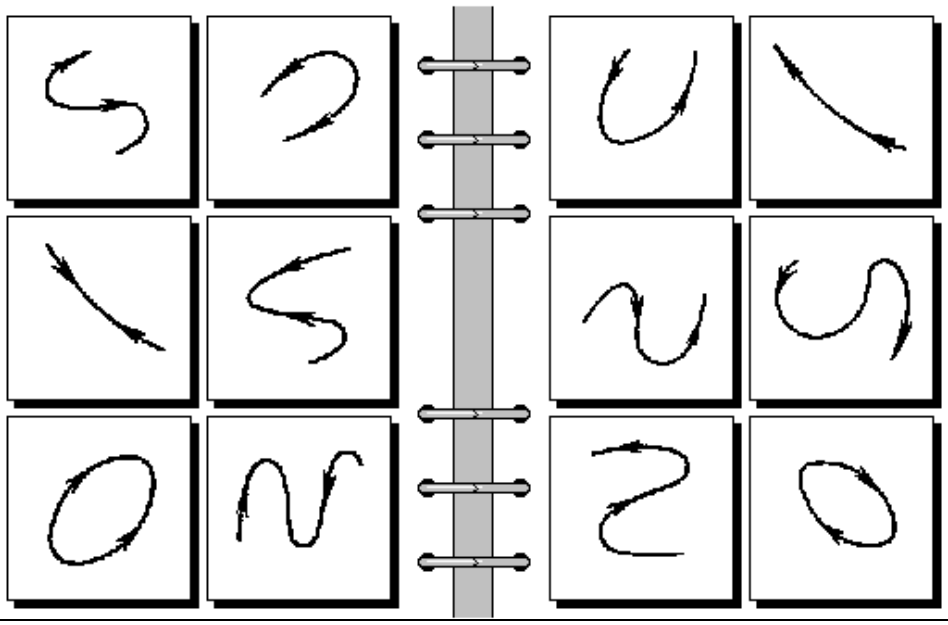
BP52



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<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**open_shaped**> ;
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<http://.../proprties/opositedirection> ;

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<http://.../proprties/**samedirection**> ;
<http://.../includes/infered/consists_of_count>
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<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**line**> , <http://.../proprties/**notempty**> ;

<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
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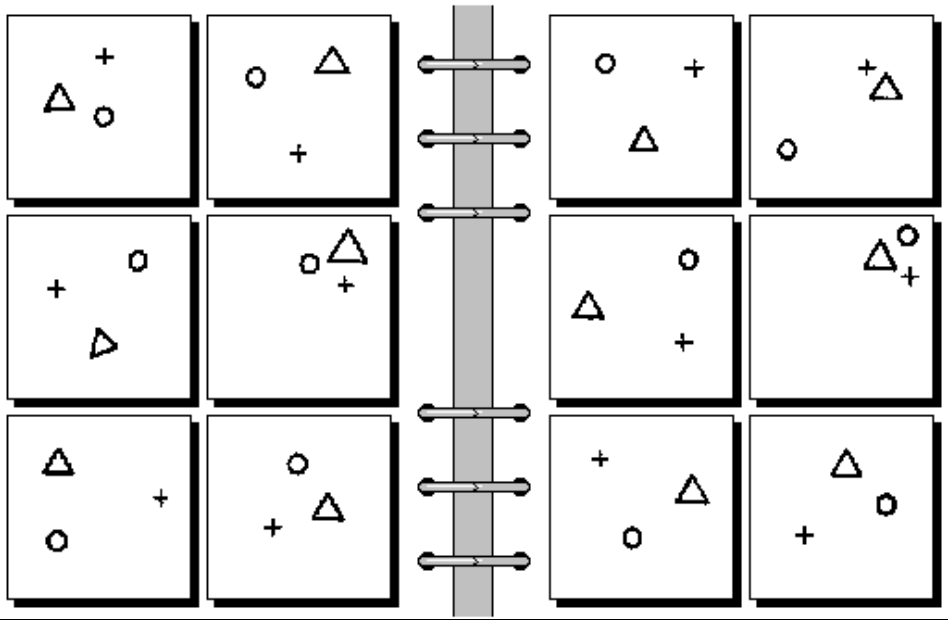
BP54



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<http://.../includes/infered/consists_of_position>
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<http://.../proprties/**notempty**> , <http://.../proprties/**circle**> , <http://.../proprties/**triangle**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**null**> ;
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<http://.../proprties/counterclockwise> ;

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<http://.../proprties/**triangle**> , <http://.../proprties/**notempty**> , <http://.../proprties/**circle**> ;
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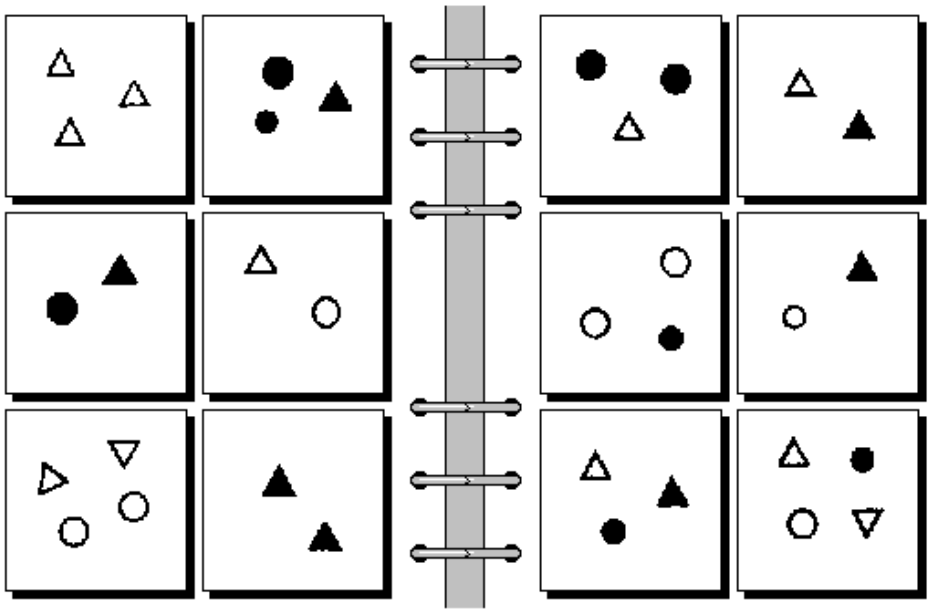
BP56



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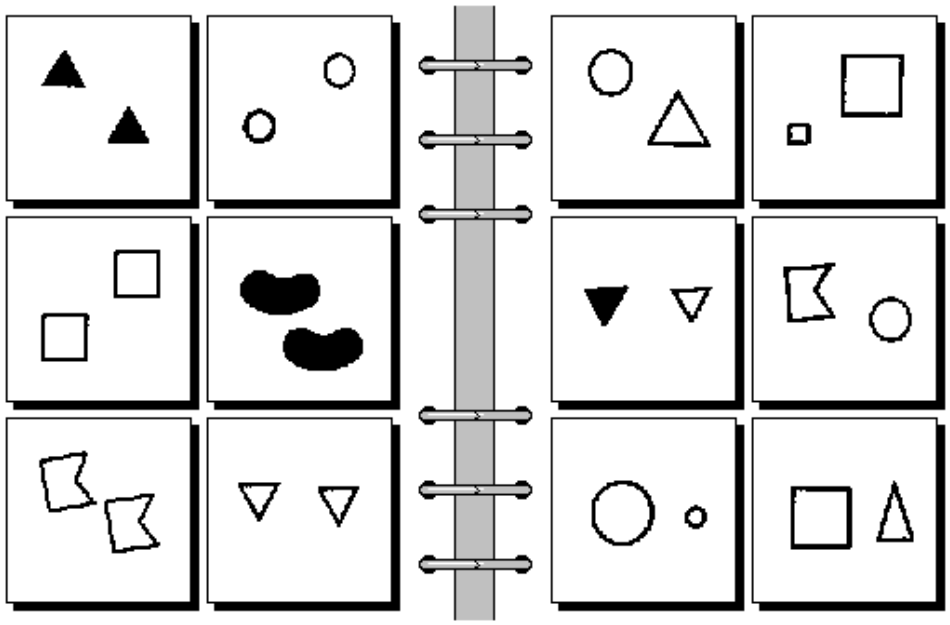
BP57



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<http://.../proprties/**2**> ;
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<http://.../proprties/**closed_shaped**> ;
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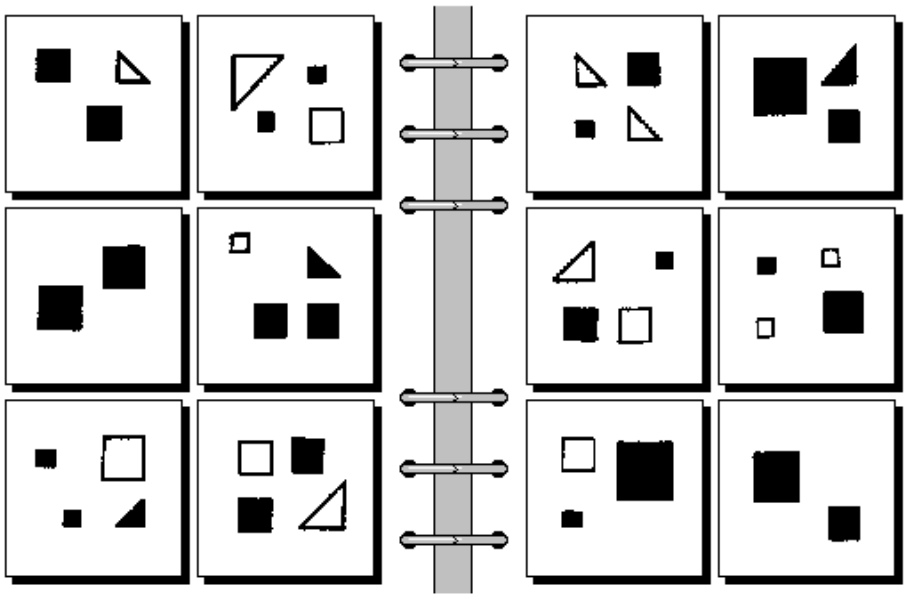
BP58



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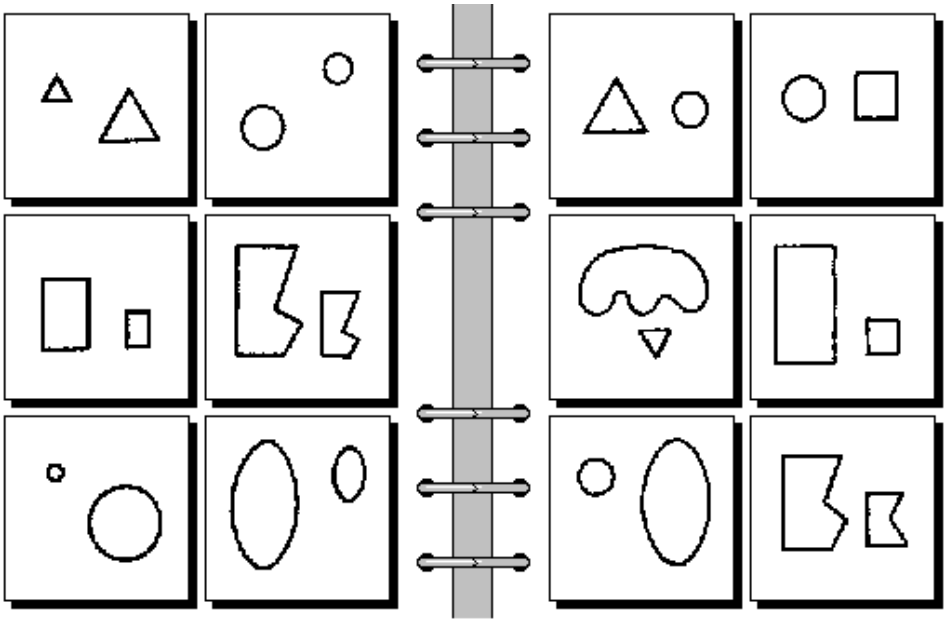
BP59



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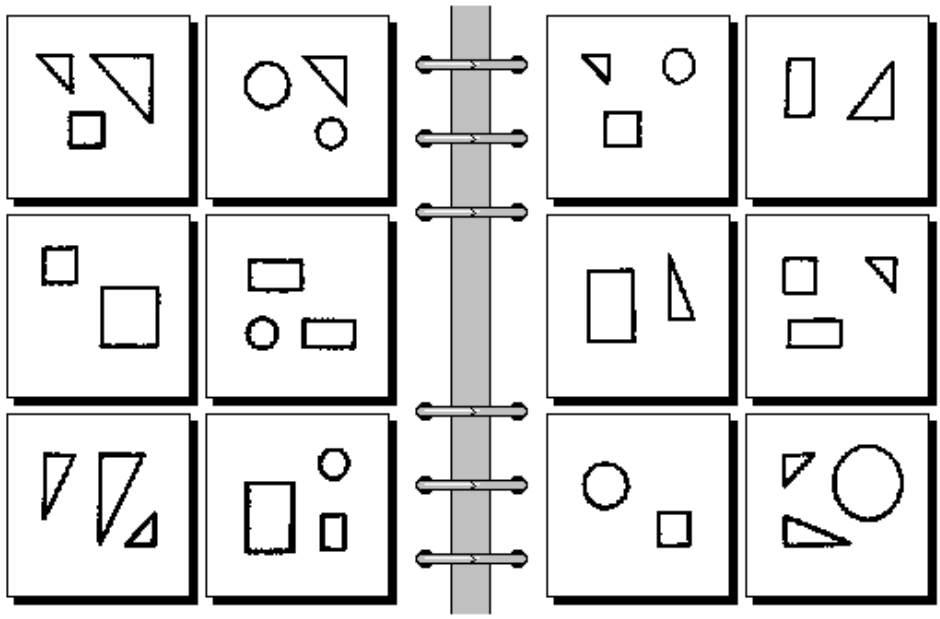
BP60



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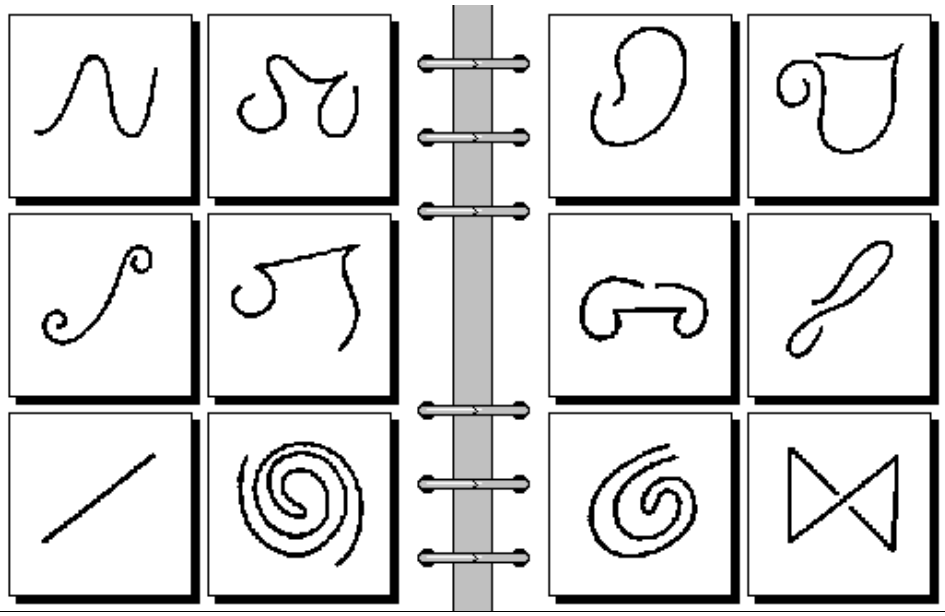
BP62



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<http://.../proprties/ends_far> ;

<http://.../proprties/right>
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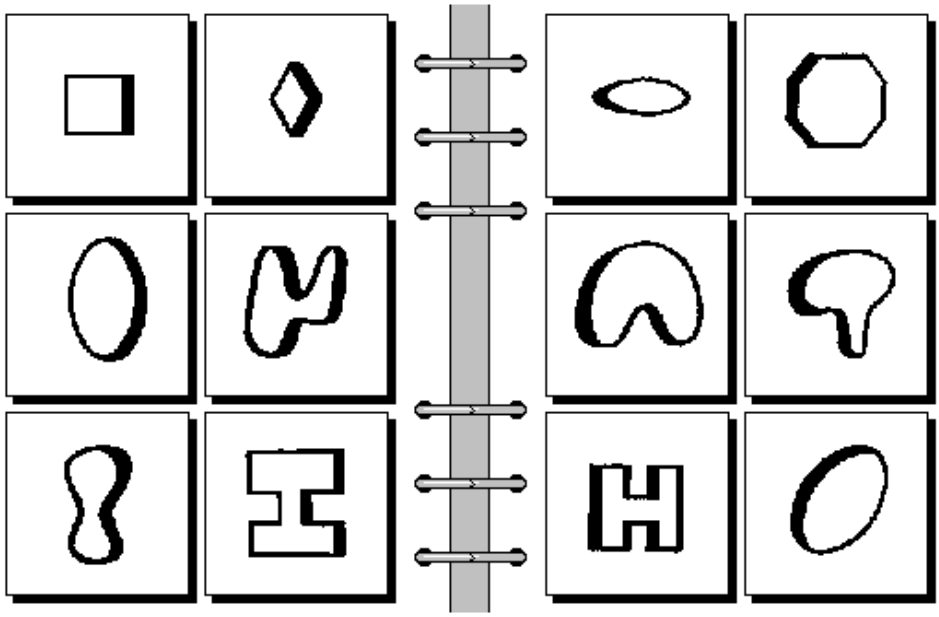
BP63



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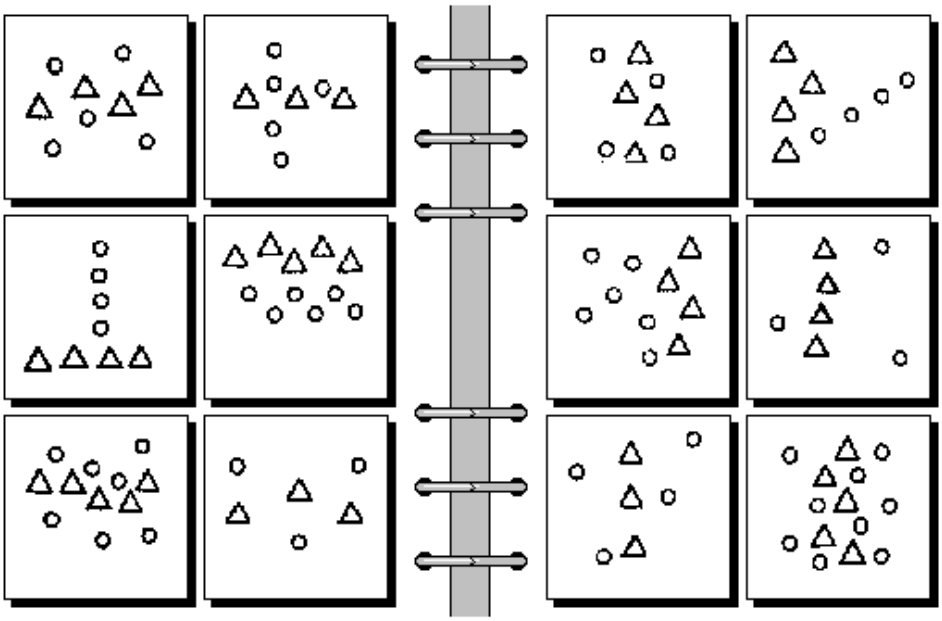
BP65



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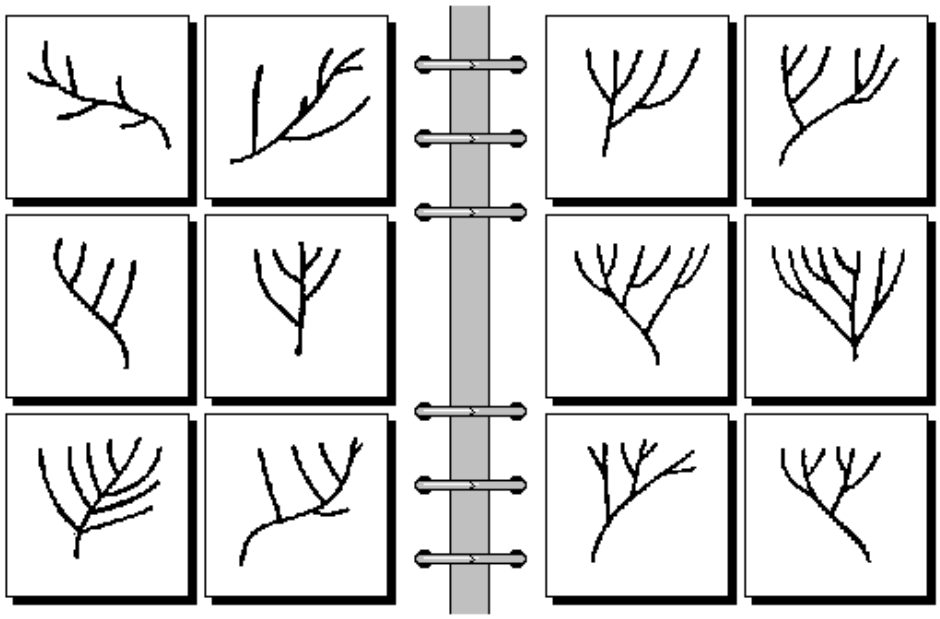
BP70



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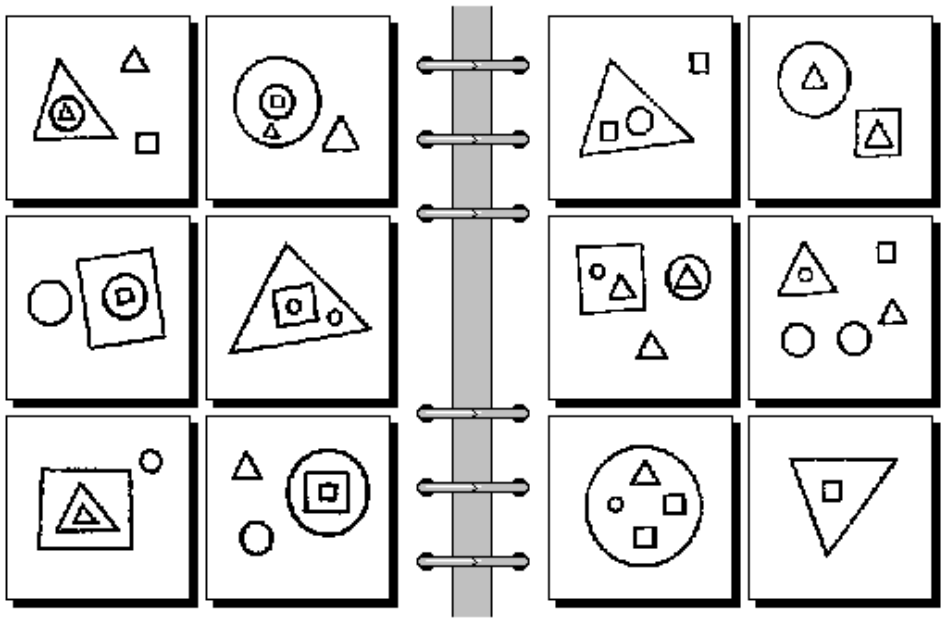
BP71



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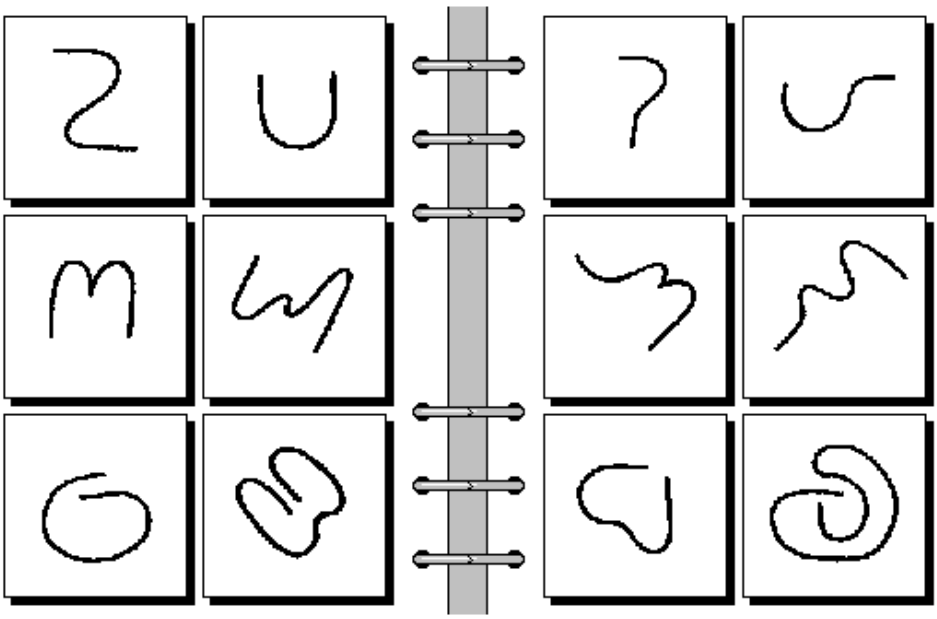
BP72



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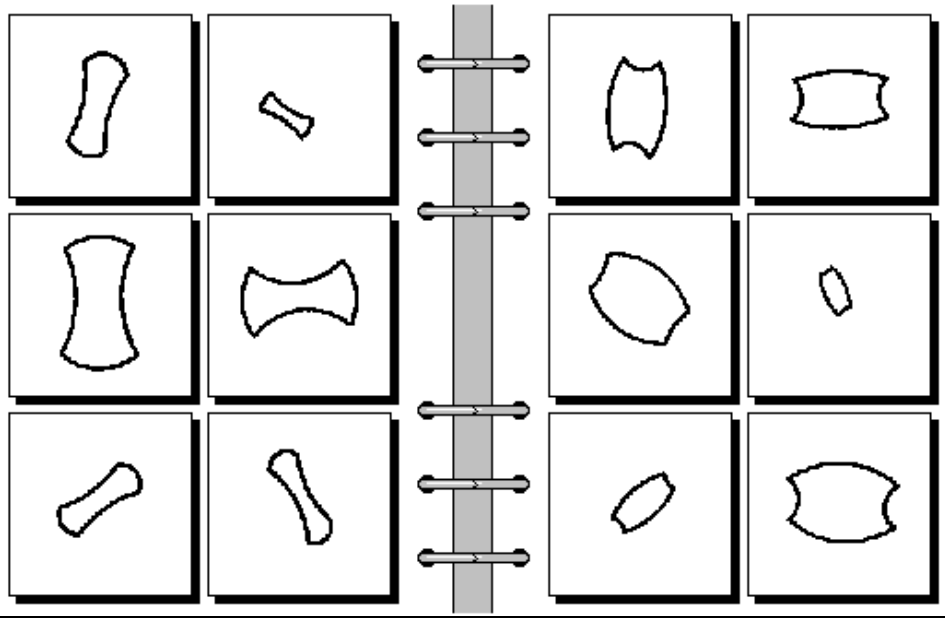
BP76



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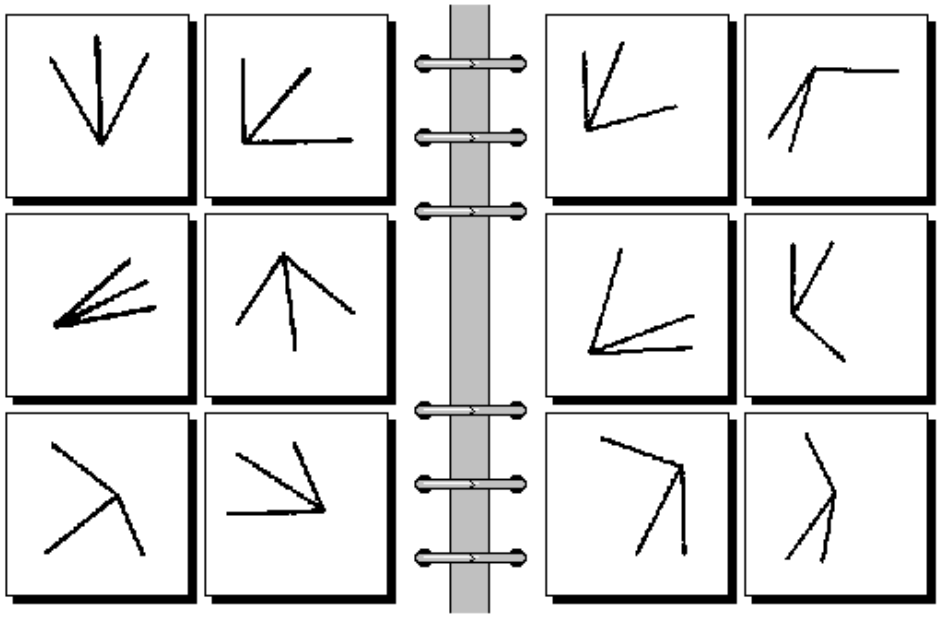
BP77



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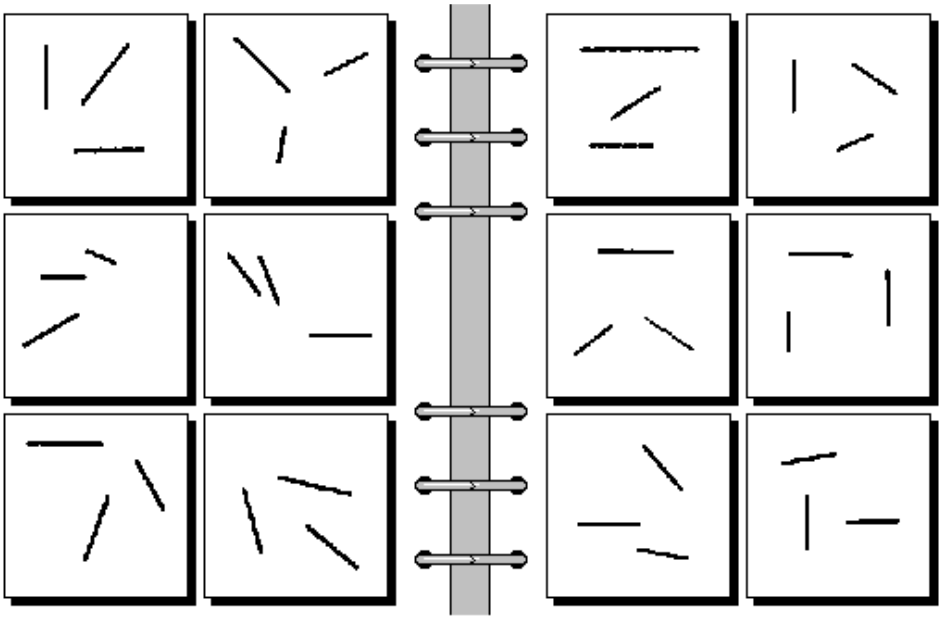
BP78



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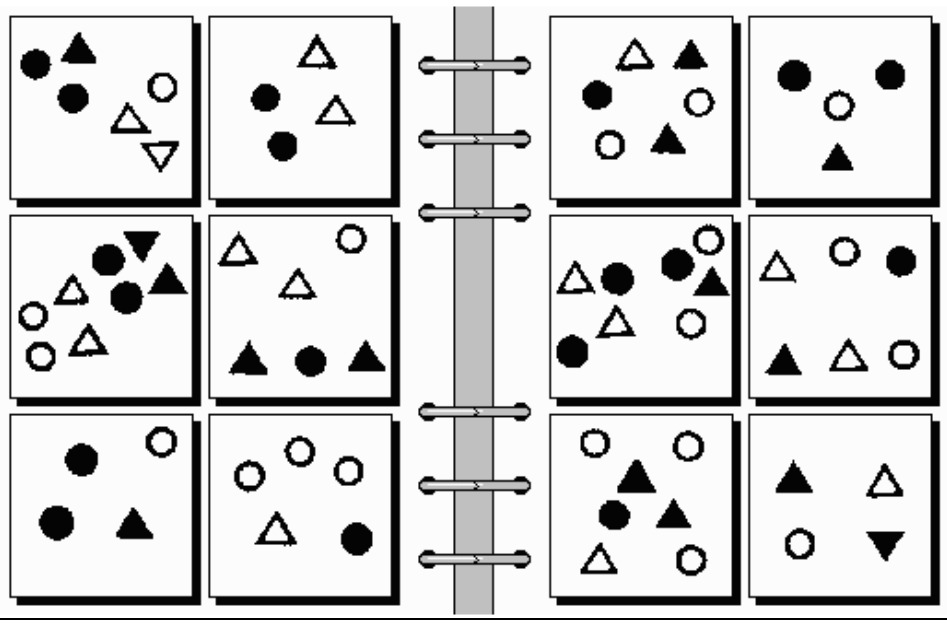
BP81



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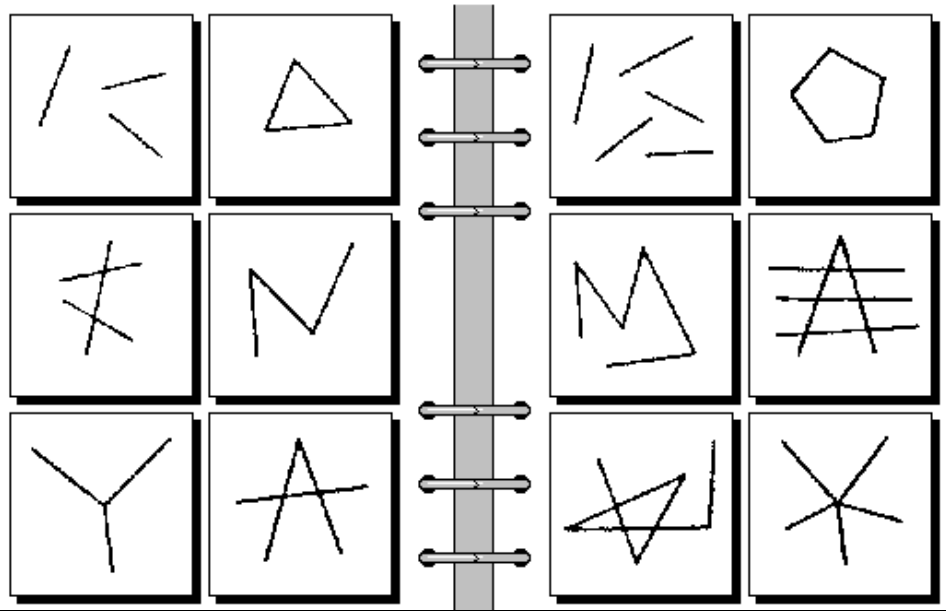
BP85



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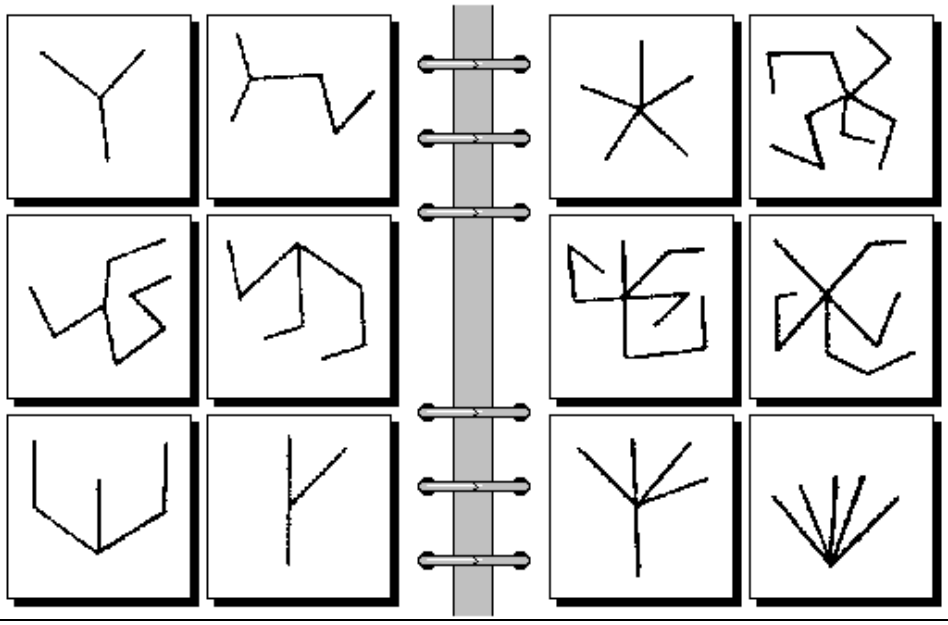
BP86



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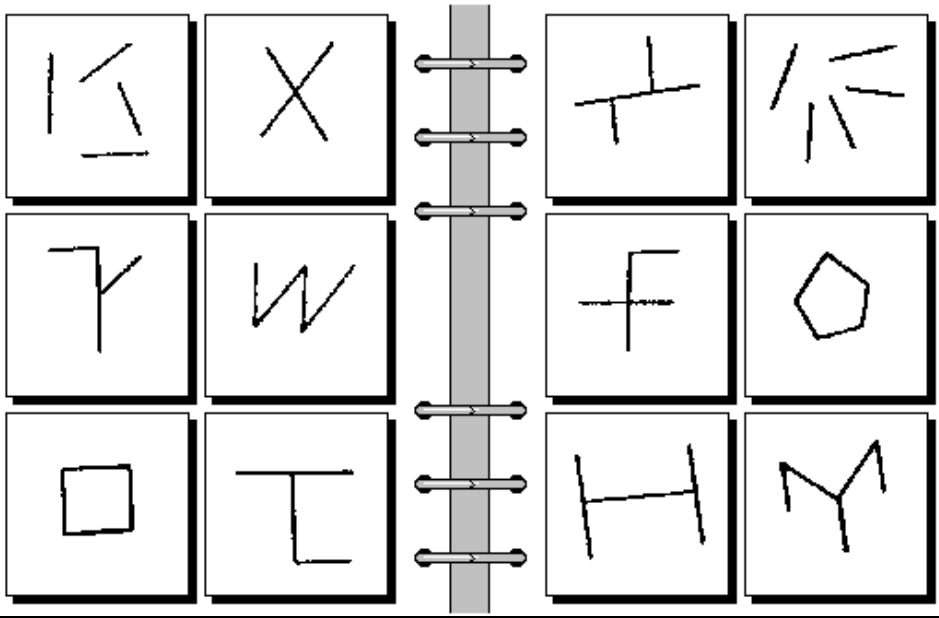
BP87



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<http://.../proprties/**line**> , <http://.../proprties/**notempty**> ;
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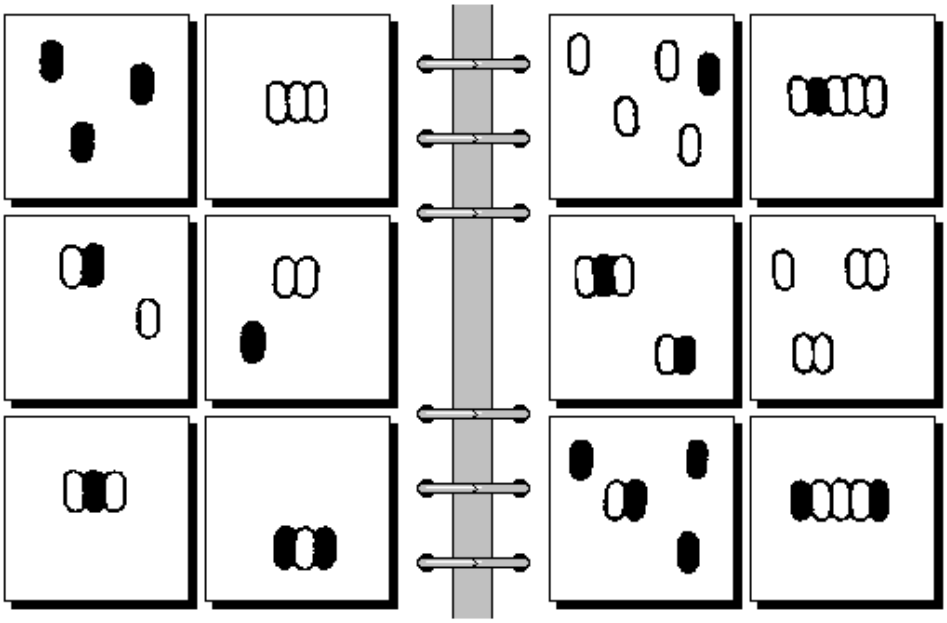
BP88



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<http://.../proprties/**middle**> ;

<http://.../includes/infered/consists_of_shape>
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<http://.../includes/infered/consists_of_size>
<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_count>
<http://.../proprties/3> ;

<http://.../proprties/right>
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<http://.../proprties/**cluster_formation**> ;
<http://.../includes/infered/consists_of_count>
<http://.../proprties/**5**> ;
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<http://.../includes/infered/consists_of_shape>
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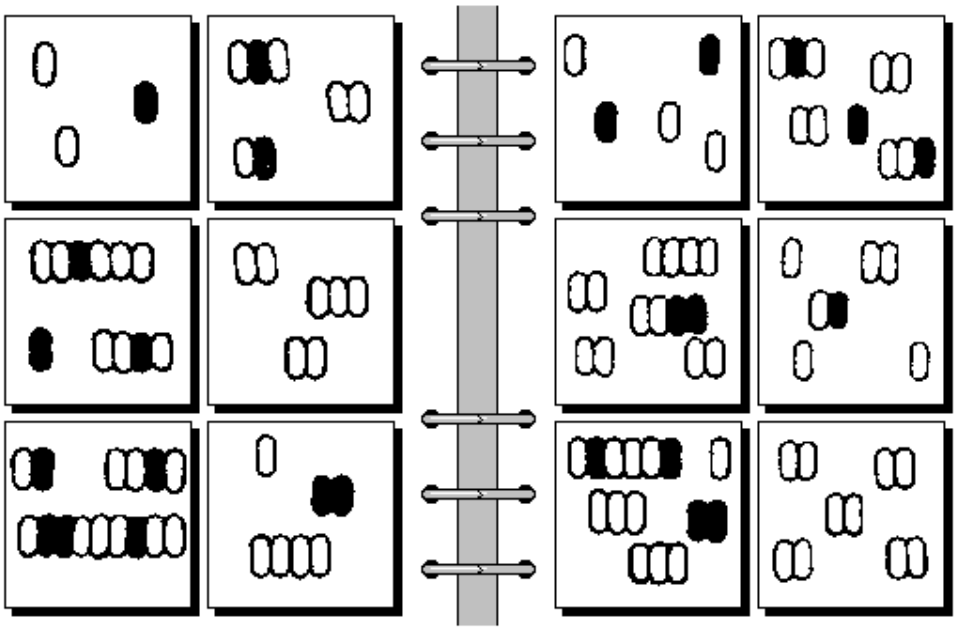
BP89



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<http://.../includes/infered/consists_of_position>
<http://.../proprties/**middle**> ;
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<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_feature_count>
<http://.../proprties/3>

<http://.../proprties/right>
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<http://.../proprties/**5**> ;
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<http://.../includes/infered/consists_of_size>
<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_count>
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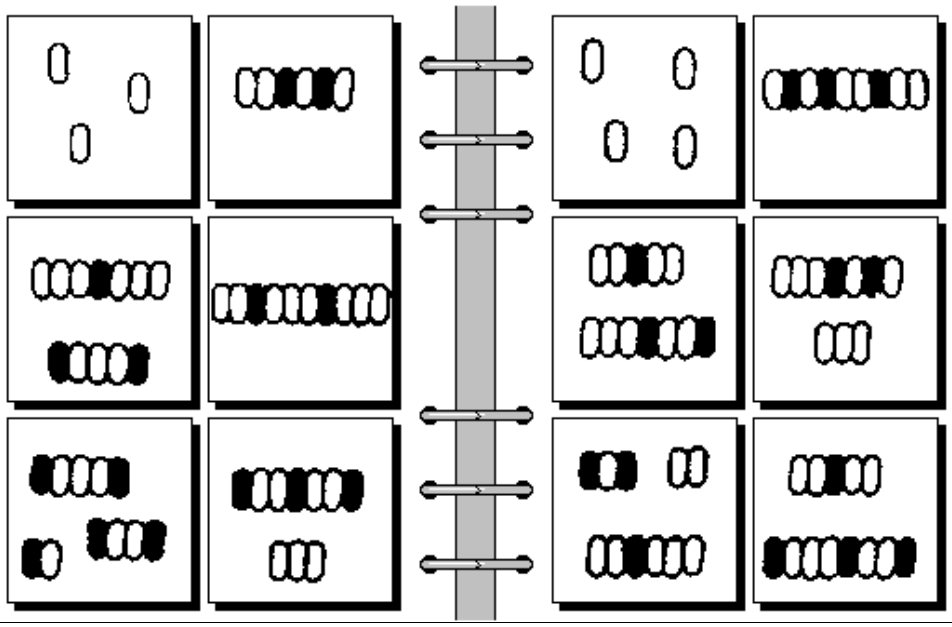
BP90



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<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/3> ;
<http://.../includes/infered/has_infered_feature_count>
<http://.../proprties/3> , <http://.../proprties/cluster_formation> ;

<http://.../proprties/right>
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<http://.../proprties/**4**> ;
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<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
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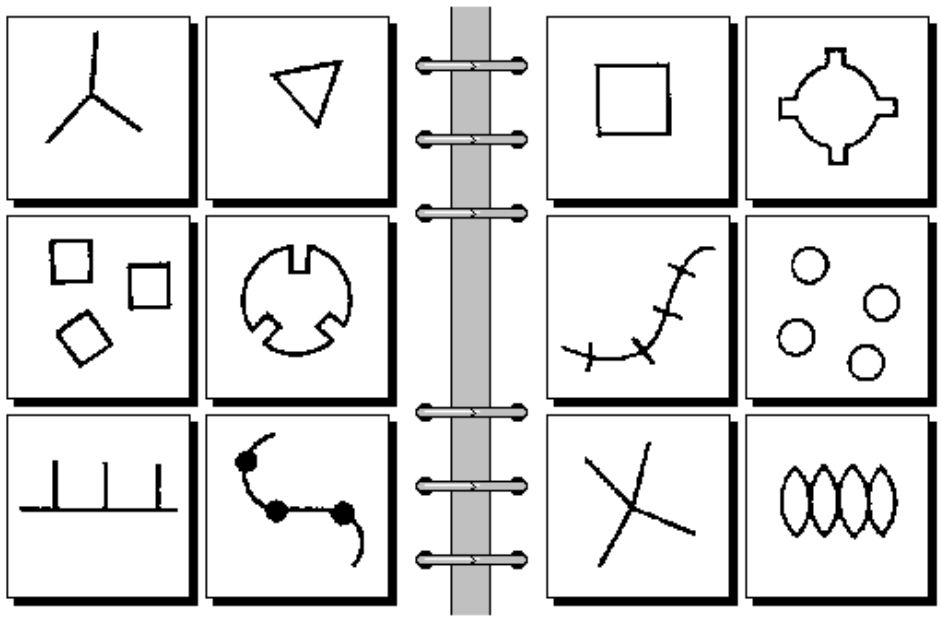
BP91



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<http://.../proprties/**3**> ;
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<http://.../proprties/**middle**> ;
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<http://.../proprties/**notempty**> ;
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<http://.../proprties/right>

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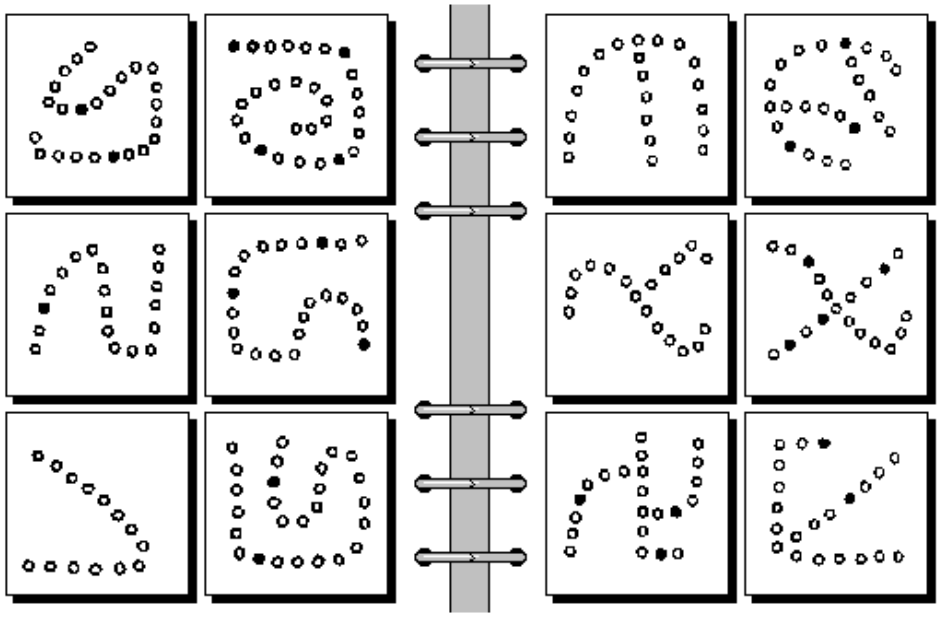
BP92



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<http://.../includes/infered/has_infered_feature_count>
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<http://.../proprties/**null**> ;
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<http://.../includes/infered/has_infered_count>
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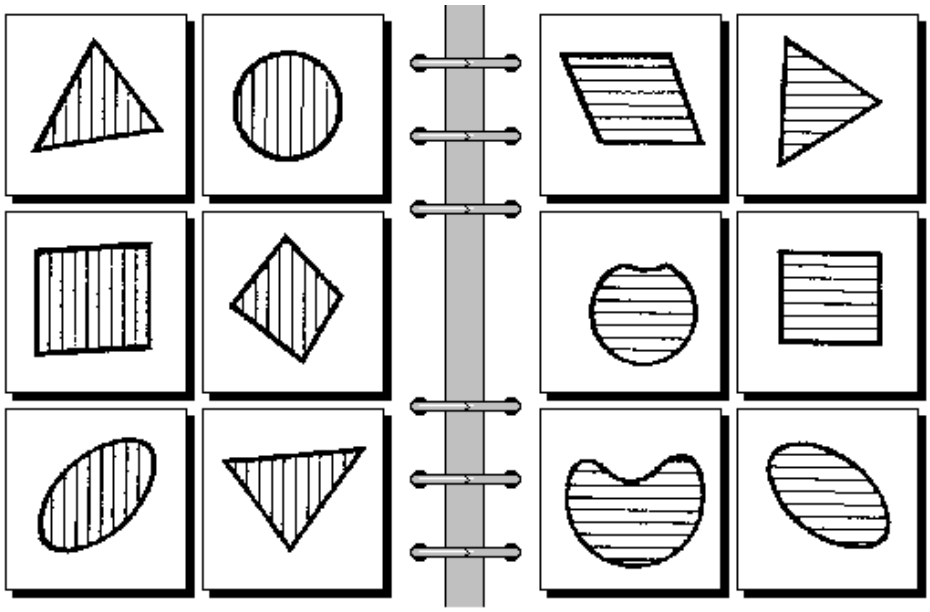
BP95



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<http://.../proprties/**middle**> ;
<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> ;
<http://.../includes/infered/consists_of_size>
<http://.../proprties/**large_figure**> ;
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<http://.../proprties/**closed_shaped**> ;
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<http://.../proprties/vertical_lines> .

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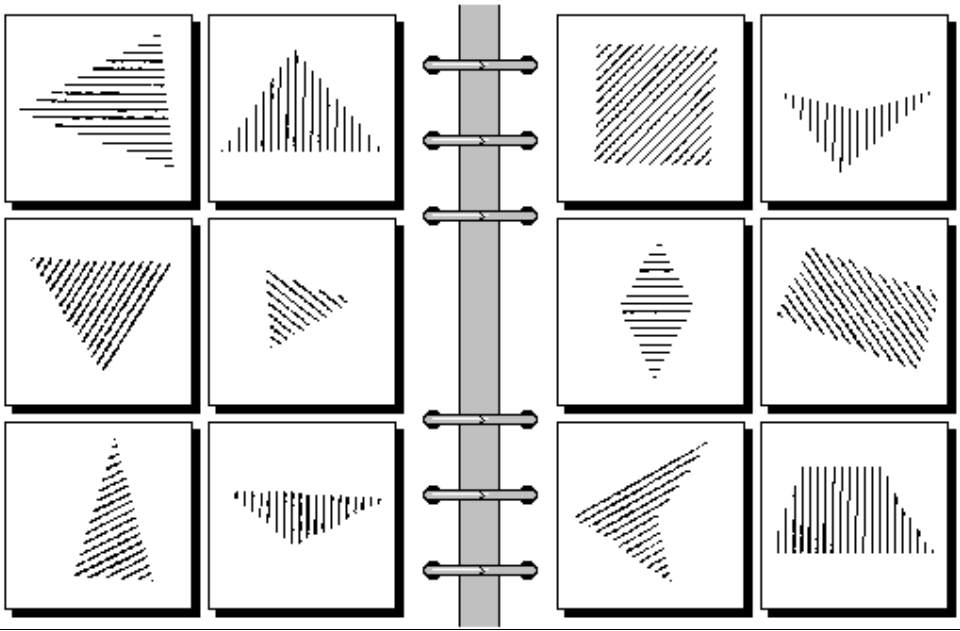
BP96



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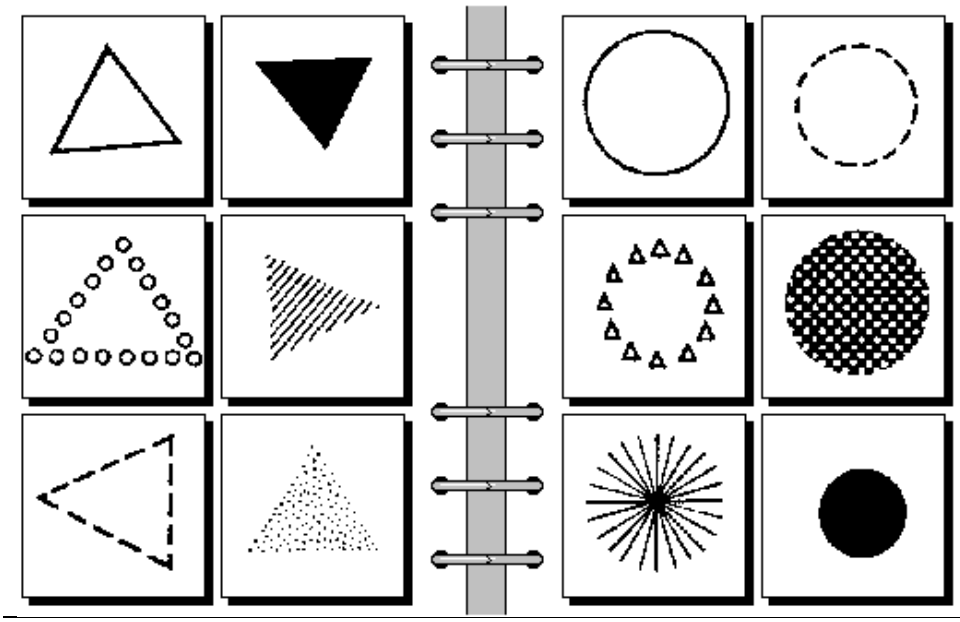
BP97



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<http://.../proprties/**large_figure**> ;
<http://.../includes/infered/has_infered_shape>
<http://.../proprties/triangle> .

<http://.../proprties/right>
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<http://.../includes/infered/consists_of_shape>
<http://.../proprties/**notempty**> , <http://.../proprties/**circle**> ;
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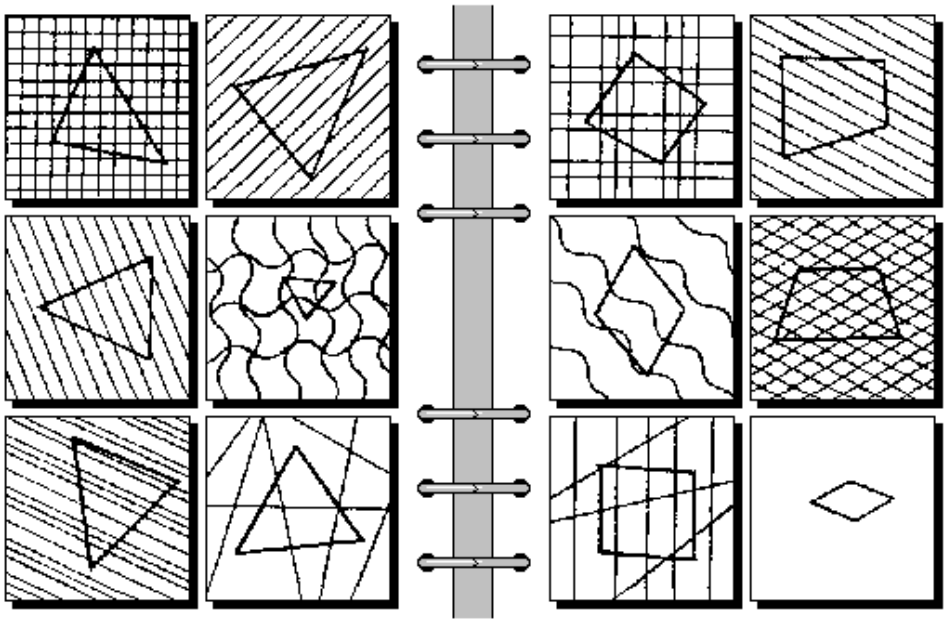
BP98



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<http://.../proprties/**closed_shaped**> ;
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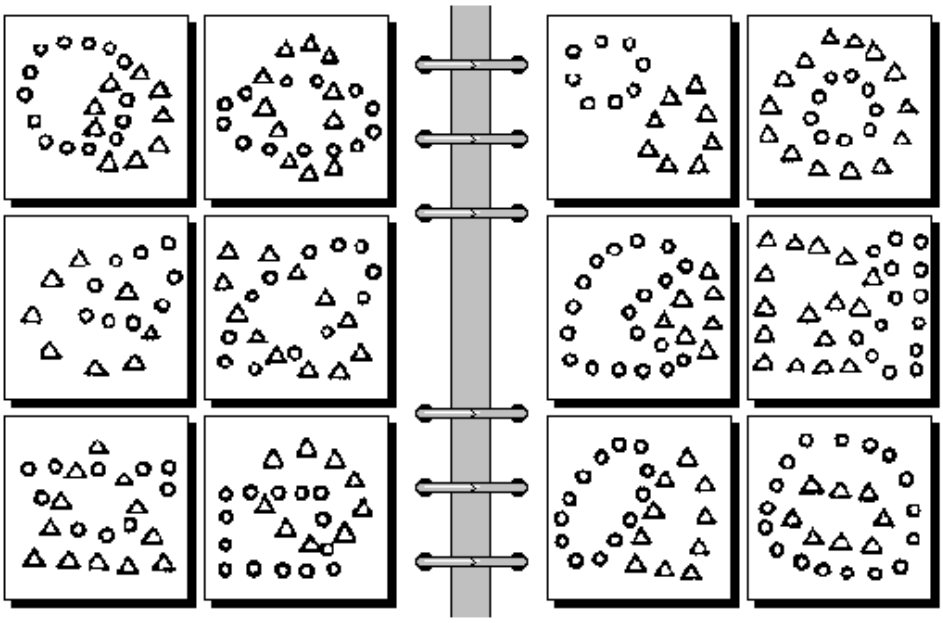
BP99



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<http://.../proprties/**small_figure**> ;
<http://.../includes/infered/consists_of_texture>
<http://.../proprties/**closed_shaped**> ;
<http://.../includes/infered/has_infered_characteristics>
<http://.../proprties/null> ;
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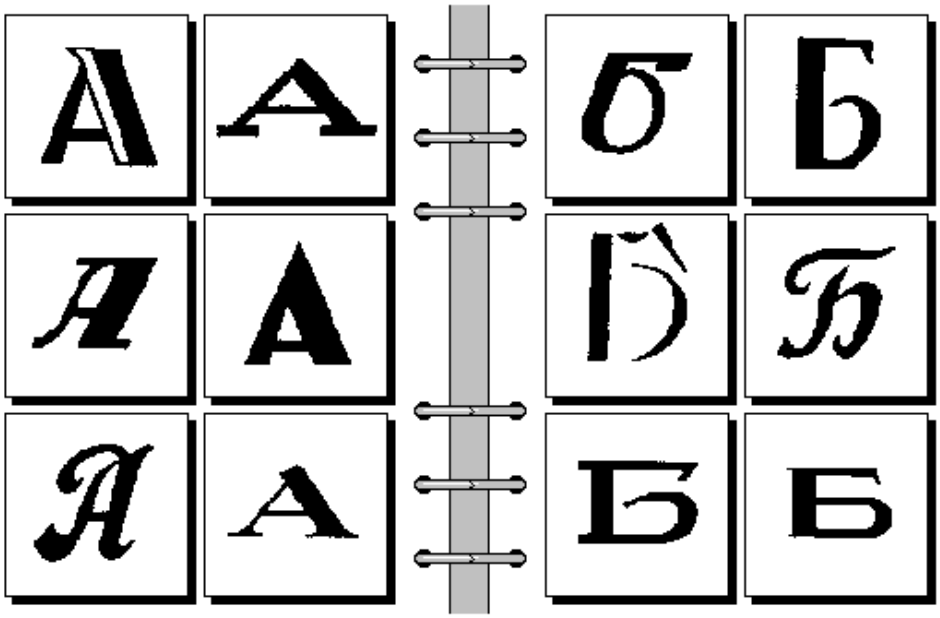
BP100



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