Cognitive Assessment of Topological Movement Patterns and Direction turns: An Influence of Scale

Thesis

Master of Science in Geospatial Technologies

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Cognitive Assessment of Topological Movement Patterns and Direction turns: An Influence of Scale

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Dedication

This thesis is dedicated to my affectionate, loving and caring parents

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Who introduced me to joy of reading from my birth,

Offered me unconditional love and support,

Enabling such a study take place today.

Words cannot sufficiently express my deep gratitude.

Declaration

I hereby declare that the submitted work has been completed by me the undersigned and I have not used any other than permitted reference sources or materials nor engaged in any plagiarism. All references and other sources used by me have been appropriately acknowledged in the work. I further declare that the work has not been submitted for the purpose of academic examination, either in its original or similar form, anywhere else.

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Abstract

Spatial relations are considered as one of the most unique aspects of spatial or geographical information and have linked the space and natural language. Many spatial relations represent distance (topological relations) and directional relations. This research discusses the role of topology for the conceptualization of different movement and furthermore to assess the influence of two different scales of spaces on cognitive classes through human subject tests. Two experiments are conducted with two different scales. Each experiment was performed by 20 participants. Experiments were fully based on the grouping paradigm. Grouping task enable to categorize the movement entities into groups and establish the cognitive categories or classes. Entities or movement patterns within a class are assumed to similar to one another but different from the entities in other classes. It is believed that the two scales of space are quite distinct in the ways people see and think about them in their mind (Downs and Stea, 1977). To assess the influence of scale on the cognitive classes, two different scales are assumed i. e bike and city and bike and park. Similarity measure and category construction of different movement patterns are assessed using both scales. All movement patterns were designed through conceptual neighborhood graph. The result of this experiment shows that different movement patterns are distinguished by the topological relations. This study not also presents the importance of the topology for conceptualization and perception of different movement patterns but also the influence of scale to distinguish the different movement pattern and to build cognitive classes. The main finding of this study is that the grouping behavior of Non- tangential proper part is found to be different in both scales. Direction relations are also an important aspect of spatial relations. Human beings use different angular information in their environment and derive information. This study not also assesses the conceptualization of different direction turns but also examine the category construction influenced by the two different scales. This research discusses the category construction of direction turns created in both scales. The results shows that human perceive different angular information and deduce this information. It is also examined that cognitive classes constructed remain same in both scale. Furthermore, linguistic description is also evaluated in this research but not in much detail. Verbal labeling of the groups participant created also gives the idea about the human perception about the two different scales.

Keywords: topological relations, directional relations, conceptual neighborhood, scale of space, cognitive classes

Chapter 1

Introduction

Object movements with respect to the area can have many spatial relations *i.e.* going in, going out, crossing etc. for example a person enters in the park and a person going out of the park. These situations are named as spatial relation. In our daily life we face a large number of spatial relations. Among several type of spatial relations topological relations are most important (Kurata, 2008) as mostly people use the topological relations in normal life to describe the location of places and objects. Directions are also basic and important spatial relations (Jing, 2008). Human beings use the directional information in describing the locations especially in way finding from their own perspectives for example clinic is on my left and school is left to the bank. Spatial information is related to the objects in space and their relationship that exist in large and small scale geographic space (Hubona, Everett, Marsh & Wauchope, 1998). Large scale geographic scale means the town/cities, states and small scale geographic space means the house, park, rooms, building etc. The most important thing is that human beings conceptualize these spatial relations into their mind and express these relations into verbal information. Language is a valuable tool to convey or transfer the useful information about the objects and things found in the world. The natural language representation of spatial relations has become an important issue in cognitive science, human computer interaction, route navigation systems and robotics as well.

The goal of this research is to how human beings distinguish and characterize different topological movement pattern and direction turns in their environment. The goal of this research is also focus to assess the influence of scale on the cognitive classes through human subject tests.

1.1 Background

Egenhofer (1991) define the topological relationship using the boundary, interior and exterior and describes that topological relations include disjoint/disconnect, equal, meet, inside, covered by, covers and overlap. Topological relationship delineates the existence of the relationship between the objects located in the space. The objects can be defined as the rivers, lakes, buildings, roads, parks etc. there are many topological relationships that exist in the space for example near, touch, overlap etc. in normal life and we describe relationships using natural language like hospital is near to my house, city main market is linked with the main road and canal etc. Freska (1992) introduced eight augmenting qualitative orientation relations namely right front, right neutral, right back, straight back, left back, left neutral and left front in human perception environment. Vorwerg & Rickheit (1998) also writes that the reference points constituting direction categories include LEFT, RIGHT, IN-FRONT, BEHIND, ABOVE, and BELOW are related to physiologically anchor preferred directions in perception (p-212).

In cognitive science the study of the spatial relation and their use in human environment has been a topic of interest for many years. All human beings use Qualitative spatial reasoning in their daily life to understand the spatial environment because information in the spatial environment is mostly available in the qualitative form.

The vital function of language is to elucidate the objects and situations in the universe. Human brain has the power to perceive the data from the world and explain it through mental representation. Many studies have explored cognitive demonstration linking to the acquisition of the spatial information. This research basically related to the cognitive science, spatial relations and the use of spatial relations in natural language.

1.2 Motivation

Cognitive process is important for human behavior and is a fundamental part of human information processing. It gives familiarity about the approach and the way human beings use their knowledge. The relationship of the human beings representation of the objects and the spatial relations and expression is getting a very interesting topic in the cognitive sciences. This interest leads to the cognitive scientist to make the research that how the human beings conceptualize the representations of the objects and how they express this into the verbal information.

Topological relations are the most important spatial relation and comprise of only qualitative measures. Some important topological properties are disconnect, partial overlap, tangential part, interior and exterior. These properties have gained the good place in cognitive science research because these properties are the essential knowledge when people conceptualize the movement of the different objects. In recent years the spatial relation studies and natural language terms has also enhanced the attraction towards this concept.

Now a day we face a large number of spatial topological relations in our daily life. Human beings have good qualities to comprehend the dissimilarity of the qualitative spatial relations. People use natural language to describe these spatial relations. The question arises how the humans make spatial concepts about the objects and events in their minds and how they use these concepts in the natural language to systematize and communicate their ideas and to use those ideas in everyday life.

In many situations, spatial information is expressed in natural language rather than the coordinates and metric information. Most of the qualitative spatial reasoning work is also focused on the knowledge of direction and human beings use the angular directions in their daily life and express it into natural language. Many locations of the things and places are usually described with respect to the important land marks, location of the known places and also using of the natural language explanation. Most of the location of the places or things is usually described by the verbal information and human beings derived information from these verbal description. People use the many directions terminologies in the normal daily life for example right, left, straight and back but still there are many other directions which are not often and easily conceptualize by the human beings in the normal life and are not often used for example at left 30° etc.

Various studies show that even though humans may perceive angular information precisely, in city street networks as well as in body and geographic spaces more generally, human conceptualize and remember it with limited precision (Klippel, 2009). This research also enhances and realizes the users to express the spatial relations in their natural language. Several different classes of scale exist in the environment. Small, medium and large scale environment has also an important influence on how human beings perceive, think and treat spatial information.

1.3 Basic Concept of Spatial relation

Spatial relation has key role to connect the space and vocal information and natural language description. These relations connect the visually perceived information with the natural language. Spatial relation defines the position or location of one object with respect to the reference object. The selection of the reference object is depends on stability and size of the object (Taylor, Gagne, & Eagleson, 2000). Several spatial expressions indicate either distance or directional relations. (schober 1993). Distance relations are usually independent of the position of the observer and called topological relations. Direction relations depend on the position of the observer for example Bank is right to the supermarket.

Topological relations describe the relationship between the objects (natural and unnatural) in the space. The canal is near to my house, John's office is linked to the main road, this road finishes at the end of the metropolitan boundary are the example of the topological relations. Direction relation defines the situation /location of the objects with reference to a specific reference object. The man is in front of the post box is one of the example of the direction relation in which post box is a reference object.

1.4 Basic Conception of spaces

Montello writes in his paper "scale and multiple psychologies of space" that scale has significant persuade on how human treats spatial information and several distinct scale classes of space and he also defines the scale as "ratio between the dimension of a representation and those of the things that it represents or in other words the relative size of the representation". Hill define small scale space as space in which the whole area and everything can be seen from one vantage point and large scale space as a space where navigation or secondary sources e.g. maps are needed.

The examples of Large scale geographic space which is city, neighborhood, town, county or any other big and large area which is linked with roads, bridges and canals and cannot be seen with from a single visual perspective. On the contrary the room, house is the examples of the small scale geographic space which can be seen from one vantage point.

1.5 Research Questions and Hypothesis

- Do human beings distinguish different movement patterns?
- How are human beings acquainted with the different directions turns?
- Does scale of the domain has influence on the cognitive classes?

For this thesis following hypothesis are selected.

Hypothesis 1: All movement patterns in the real world are distinguished on the basis of their topological characteristics.
Hypothesis 2: All moving entities in the surrounding environment depict different angular information.
Hypothesis 3: Different scale of spaces has an effect on the characterization of moving entities.

1.6 Structure of thesis

The thesis outline can be divided into five chapters. The first chapter gives a brief introduction, motivation, aim of the present research work. It also provides the basic idea about the spatial relations and human conception about the spaces. The remnant of the thesis is organized as follows.

The chapter two is for the literature review where related research work has been discussed. It covers the topological and directional theories and models related to the research work. The techniques used on the cognitive assessment are also reviewed. Chapter three discussed the detailed methodology. In this chapter the materials to conduct the experiment and experiment procedures are discussed. All the findings and analysis are illustrated in chapter four. Lastly, chapter five concludes the research work and recommends the future work.

Chapter 2

Literature Review

2.1 Spatial Relation

Spatial relations are regarded as one of the most unique aspects of spatial or geographical information and have linked the space and natural language. Spatial relation defines the position of one object in space in reference to the other object. The secondary object can be termed as reference object. There are many factors involved in selecting a reference object such as size, mobility, stability, knowledge of listener, knowledge of speaker (Talmy 1983). Freeman (1975) presented a very early review on formal representation of the spatial relations. He proposed thirteen relations i.e left of, right of, beside (alongside, next to), above (over, higher than, on top of), below (under, underneath, lower than), behind (in back of), in front of, near (close to, next to), far, touching, between, inside (within) and outside. The visually perceived location is specified by perceived distance and direction (Loomis et al, 1996). Spatial expressions denote either distance or directional relations. Both types may combine in natural language use (schober, 1993).

Distance and direction relations are commonly used in natural language. Distance relations are named as topological relations. Topological relations describe the position of the object with reference to the reference object and are independent on the position of the observer. A is near to B, C is far away from the D are the examples of distance relations. On the contrary, in directional relations objects are located with respect to each other in terms of their relation to the observer. Direction relations depend on the position of the observer and because of the particular perspective they are also referred to Projective relations (Moore, 1976).

2.1.1 Topological Models

How two objects intersect with each other and what the relationship exist between the two objects is concerned with the topological relations. The study of topological relations has been studied for many decades in chase of spatial arrangements of the objects. Topological relations between spatial objects are the most important kind of qualitative spatial information (Li & Liu 2010). Topological relations are subset of geometric relations and do not include any quantitative measures only qualitative measures. Dozens of relation models have been proposed (Li & Liu 2010). These models usually make a small number of distinctions and therefore can only cope with spatial information at a fixed granularity of spatial knowledge (Li & Liu 2010). Topological relationship delineates the existence of the relationship between the objects located in the space. The objects can be defined as the rivers, lakes, buildings, roads, parks etc. there are many topological relationship that exist in the space for example near, far, touch, overlap etc. in normal life and we describe relationships using natural language like university is far from my house, city centre is near to my house. Egenhofer (1991) delineate the topological relationship using the interior, boundary and exterior and concluded the eight topological relations i.e disjoint/disconnect, equal, meet, inside, covered by, covers and overlap as shown in figure 2.1.

In Region connection calculus (Cohn , A.G., Bennett , B., Gooday, J., Mark, N.G., 1997) eight relationships are indentified. DC (Disconnected), EC (Externally connected), PO (Partial overlap), EQ (Equal), TPP (Tangential proper part), NTTP (non tangential proper part) and converse relations TPP-1 and NTPP-1 which are called RCC-8 relation (figure 2.2).

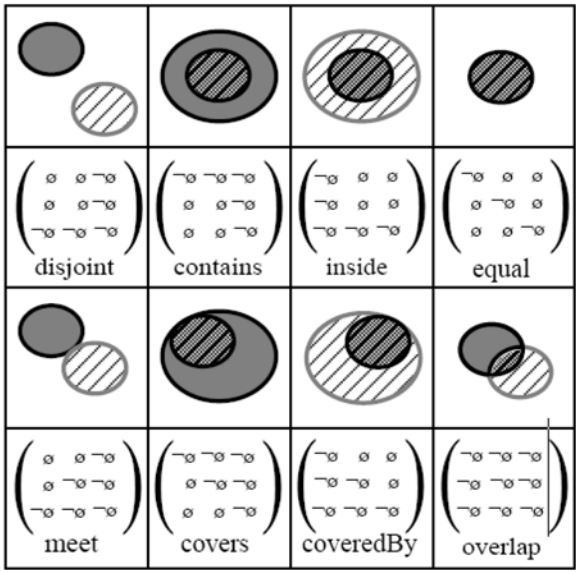


Figure 2.1: 9-Intersection topological relationships

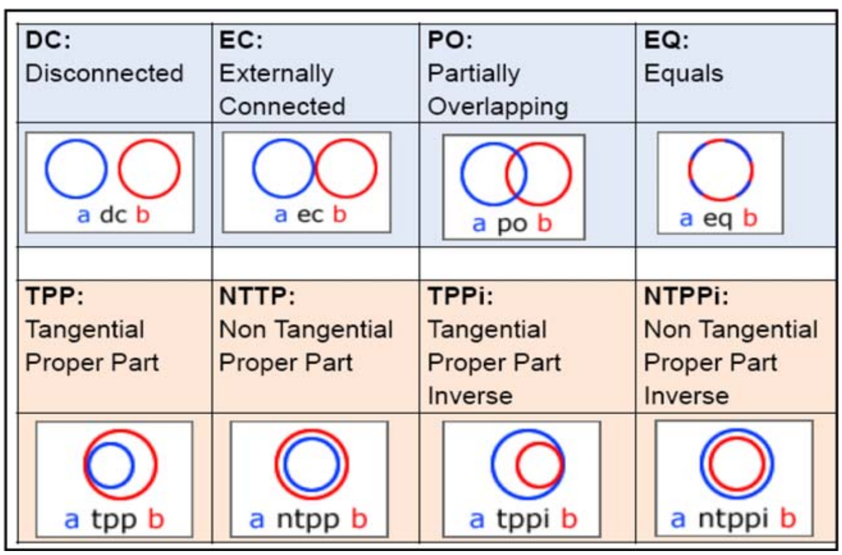


Figure 2.2: RCC 8 Relationship

Egenhofer and Herring (1994) proposed the 9-intersection model for spatial relations. This model makes a distinction between the interior, exterior and boundary of each spatial entity. The spatial relation between the two entities is illustrated by 3 by 3 intersection matrix. The matrix records weather the intersection between the one part of entity and the other part of the entity is empty or non-empty. The 9-intersection model discriminate eight spatial relations between the two simple connected regions with no holes and 33 relations between two simple lines and 19 spatial relations between a simple line and a simple region. Spatial entity could be one and two dimensional. For one dimensional entity such as lines the boundary consist of two end nodes and interior would be the every point exist on the line. In case of two dimensional entities such as region the definition of interior, exterior and boundary would be instinctive.

Kurata and Egenhofer (2007) proposed an extension of the 9-intersection called 9+-intersection model between the directed line segment and a region in a two dimensional space. This model structures the characteristics of the moving agent with respect to a region. This model made a distinction of the line's boundary into two subparts i. e start and end point. The 9+-intersection distinguishes the 26 directed line region relationships as shown in figure 3. The conceptual neighborhood graph of the 26 directed Line region relations (Figure 2.3) is made and applied to the iconic depiction of movement patterns that satisfy a qualitative condition.

Figure 2.4 shows a conceptual neighborhood graph (Egenhofer and Al-Taha, 1992, Freska, 1992) of different movement patterns of two spatially extended entities. The concept of this neighborhood graph is based on Allen's time interval (Allen, 1983). This graph employing the two frameworks for characterizing topological information i. e RCC-8 (Randell, Cui and Cohn, 1992) and 9-intersection model (Egenhofer, & Franzosa 1991).

Klippel and Li (2009) studied the movement pattern of individual entities at the geographic scale. They conducted a behavioral experiment on the similarity of the topological relations. They specifically proposed to assign weights to edges of the conceptual neighborhood to improve the cognitive adequacy of topology based similarity measures. Linguistic influences on the movement pattern categorization are also assessed in this research. After creating a similarity matrix to judge the

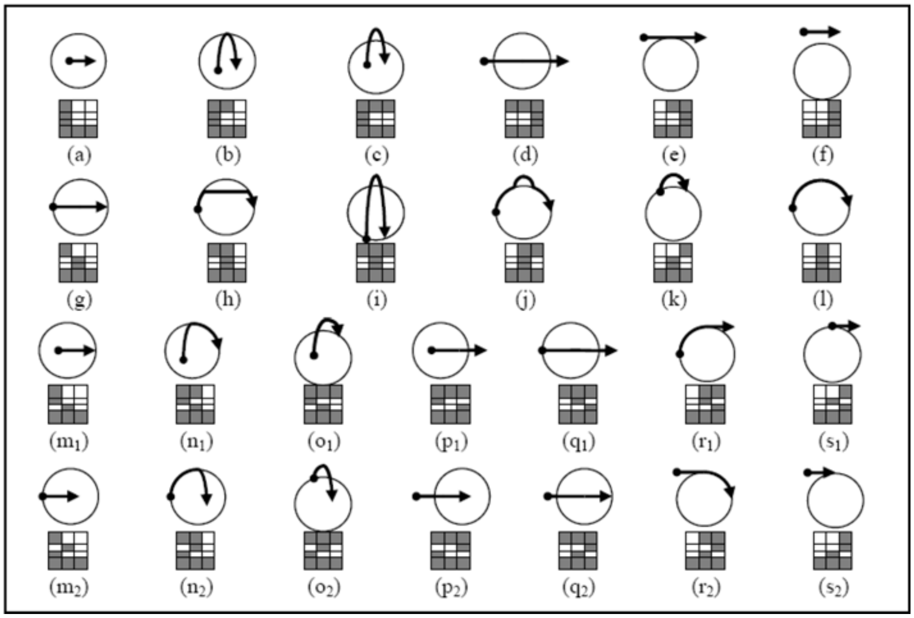


Figure 2.3: 26 topological DLine-region relations, together with the patterns of the corresponding 9+-intersection matrices

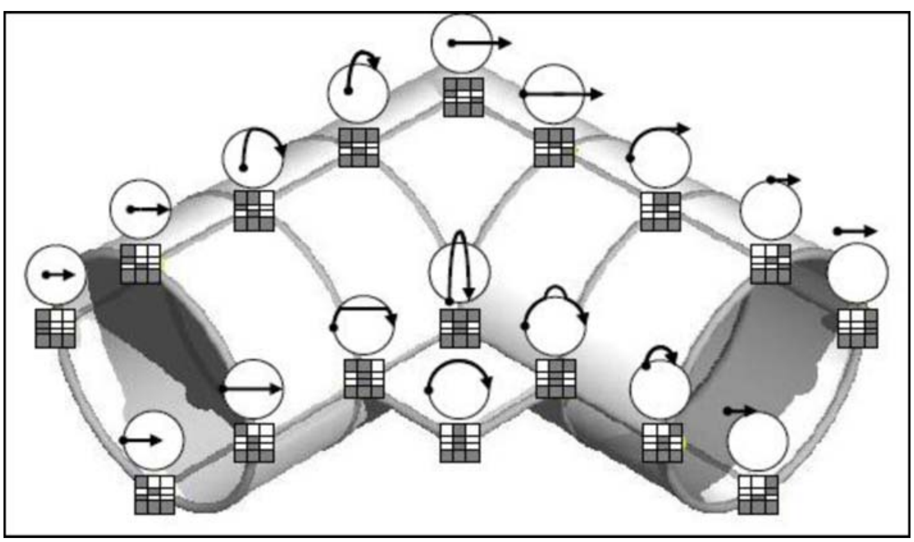


Figure 2.4: A conceptual neighborhood graph of the 26 topological DLine-regions

similarity of the relation, the ward method and average complete linkage methods are used to yield similar clustering structure. According to the author different granularity levels exists in the topological relation conceptualization so the author proposed to use weights by using weight fusion coefficients. According to the researcher the fusion coefficient is a measure that indicates the distance at which two clusters join together and describe the closeness of the topological relations.

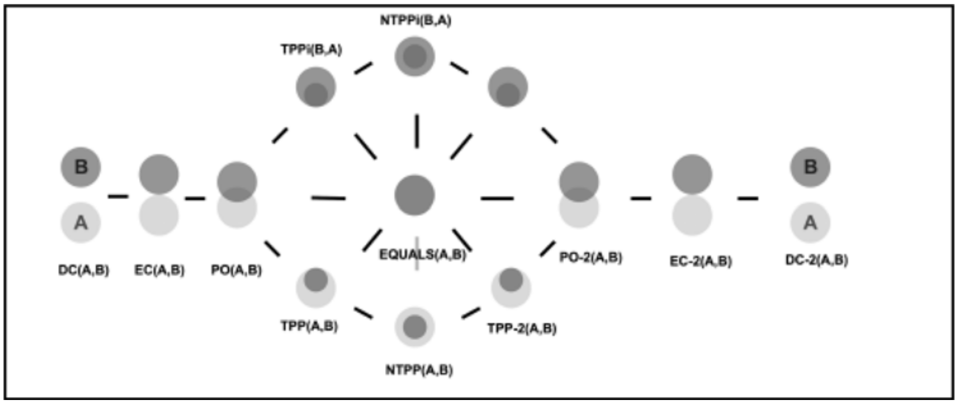


Figure 2.5: Conceptual Neighborhood graph (Source: Klippel, 2009)

2.1.2 Directional Models

Directions relations have been used in different field's i. e way finding assistance system (Klippel, Dewey, Knauff et al, 2004) and spatial data query language (Egenhofer, 1997). Until now a variety of direction models have been proposed to depict the direction relations such as Projection based and cone based (Frank, 1996), triangular mode (Haar, 1976), two dimensional string (Chang, Shi, & Yan, 1987) and direction relation matrix (Goyal, 2000). Some of the models are intended for points such as cone and projection based models and some are designed for the extended objects such as triangular model, 2D string and direction relation matrix. Cardinal directions link the angular direction between a position and a target to some other directions. The cone based directional model divides the planer space around a point into four or eight directions (Frank, 1996) as shown in figure 2.6.

The projection-based model divides a planar space into eight directions according to a horizontal and vertical line through the reference point (Frank, 1996) as shown in figure 2.7.

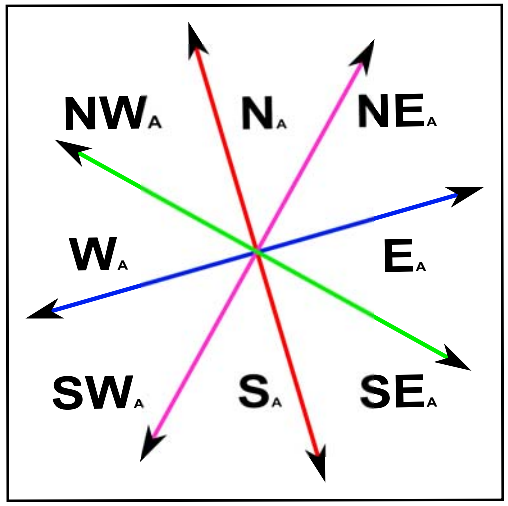


Figure 2.6: Cone based directional model

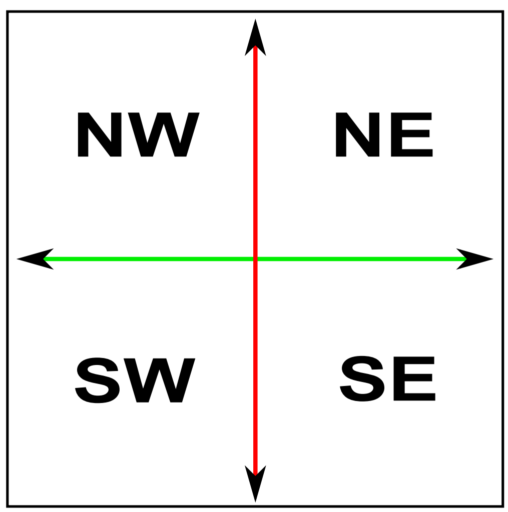


Figure 2.7: Projection based directional model

In a triangular model, directions can be defined if the centroids of a target objects falls inside a triangular area extended outward from the centroid of a reference object (Haar, 1976) (Fig. 2.8). But this triangular model does not consider the shape, size and distances between the objects. This model was enhanced (Fig. 2.9) by bringing the MBR of a reference region (Peuquet and CI-Xiang, 1987). In 2D String model direction information is implied in the two strings.

Direction-relation matrix is developed to capture directions more specifically than other models because it uses the correct representation of the target object. Direction relation Matrix divides the planar space embedded with a reference region A into nine directions as shown in figure 2.10. The direction relations between two regions can be captured by a 3 x 3 matrix (equation 2.1).

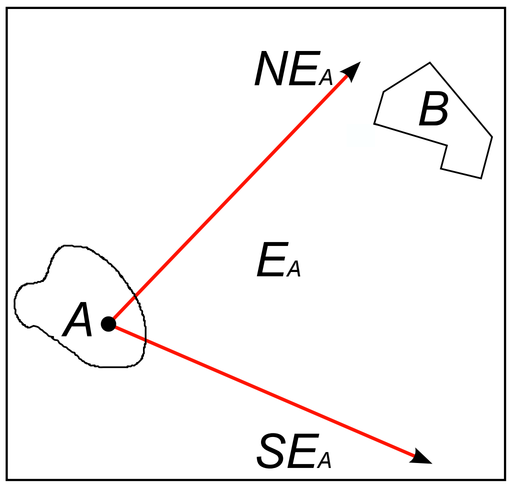


Figure 2.8: Triangular based model

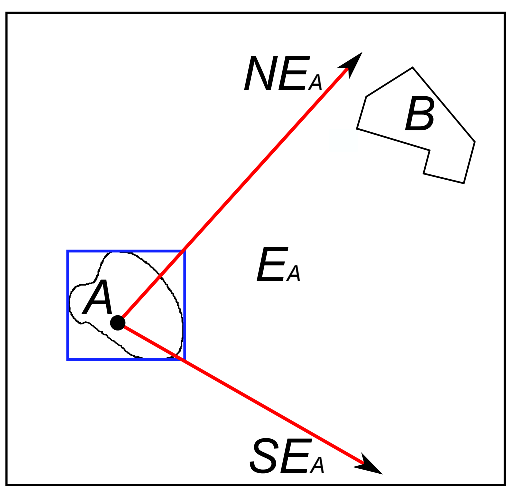


Figure 2.9: Enhanced triangular based model

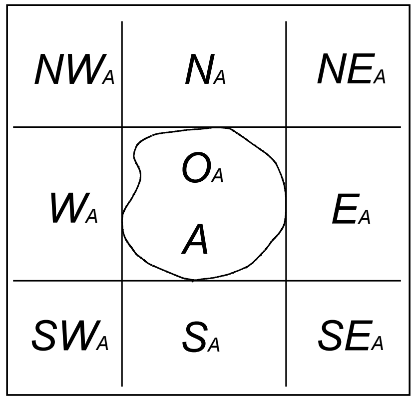


Figure 2.10: Direction relation matrix model

$$M_D(A,B) = \begin{bmatrix} NW_A \cap B & N_A \cap B & NE_A \cap B \\ W_A \cap B & O_A \cap B & E_A \cap B \\ SW_A \cap B & S_A \cap B & SE_A \cap B \end{bmatrix} \tag{2.1}$$

2.2 Mental Representation of spatial language

Human beings are able to categorize the set of entities /movement patterns into groups. Categorization establishes equivalent classes and minimizes the information and cognitive science deals with this categorization. Entities which are placed in one group are treated as similar but different from the entities grouped into different group. It is not tough to see that human perception of spatial relationships is a very important finding to put up a model of an automatic system for learning spatial relationship. Marks and Egenhofer (1994) discussed how humans think and talk about spatial relations. Centroid method (Miyajima, Ralescu, 1994), compatibility method (Miyajima, Ralescu, 1994) and angle aggregation (Krishnapuram, Keller, Ma, 1993) method are produced about the human perception about the spatial relation. Wang and Keller, 1995 did research about the Human-based spatial relationship generalization through neural/fuzzy approaches they introduced two new approaches the single neural network and the multiple neural network (Choquet integral fusion system) for learning and analyzing four primitive spatial relations. Results of Wang and Keller's methods of testing human judgment shows that these methods work effectively and in an analysis system.

In many situations spatial information is usually expressed in natural language rather than using coordinates. In these cases metric spatial information is not able to be acquired. The main attribute human beings uses in stipulate perceived location are distance and direction relations. Direction relation is a significant spatial relation. Description and demonstration for direction relations have diverse levels of detail because of different scales of the embedding spaces (Jing, Gang and Rui, G. 2008). Humans have a natural and instinctive understanding of vocabulary such as right, left, straight, up, down, near and far. People learn the knowledge about the world not only from experiencing the world but also from the description, illustration and depiction. Many studies have been done related to the representation of spatial information into natural language. Language is an effective tool to describe the location of the objects in the world. Direction relation portray the location of the target object with reference to the other object and people use a set of simple language sentences to describe these situations. For example Lake is east of the University; Mountainous region is north to the Village.

Each object in the world has some visual displays and has some relation. Even very simple displays have some enormous spatial information and this is not an easy task to convert this spatial information into natural language. During this verbal translation there are many uncertainties and misapprehension. As all spatial information is communicated through language so to remove the ambiguities is been an important issue. Taylor, Gagne and Eagleson (2000) experiment shows that the choice of reference frame can be affected by the recognition of an object, or on cognitive considerations of its functionality with respect to another object. Taylor (2000) also defines the three types of reference frames which are used to express spatial relations: deictic, intrinsic, and environmental. The spatial relationship from speaker's point of view is presented in deictic reference frame. For example the computer is in front of the student means the student is in between the speaker and computer. An intrinsic reference frame presents the spatial connection in terms of the objects in the scene. For example in the statement "the student is in front of the computer' the intrinsic concept can be explain that the student itself is in front of the computer despite of the location / position of the speaker. In an environmental reference frame spatial relationships are in terms of the environment. For example east, west, north south, north east and west etc are environmental spatial notations.

2.3 Scale of spaces

Spaces can be understood through visual perception and language. The idea that there must be a common demonstration of perceptual and linguistic inputs is not new. The way human beings conceptualize the spaces in the environment is an important consideration. Scale has influence that how human beings treats spatial information (Montello, 1993) and distinguish the classes of scales of environment qualitatively. Naive Physics also called 'common-sense physics' deals with the ways in which people typically think that physical objects behave. Geographers and psychologist (Downs and Stea, 1977 & Ittelson, 1973) have characterized the space into small, medium and large scale space. Montello (1993) distinguish the four major classes for psychological space: Figural, Vista, Environmental and Geographical and Figural space. This distinction of these classes was on the basis if the projective size relative to the human body, not its actual size. Figural space is smaller than the human body and is apprehended without any locomotion. Vista space is larger than the human body but it can be apprehended without locomotion such that single rooms, town squares and small valleys. Environmental space is projectivly larger than the body and it is and surrounds it. It is in fact too large and obscured to apprehend directly without considerable locomotion such as cities. Geographical space is projectively much larger than the body and cannot be apprehended directly through locomotion; rather, it must be learned via symbolic representations such as maps or models that essentially reduce the geographical space to figural space. His experiments results implied that people face and differentiate this type of scale of spaces while delineating different spatial relations. Downs and Stea (1977) write in his book that "the two scales of space are quite distinct" (p 197) in the ways people see and think about them in their mind. Downs and Stea (p. 199) also define the "small-scale perceptual space" and "large-scale geographic space. Kuipers (1978) defined large-scale space as "space whose structure cannot be observed from a single viewpoint" and small-scale space to refer to subsets of space which are visible from a single point (p-129). Mandeler (1983) distinguish three classes of psychological spaces as small, medium and large scale spaces. He defined that small scale spaces can be observed from a single viewpoint such as room. Medium scale spaces are by the mind apprehended through locomotion about the spaces but he further added that the spatial relationship between them can still be views from a single view point such as houses, towns. Large scale spaces represent a very special case because in general they are apprehended via maps such as states and countries. Grling and Golledge (1987) also distinguished between small, medium and large scale "environments". He gave the examples that's a room would be an example of a small-scale environment, a building or neighborhood would be medium-scale environments, and spaces at the scale of cities and beyond are large-scale environments. In this classification basis of distinction was not specified.

Chapter 3

Methodology

This chapter deals in data preparation and summarizes the detailed methods adopted to obtain the goals of the research. The Experiment procedures and organization are also discussed here in depth.

3.1 Experiments

We conducted two experiments. A domain with two scales is assumed. The Bike and the city referred to scale 1 and the bike and park is referred to as scale 2. The first experiment was involved two tasks. Task one assess the similarity measure of different movement pattern on scale one **(bike and city)** and task two was involved to assess the similarity of direction turns on scale one. Second experiment was tested on scale two **(bike and park)** and was involved two task. Task one evaluate the similarity measure of different movement pattern on scale two (bike and park) and task two was involved to examine the similarity of direction turns on scale two but on a different participant group. Each task was followed by linguistic labeling. This design allows us to see scale influences on the cognitive classes.

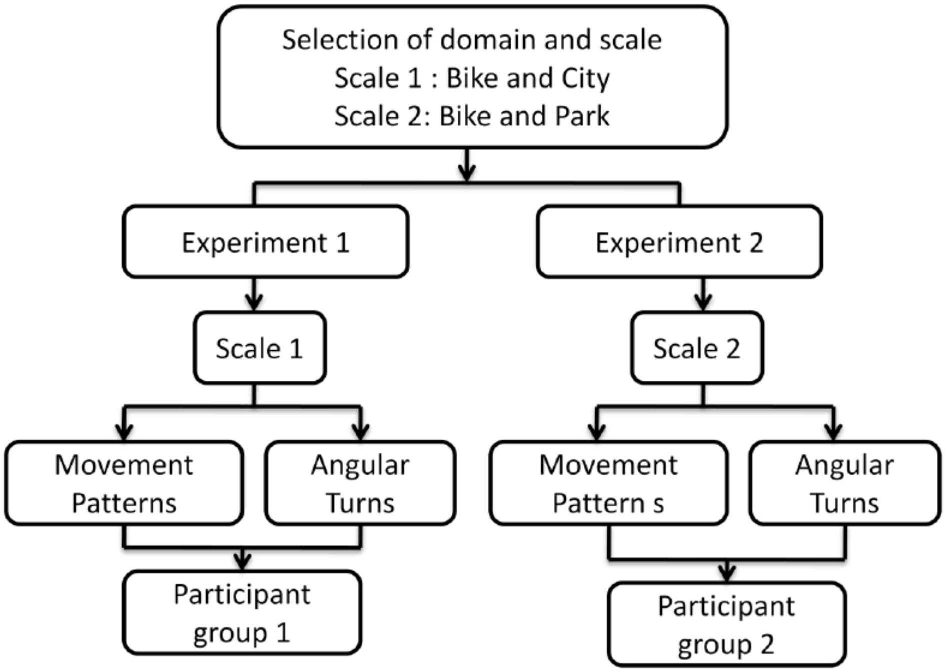


Figure 3.1: Experiments Methodology Flowchart

3.2 Experiment 1

In this experiment firstly, we assessed the conceptual knowledge of different movement pattern and category construction using a grouping task. Main reason of using the grouping task is that human beings mainly use conceptual knowledge to determine the similarity of given stimuli. Stimuli are placed into the same group if they are considered as similar and they are placed into different groups if they are assumed as dissimilar (Klippel, 2009). Envision of different direction turns is examined in second task of the experiment.

3.2.1 Experiment Material (Task 1)

To check how the human beings perceive about the different topological relations and how the influences of scale on their perception, randomly three different animated path of bike passing through the city (The shape of city Lisbon is used) are constructed using Adobe Flash CS5 (figure A.1 and figure A.2 in Appendix).

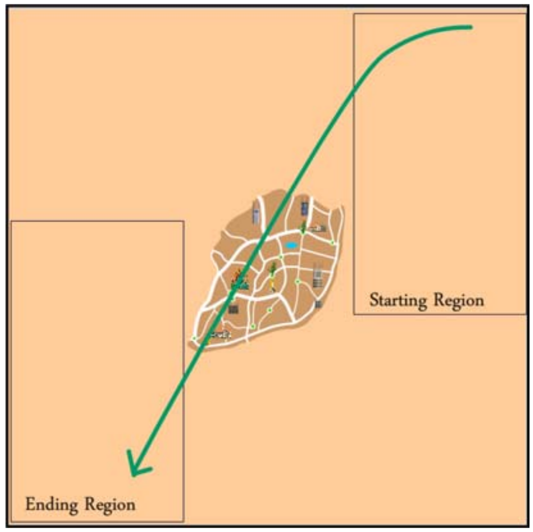


Figure 3.2: one path of the animated icon

The stimuli size is 120 x 120 pixels. The starting and ending regions are also defined as 40 x 70 pixels in size (Klippel and Li, 2009). The starting and ending coordinates are randomized inside the defined boundaries of topologically defined equivalent classes. Ending relation is visually made clear. The speed of the bike is also kept constant in all movement paths. To get the same speed, the path length / frame ratio is normalized *i.e.* the longer the movement path, the more frames are used to keep the speed same in all animated stimuli (Klippel and Li, 2009). Between the repetition of the movement path, a small break / pause is kept.

Figure 3.1 shows a path of one animated icon. It is clear that a disconnect region is chosen from which all starting coordinates are selected. Similarly ending coordinates are selected from the defined ending region. Partial overlap is considered as 50 percent overlapping between the bike and the city and between the bike and park as well. The EC, PO and TPP relations coordinates are randomized using only vertical coordinates.

The start relation for all the movement patterns is disconnected or disjoint (DC) which follows a continuous path having the relations EC, PO, TPP, NTPP and then this topological relations repeat and we name them as a TPP-II, PO-II, EC-

II, DC-II (Fig. 3.2). So we make a distinction of nine possible relations. We decide to select the 3 icons for one topological relation for one equivalent class as we have three paths. So in total we get 27 stimuli for scale one (figure A.3 and figure A.5 in Appendix).

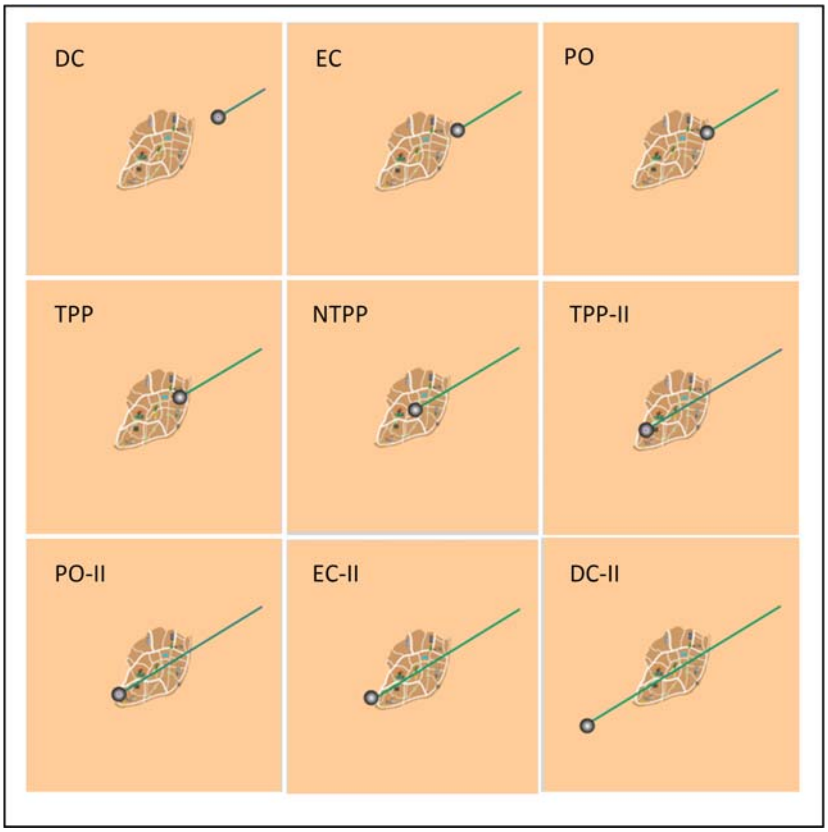


Figure 3.3: Examples of different position of bike passing through the city

3.2.2 Experiment Material (Task 2)

The task two was to analyze the direction concepts which human being thinks and also scrutinize the influence of scale on direction. Different direction/angular categories are assumed in this task. Direction terminology is followed from the Klippel experiment (Klippel and Montello, 2007) as a basis for this research. A full circle (360°) will be used as a reference for this research. Figure 3.3 demonstrates that the circle angles start at 6 o'clock and referred to 0° and 360° degree, 3 o'clock which is the perpendicular right is called 90° , 12 o'clock/straight is referred to as 180°, and perpendicular left/9 o'clock is referred to as 270°(Klippel and Montello, 2007).

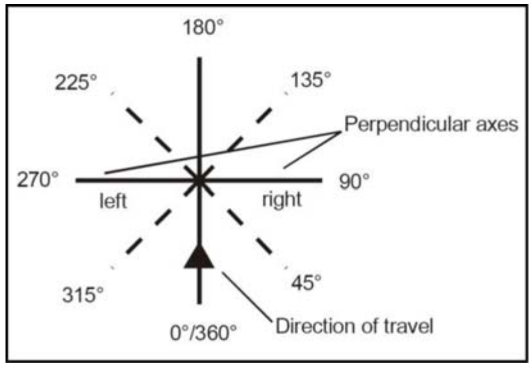


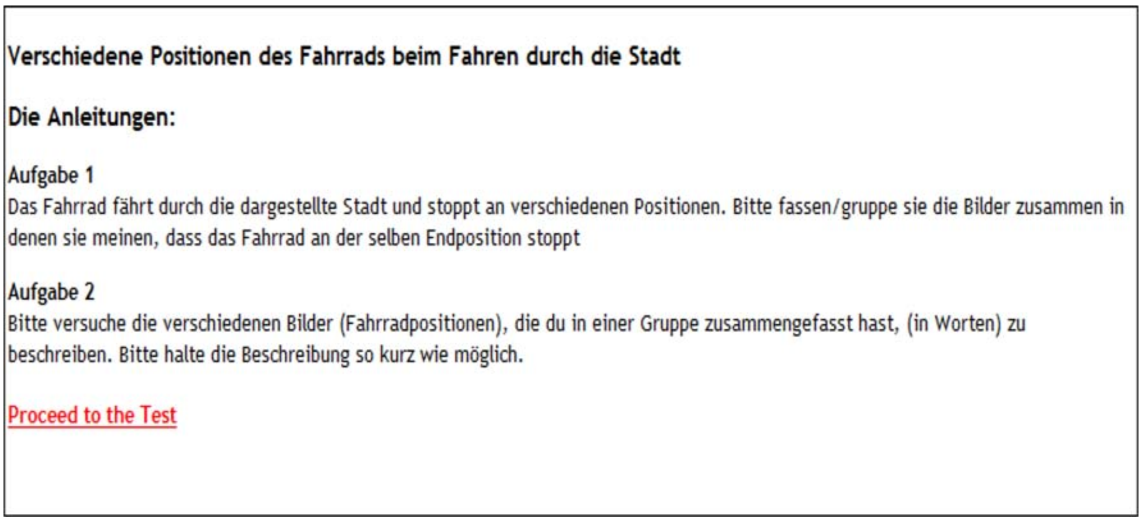
Figure 3.4: Depiction of the direction terminology Source:(Klippel and Montello, 2007)

We started with the typical direction model of 45°, 90°, 135°, 180°, 225°, 270° and 315° and sectors are bisected until we got the angular direction differentiating at the 5.625°. The back sector angles between 337.5° and 22.5° were excluded because of the spiky turns (Klippel and Montello, 2007). All stimuli are constructed using Adobe Flash CS5. Some of stimuli are shown in figure A.5 of Appendix. The shape of the park and city is the same as used in topological segment. Again the stimuli size is 120 x 120 pixels. The speed of the bike is also kept constant in all movement paths. Speed of the animation is also kept constant in all animated stimuli. Between the repetition of the movement path, a small break / pause is kept. 55 stimuli are used for scale one.

3.2.3 Experiment Procedure

All animated icons were displayed to the participants through a web page which was prepared using php and html. Grouping task is used, which is a vital technique to scrutinize conceptual knowledge and category construction in human mind. General instructions are provided to the participants. We also told about the functionality of the grouping task. In the instructions all subjects will be asked to group the same items. Instructions were also placed on the web page in German. (In

German:Das Fahrrad fährt durch die dargestellte Stadt und stoppt an verschiedenen Positionen. Bitte fassen/gruppe sie die Bilder zusammen in denen sie meinen, dass das Fahrrad an der selben Endposition stoppt). In instructions they were told "Please consider that bike is passing through the city in these images. Bike Stops at different positions. Please make groups of the images in which you think bike stops in similar end positions". After reading the instructions, a button 'proceed to test' was placed to precede the experiment.



Verschiedene Positionen des Fahrrads beim Fahren durch die Stadt

Die Anleitungen:

Aufgabe 1
Das Fahrrad fährt durch die dargestellte Stadt und stoppt an verschiedenen Positionen. Bitte fassen/gruppe sie die Bilder zusammen in denen sie meinen, dass das Fahrrad an der selben Endposition stoppt

Aufgabe 2
Bitte versuche die verschiedenen Bilder (Fahrradpositionen), die du in einer Gruppe zusammengefasst hast, (in Worten) zu beschreiben. Bitte halte die Beschreibung so kurz wie möglich.

Proceed to the Test

Figure 3.5: Instructions given for the experiment

On the left side, all icons are presented. Participants can drag, place and make group the icon on right side (figure 3.5). Place is also kept for labeling the groups. The criteria for grouping and the number of groups were totally depend on the participants. Besides that, the participant age, sex, study background and time taken by each participant to complete the task is also noted. Participants were also advised (In German: Bitte versuche die verschiedenen Bilder (Fahrradpositionen), die du in einer Gruppe zusammengefasst hast, (in Worten) zu beschreiben. Bitte halte die Beschreibung so kurz wie möglich) to label the groups they created. It is also requested to the participants to keep the description short and comprehensive. Participants could also label the groups in the same window.

Figure 3.6: Screenshot of the window which participant saw initially in experiment 1

Similarly in task two instructions were also given (In German: Die Bilder zeigen unterschiedliche Richtungen, in die das Fahrrad sich in der Stadt bewegen kann. Bitte gruppiere die Bilder entsprechend ihrer Ähnlichkeit in Bezug auf die Richtung des Fahrrads. Erstelle dabei so viele Gruppen wie du möchtest). In this task participants were asked to consider that bike is moving in different directions in the city and to place the stimuli depicting the similar turns of bike in one group and dissimilar into the other groups. Participants were free to choose groups as many as they want. After finishing the task, results were stored by clicking the save option.

3.3 Experiment 2

Experiment 2 employed the same task, setting and material and shape as in experiment 1 but with a different scale of domain i. e bike and park. This experiment required the different participants group.

3.3.1 Experiment Materials (Task One)

We slightly modified the color of the stimuli material from experiment 1. We used 27 animated stimuli and all stimuli were constructed (figure A.6, figure A.7 and figure A.8 in Appendix) using the same methods as in experiment 1. Exactly the same grouping tools were used as in experiment 1 with the same interface.

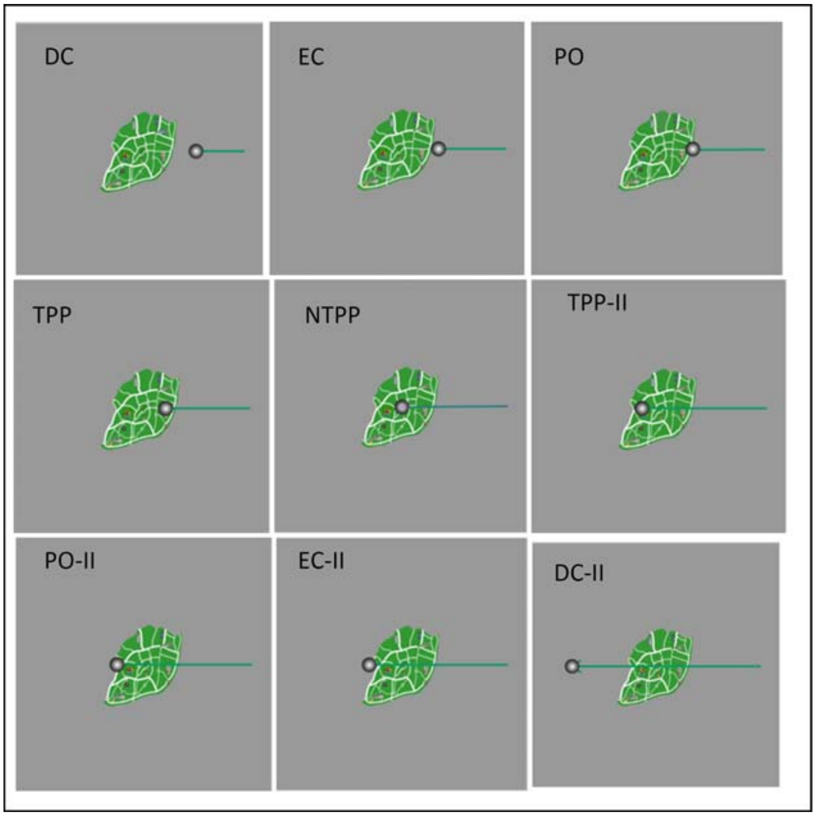


Figure 3.7: Example of different position of bike passing through the park

3.3.2 Experiment Materials Task two

Second task also employed the same methods as in experiment 1 but with a different color of stimuli. Stimuli having the same angular directions are prepared. Some stimuli are presented in (figure A.9 and figure A.10 in Appendix) .

3.3.3 Experiment Procedure

The procedure for experiment 2 was the same as for experiment 1 except the participant group. Here again all animated icons were displayed to participants via web page. Again grouping task is used. For task one instructions are provided (In german 'Das Fahrrad fährt durch die dargestellte park und stoppt an verschiedenen Positionen. Bitte fassen/gruppe sie die Bilder zusammen in denen sie meinen, dass das Fahrrad an der selben Endposition stoppt. In English : Please consider that bike is passing through the city in these images. Bike Stops at different positions. Please make groups of the images in which you think bike stops in similar end positions).By clicking a button proceed to the test" a page was opened. In this page the screen was divided into two parts. All the stimuli material consisting of depicting topological relation is placed on the left side randomly. At the start the right side of the screen was empty. Participants can create the groups of animated icons simply by dragging and dropping. Participants were free to choose groups as many as they can. They could place as many images they want in on group which they considered are similar. After that they were also told to describe the groups in words which they created. (Bitte versuche die verschiedenen Bilder (Fahrradpositionen), die du in einer Gruppe zusammengefasst hast, (in Worten) zu beschreiben. Bitte halte die Beschreibung so kurz wie möglich).

In task two, All the stimuli material consisting of depicting directional turns of bike is placed on the left side randomly and participants were told to make groups on the right side showing that the similar turning possibilities in one groups in such a way to maximize the similarities of stimuli within groups. (In german :Die Bilder zeigen unterschiedliche Richtungen, in die das Fahrrad sich im Park bewegen kann. Bitte gruppiere die Bilder entsprechend ihrer Ähnlichkeit in Bezug auf die Richtung des Fahrrads. Erstelle dabei so viele Gruppen wie du möchtest). it is also said to give the verbal labeling against each group they created. (Bitte versuche die verschiedenen Bilder (Richtungen des Fahrrads), die du in einer Gruppe zusammengefasst hast, (in Worten) zu beschreiben. Bitte halte die Beschreibung so kurz wie möglich).

Figure 3.8: Screenshot of the window which participant saw initially in experiment 2

Chapter 4

Results and Discussion

Cluster analysis allows us to examine the similarities of observations or objects. This method allows one to explore the structure of the data set. In other words, cluster analysis sorts the data into similar clusters that share similar characteristics. The cluster analysis displays the results a tree diagram called dendrogram. The branching-type nature of the dendrogram represents a hierarchy of categories based on degree of similarity.

4.1 Results of Experiment 1

4.1.1 Participants

20 participants (13 females and 7 male) of homogeneous language (German only) from the University of Mnster, Department of physics and Mathematics and University of Duisburg Essen are participated in the experiment. All participants were the university students having different study backgrounds (Chemistry, Physics, Mathematics, Biology and Engineering) including one participants who had the cognitive science back ground. Participant's age was between the 22 to 36 years. The participants took 20-35 minutes for first task and 20 to 50 minutes for the second task. Participants were not paid for the experiment and they performed the experiment on voluntary basis.

4.1.2 Task one

The result of the each participant was encoded in a 27 x 27 similarity matrix (table 4.1). The matrix rows and columns correspond to the number of stimuli used in the experiment. It is a symmetric similarity matrix and encodes all possible similarity ratings between two stimuli and produced a matrix of 729 cells. The major purpose of constructing the similarity matrix is that it encodes the results of category by each participant.Once the similarity matrix is obtained, several analyses can be performed to analyze the categorical grouping data, we subjected the similarity matrix to a hierarchical cluster analysis. The analysis was performed using the statistical tool box function of Matlab R2010b with the default similarity measure of Euclidean distance. This is probably the most commonly chosen type of distance. The main advantage of the Euclidean distance is that it considers all possible pairing (Russel A, R., 1999) and is easy to interpret. Mathematically, distance between a point x (x_1, x_2 etc.) and a point y (y_1, y_2 etc.) is:

$$d = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \tag{4.1}$$

Average, ward's and complete linkage methods are applied to cross validate the results. All methods show a similar clustering structure. Figure 4.1 and 4.2 shows the resultant dendrograms generated using average and ward method respectively. The variables are represented vertically. The links between the variables are U-Shaped lines. The distances are shown horizontally. The following dendrogram shows the following clusters; NTPP is also forming a distinct cluster and are conceptually more similar to the cluster formed by TPP and TPP-II and Showing more similarity among these variables. DC and DC-II relations are assumed to be same and same are the case with the EC and EC-II. DC and EC are also found to be more similar than other relations.

Cophenetic correlation has already been used by Petchey et al. (2007) or discussed by Petchey and Gaston (2006) to evaluate the quality of the dendro-

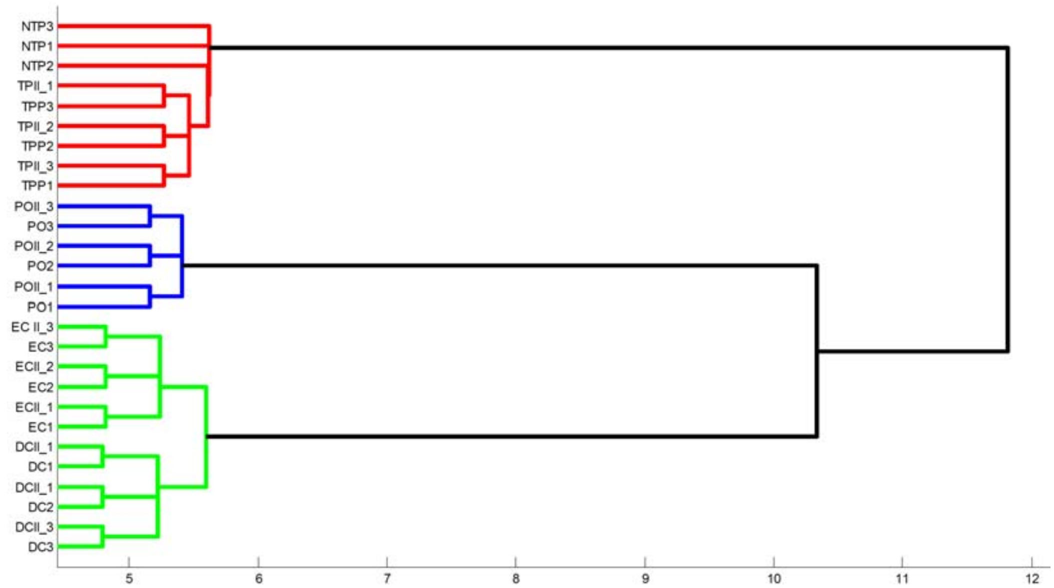


Figure 4.1: Cluster Analysis using Average linkage method for task 1of Experiment 1

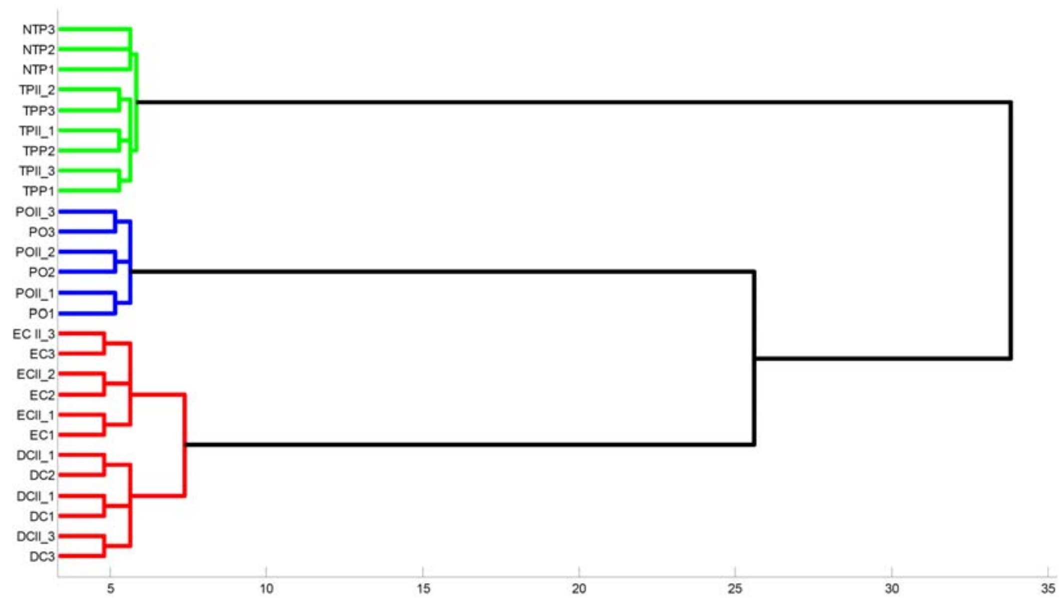


Figure 4.2: Cluster Analysis using ward's method for task 1of Experiment 1

	DC1	DC2	DC3	EC1	EC2	EC3	PO1	PO2	PO3	TP P1	TP P2	TP P3	NTP P1	NTP P2	NTP P3	TP PII_1	TP PII_2	TP PII_3	PO II_1	PO II_2	PO II_3	EC II_1	EC II_2	EC II_3	DC II_1	DC II_2	DC II_3
DC1		20	20	12	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	12	12	12
DC2	20		20	12	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	12	12	12
DC3	20	20		12	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	12	12	12
EC1	12	12	12		20	20	5	5	5	1	1	1	0	0	0	0	0	0	4	4	4	14	14	14	9	9	9
EC2	12	12	12	20		20	5	5	5	1	1	1	0	0	0	0	0	0	4	4	4	14	14	14	9	9	9
EC3	12	12	12	20	20		5	5	5	1	1	1	0	0	0	0	0	0	4	4	4	14	14	14	9	9	9
PO1	0	0	0	5	5	5		20	20	3	3	3	0	0	0	0	0	0	16	16	16	4	4	4	0	0	0
PO2	0	0	0	5	5	5	20		20	3	3	3	0	0	0	0	0	0	16	16	16	4	4	4	0	0	0
PO3	0	0	0	5	5	5	20	20		3	3	3	0	0	0	0	0	0	16	16	16	4	4	4	0	0	0
TPP1	0	0	0	1	1	1	3	3	3		20	20	10	10	10	17	17	17	0	0	0	0	0	0	0	0	0
TPP2	0	0	0	1	1	1	3	3	3	20		20	10	10	10	17	17	17	0	0	0	0	0	0	0	0	0
TPP3	0	0	0	1	1	1	3	3	3	20	20		10	10	10	17	17	17	0	0	0	0	0	0	0	0	0
NTP P1	0	0	0	0	0	0	0	0	0	10	10	10		20	20	10	10	10	0	0	0	0	0	0	0	0	0
NTP P2	0	0	0	0	0	0	0	0	0	10	10	10	20		20	10	10	10	0	0	0	0	0	0	0	0	0
NTP P3	0	0	0	0	0	0	0	0	0	10	10	10	20	20		10	10	10	0	0	0	0	0	0	0	0	0
TPP II_1	0	0	0	0	0	0	0	0	0	17	17	17	10	10	10		20	20	4	4	4	1	1	1	0	0	0
TPP II_2	0	0	0	0	0	0	0	0	0	17	17	17	10	10	10	20		20	4	4	4	1	1	1	0	0	0
TPP II_3	0	0	0	0	0	0	0	0	0	17	17	17	10	10	10	20	20		4	4	4	1	1	1	0	0	0
POII_1	0	0	0	4	4	4	16	16	16	0	0	0	0	0	0	4	4	4		20	20	6	6	6	0	0	0
POII_2	0	0	0	4	4	4	16	16	16	0	0	0	0	0	0	4	4	4	20		20	6	6	6	0	0	0
POII_3	0	0	0	4	4	4	16	16	16	0	0	0	0	0	0	4	4	4	20	20		6	6	6	0	0	0
ECII_1	10	10	10	14	14	14	4	4	4	0	0	0	0	0	0	1	1	1	6	6	6		20	20	11	11	11
EC II_2	10	10	10	14	14	14	4	4	4	0	0	0	0	0	0	1	1	1	6	6	6	20		20	11	11	11
EC II_3	10	10	10	14	14	14	4	4	4	0	0	0	0	0	0	1	1	1	6	6	6	20	20		11	11	11
DCII_1	12	12	12	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11		20	20
DC II_2	12	12	12	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	20		20
DC II_3	12	12	12	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	20	20	

Table 4.1: Similarity matrix of movement patterns (Exp.1, scale 1)

gram. The cophenetic correlation is a measure of how truly a dendrogram preserves the pair wise distances between the original data points. It is defined as 'the linear correlation coefficient between the cophenetic distances obtained from the tree, and the original distances (or dissimilarities) used to construct the tree' (Mathswork). Cophenetic correlation is the correlation between the actual dissimilarities as recorded in the original dissimilarity matrix, and the dissimilarities which can be read off of the dendrogram.

Mathematically, the cophenetic correlation is

$$\rho = \frac{\sum_{i<j}(d_{ij} - d)(d^*_{ij} - d^*)}{\left[\sum_{i<j}(d_{ij} - d)^2 \sum_{i<j}(d^*_{ij} - d^*)^2\right]^{1/2}} \tag{4.2}$$

Here d_{ij} is the euclidean distance between units i and j. d^*_{ij} is the corresponding minimal distance or cophenetic distance between units i and j in the output dendrogram resulting from some particular hierarchical algorithm. d^* is the average distance from a sample size n and defined as following

$$d = \frac{\left[\sum_{i<j} d_{ij}\right]}{[2\,(n^2 - n)]} \tag{4.3}$$

The magnitude of the cophenetic correlation coefficient value ρ should be very close to 1 for a high-quality solution (Mouchet et al. 2008). We have calculated the ρ value against ward, and average method and it gives 0.9790 and 0.9812 respectively.

Multidimensional scaling (MDS; Kruskal and Wish, 1978) can provide an effective ordination of similarities among the variables. MDS is also based on similarities and attempts to find the structure in a set of distance measures between variables. This technique produces a map-like representation that shows the best possible fit for all similarity ratings in two dimensions. Multi dimensional scaling (MDS) result shows clear cluster structure. Animated stimuli are represented by small circle/points. The clusters formed by DC and EC variables are found to be near to each other. Similarly, the cluster formed by NTPP is placed together with the cluster formed by TPP and TPP-II variables. The result also indicate that the PO and PO-II are found to be in one cluster and are quite far from other clusters. Results of linguistic labeling task that participants created are not analysed

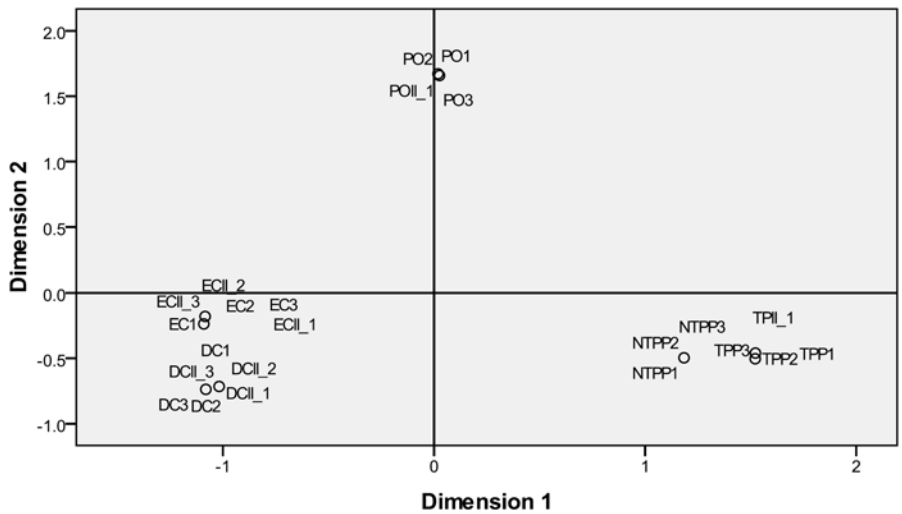


Figure 4.3: Euclidean distance model

in much detail. Number of groups varied from 3 to 7. Table 4.2 shows an example for a participant who created four individual groups.

It is identified that linguistic description for each relation varies. Different verbal labeling is found for DC and EC and some of them are; eingeben nicht (does not enter), hält am Anfang der Stadt (stop in the start of the city), hält ausserhalb der Stadt (stop outside the city), Richtung zur Stadt (towards the city), Das Fahrrad beginnt ausserhalb der Stadt und hält ausserhalb der Stadt(the bike start outside the city and stops outside the city) .Some labeling of all NTPP relations *i.e.* hält im Stadtzentrum (stops in the city centre), im Zentrum (in centre), innenstadt(centre). grouping behaviour of the stimuli is also observed. DC, EC, DCII, and ECII are mostly grouped together, but in some cases ECII is grouped with POII relations and labeled as the bike is leaving / going outside the city. TPP, PO and EC relations are also sometimes grouped together and labeled as das Fahrrad hlt am Anfang / ber der Grenze (Bike is stopping at the beginning). TPP and TPPII is most of the time grouped together and NTPP is found in an individual group in

No. of Groups	Linguistic Description	Stimuli placed in group
1	Das Fahrrad befindet sich im der Stadt	TPP-1, TPP -2, TPP -3, TPP II-1, TPP II-2, TPP II-3
2	Das Fahrrad hält ausserhalb der Stadt	EC-1, EC-2, EC-3, DC-1, DC-2, DC-3 DCII-1, DCII-2, DCII-3, ECII-1, ECII-2, ECII-3
3	Das Fahrrad hält im Stadtzentrum	NTPP-1, NTPP -2, NTPP -3
4	Das Fahrrad hält an der Grenze	POII-1, POII-2, POII-3 PO-1, PO-2, PO3

Table 4.2: Linguistic Description created by one participant in Experiment 1

majority of the cases.

4.1.3 Task Two

Each participant's grouping was encoded in a similarity matrix 55 x 55 (table A.1 in Appendix). The number of animated stimuli corresponds to the matrix columns and rows. Similarity matrix put all possible similarity ratings between two stimuli. After creating a similarity matrix, hierarchical cluster analysis is performed using the similarity measure standardized Euclidean distance. The main reason of using the standardized Euclidean distance is the numerical scale of the variables found in similarity table. If the numerical scale varies then by use of the Euclidean distance, the distance will be dominated by the variables with larger numerical scale (Yang and Trewn, 2004) for example if the range of values on the first variable is greater than the range of values on the second, the n the first variable will hold more weight in determining the similarities among all the objects. Standardized Euclidean distance enables variables to contribute more equally to the similarities among all objects. (Romesburg, 1984,). Given an m-by-n data matrix **X**, which is treated as m (1-by-n) row vectors $x_1, x_2, ..., x_m$, the various distances between the vector x_s and x_t are defined as follows:

Mathematically,

$$d_{st}^2 = (x_s - x_t)V^{-1}(x_s - x_t)' \tag{4.4}$$

where **V** is the n-by-n diagonal matrix whose j^{th} diagonal element is $S(j)2$, where **S** is the vector of standard deviations.

Average, wards's, single and complete linkage methods are applied to cross validate the results. Outcome of ward's method (Figure 4.6) gives compact clusters, while single method (Figure 4.4) gives a chain type clustering. Dendorgrams prepared by all methods shows the seven different categories; Left (L), Right (R), Right Front (RF), Left Front (LF), Right Back (RB) and Left Back (LB). These seven categories are characterized by the participants in experiments. The right and left turn angular boundaries are varying in different groups which mean that no participant grouped perpendicular axis (90° and 270°) alone. It is also scrutinized that angles around 73° to 106° are mostly perceived as right turns and angles around 247° to 286° as left turns. The straight ahead 180° axis is not grouped alone. The clusters formed by right front (turn from 112° to 163°) and left front (turn from 196° to 247°) also shows the right front and left front parts. The right and left back turns are also discriminated from the other sectors.

To compare a model of the similarity behavior to actual behavior in the dendorgram plotted above, we measured cophenetic correlation coefficient for all clustering methods. ρ values (0.970 for average linkage method, 0.9439 for ward method, 0.9707 for single method and 0.9564 for complete method) are very close to one shows that dendrograms plotted from all methods shows a good fit model of similarity behavior.

Linguistic description task that participant carried out following to grouping is not discussed in depth. We find that a participant created nine individual groups; nach links abbiegen (turn left), nach rechts abbiegen (turn right), immer gerade aus (Straight ahead), gerade aus, dann schräg nach links abbiegen (straight, then turn diagonally to the left), gerade aus, dann schräg nach rechts abbiegen (straight, then turn diagonally to the right), gerade aus, dann links abbiegen. Die Strasse

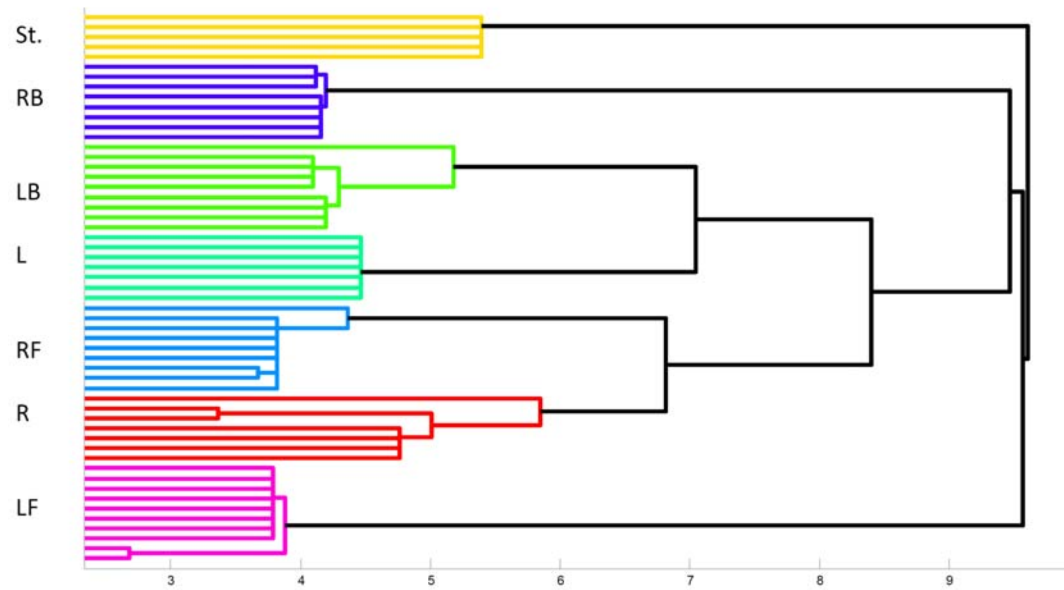


Figure 4.4: Cluster Analysis using Single linkage method for task 2 of Experiment 1

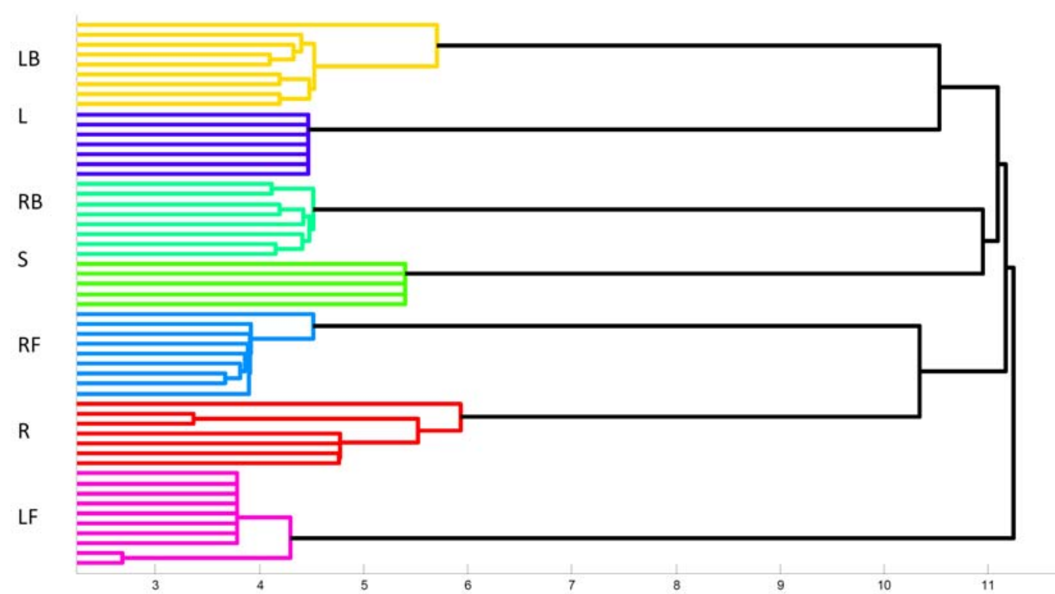


Figure 4.5: Cluster Analysis using Average linkage method for task 2 of Experiment 1

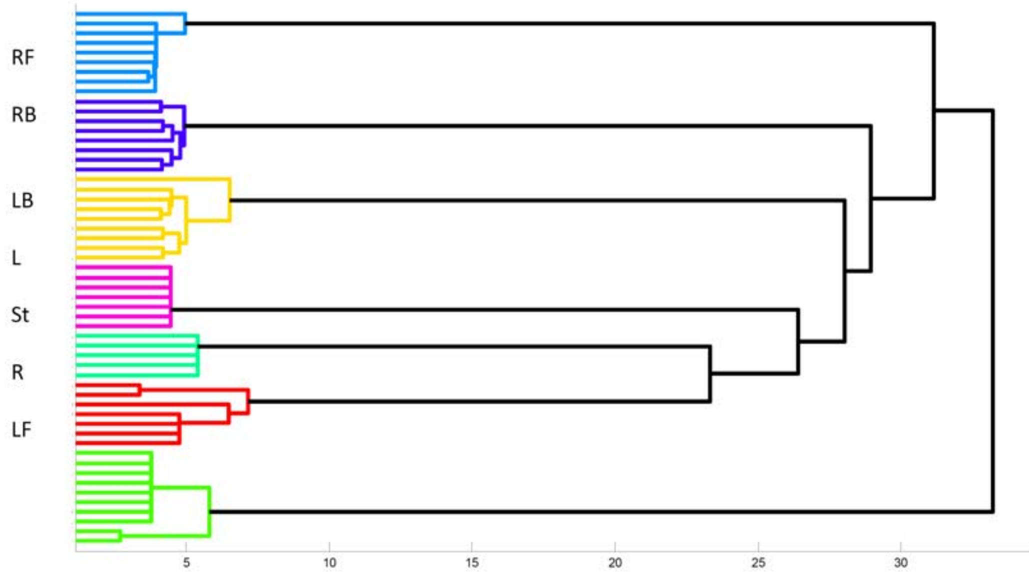


Figure 4.6: Cluster Analysis using Ward's method for task 2 of Experiment 1

macht einen starken Knick, fast parallel zum Anfangsstartpunkt (straight, then turn left. The road makes a sharp bend, almost parallel to the initial starting point), gerade aus, dann rechts abbiegen. Die Strasse macht einen starken Knick, fast parallel zum Anfangsstartpunkt (straight, then turn right. Road makes a sharp bend, almost parallel to the initial starting point), Rechts nach hinten abbiegen (Towards Right back), Links nach hinten abbiegen (towards Left back). In some cases, right and left back turns are also labeled as; Das Fahrrad biegt in eine stark gekrümmte Rechtskurve ab (bike makes a strong right back turn) and biegt in eine stark gekrümmte Linkskurve ab(bike makes a strong left back turn).
Another Seven individual groups created by participants has been described as; nördliche Richtung (North), östliche Richtung (East), westliche Richtung (west), südwestliche Richtung (southwest), südöstliche Richtung, (southEast), nördöstliche Richtung (NorthEast), nrdwestliche (NorthWest).

4.2 Results of Experiment 2

4.2.1 Participants

20 participants (11 females and 9 male) of homogeneous language (German only) from the University of Mnster, Department of physics and Mathematics and University of Duisburg Essen are participated in the experiment. All participants were the university students having different study backgrounds (Chemistry, Physics, Mathematics, Biology and Engineering) including two participants who had the cognitive science back ground. Participant's age was between the 22 to 36 years. The participants took 20-35 minutes for first task and 20 to 50 minutes for the second task. Participants were not paid for the experiment and they performed the experiment on voluntary basis.

4.2.2 Task one

The grouping of each participant results in a 27 x 27 similarity matrix (table 4.3). It is a symmetric similarity and has 729 cells.Likewise the experiment 1, we performed the hierarchical cluster analysis with the default similarity measure of Euclidean distance to analyze the categorical grouping data. Three different clustering methods: Ward, average linkage and complete are used to generate dendrograms. All methods shows a similar clustering structure (Figure 4.7 and 4.8). From the figure 26 we can examine the grouping behavior of the NTPP which is not grouped alone but mostly grouped with TPP and TPP-II relations. TPP, TPP-II and NTPP are found similar to each other than other relations. DC and EC are also conceived as similar. Linkage pattern in shows that TPP, TPP-II and NTPP are seems to be more similar than other relations. All equivalent classes of DC and DCII are appeared in one cluster and same is the case with EC and ECII relations. Clustering structure of DC and EC shows that these are conceptually similar each other. Figure also shows that clusters formed by PO and POII meet at very high distance with the joint cluster of DC and EC which shows a higher dissimilarity.

The magnitude of the cophenetic correlation coefficient value ρ=0.9912 (for

0	DC1	DC2	DC3	EC1	EC2	EC3	PO1	PO2	PO3	TP P1	TP P2	TP P3	NTP P1	NTP P2	NTP P3	TP PII_1	TP PII_2	TP PII_3	PO II_1	PO II_2	PO II_3	EC II_1	EC II_2	EC II_3	DC II_1	DC II_2	DC II_3
DC1		20	20	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	15	15	15
DC2	20		20	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	15	15	15
DC3	20	20		10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	15	15	15
EC1	10	10	10		20	20	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	17	17	17	7	7	7
EC2	10	10	10	20		20	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	17	17	17	7	7	7
EC3	10	10	10	20	20		1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	17	17	17	7	7	7
PO1	0	0	0	1	1	1		20	20	2	2	2	0	0	0	1	1	1	19	19	19	1	1	1	0	0	0
PO2	0	0	0	1	1	1	20		20	2	2	2	0	0	0	1	1	1	19	19	19	1	1	1	0	0	0
PO3	0	0	0	1	1	1	20	20		2	2	2	0	0	0	1	1	1	19	19	19	1	1	1	0	0	0
TPP1	0	0	0	0	0	0	2	2	2		20	20	16	16	16	18	18	18	0	0	0	0	0	0	0	0	0
TPP2	0	0	0	0	0	0	2	2	2	20		20	16	16	16	18	18	18	0	0	0	0	0	0	0	0	0
TPP3	0	0	0	0	0	0	2	2	2	20	20		16	16	16	18	18	18	0	0	0	0	0	0	0	0	0
NTP P1	0	0	0	0	0	0	0	0	0	16	16	16		20	20	14	14	14	0	0	0	0	0	0	0	0	0
NTP P2	0	0	0	0	0	0	0	0	0	16	16	16	20		20	14	14	14	0	0	0	0	0	0	0	0	0
NTP P3	0	0	0	0	0	0	0	0	0	16	16	16	20	20		14	14	14	0	0	0	0	0	0	0	0	0
TP II_1	0	0	0	0	0	0	1	1	1	18	18	18	14	14	14		20	20	2	2	2	1	1	1	0	0	0
TP II_2	0	0	0	0	0	0	1	1	1	18	18	18	14	14	14	20		20	2	2	2	1	1	1	0	0	0
TP II_3	0	0	0	0	0	0	1	1	1	18	18	18	14	14	14	20	20		2	2	2	1	1	1	0	0	0
POII_1	0	0	0	1	1	1	19	19	19	0	0	0	0	0	0	2	2	2		20	20	2	2	2	0	0	0
POII_2	0	0	0	1	1	1	19	19	19	0	0	0	0	0	0	2	2	2	20		20	2	2	2	0	0	0
POII_3	0	0	0	1	1	1	19	19	19	0	0	0	0	0	0	2	2	2	20	20		2	2	2	0	0	0
ECII_1	8	8	8	17	17	17	1	1	1	0	0	0	0	0	0	1	1	1	2	2	2		20	20	8	8	8
EC II_2	8	8	8	17	17	17	1	1	1	0	0	0	0	0	0	1	1	1	2	2	2	20		20	8	8	8
EC II_3	8	8	8	17	17	17	1	1	1	0	0	0	0	0	0	1	1	1	2	2	2	20	20		8	8	8
DCII_1	15	15	15	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8		20	20
DC II_1	15	15	15	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	20		20
DC II_3	15	15	15	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	20	20	

Table 4.3: Similarity matrix of movement patterns (Exp.2, scale 2)

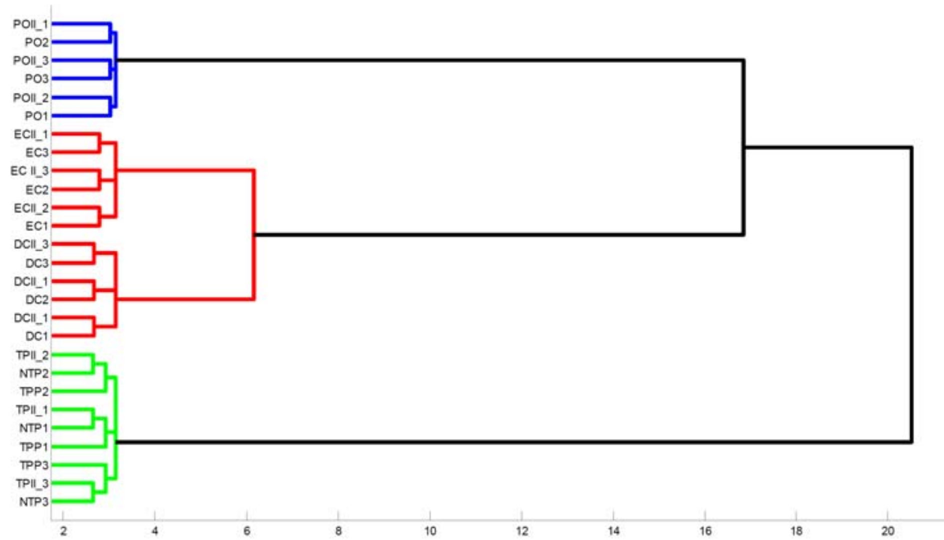


Figure 4.7: Cluster Analysis using ward's method for task 1 of Experiment 2

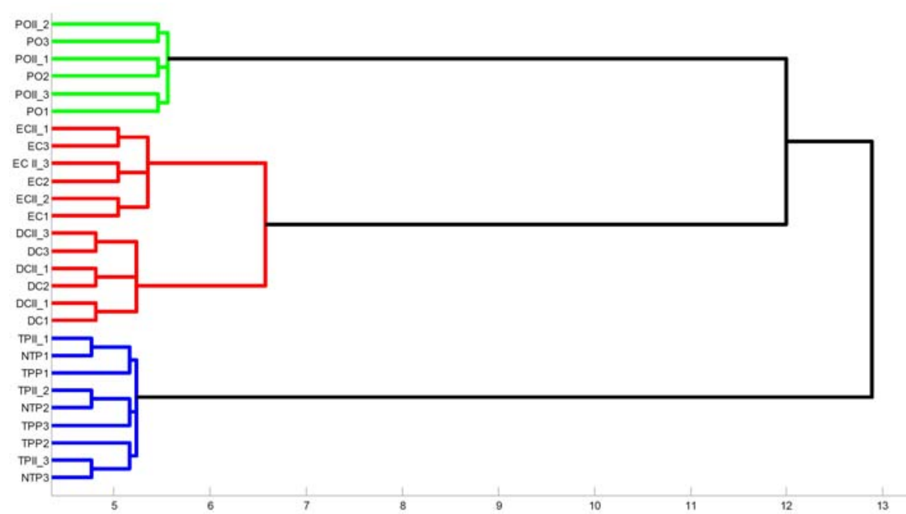


Figure 4.8: Cluster Analysis using Average linkage method for task 1 of Experiment 2

ward's method) and 0.9952 (for average linkage method) validate the faithfulness of dendrogram. Similarly, MDS technique is applied to validate the results. The resultant perceptual map depicts the relative positioning of all variables. From figure 4.9 it is clear that three clear clusters. TPP, TPP-II and NTPP variables are appeared to be in one cluster and far from the cluster formed by DC and EC variables. Both PO and PO-II are placed far away forming one cluster.

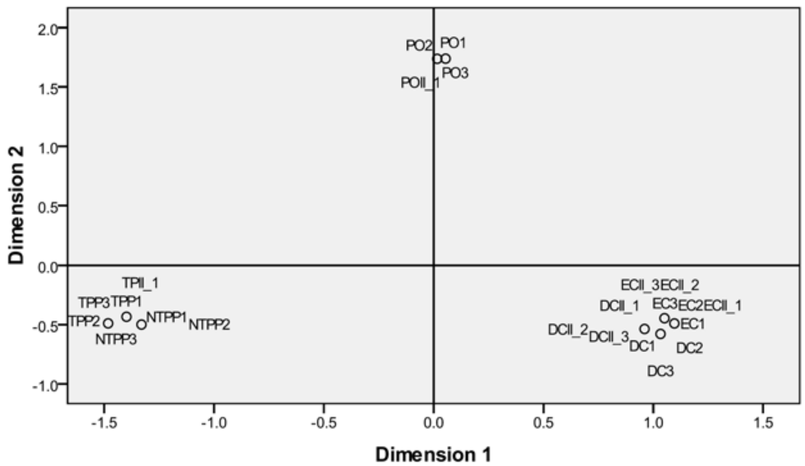


Figure 4.9: Euclidean distance model for scale 2

It is not possible to put all linguistic labeling but some of the description created by participants for different relations can be seen here. For DC and EC we found; Das Fahrrad bewegt sich auf den Park zu, hlt jedoch und befährt diesen nicht (The bike is moving towards the park but stops and does not enter), Das Fahrrad ist entfernt von dem Park (the bike is away from the park), Das Fahrrad ist dabei den Park zu befahren (Bike is about to enter in the park). We also examined that the participants who placed DC-II and EC-II into the same group and described as; Das Fahrrad durchquert den Park (durch den Mittelpunkt) und hält auerhalb des Parks (The bike passes through the centre of the park and stops outside) ,Das Fahrrad verlässt den Park und hlt weit vom Park entfernt (The bike goes out from the park and stops far from the park). If look into the description given to the TPP, TPP-II and NTPP relations we mostly found; innen (inside), Hält innen (stop inside) and hält im des parks (inside the park) . Table 4.4 shows example of linguistic description created by one participant.

No. of Groups	Linguistic Description	Stimuli placed in group
1	Das Fahrrad berührt die Grenzen des Parks.	POII-1, POII-2, POII-3 PO-1, PO-2, PO3
2	Das Fahrrad befindet sich in der Nähe des Parks.	EC-1, EC-2, EC-3, ECII-1, ECII-2, ECII-3,
3	Das Fahrrad hat den Park befahren	TPP-1, TPP-2, TPP-3, TPPII-1, TPPII-2, TPPII-3, NTPP-1, NTPP-2, NTPP-3,
4	Das Fahrrad befindet sich weit vom Park entfernt	DC-1, DC-2, DC-3 DCII-1, DCII-2, DCII-3

Table 4.4: Linguistic Description created by one participant in Experiment 2

4.2.3 Task two

We prepared a similarity matrix 55 x 55 (table A.2 in Appendix). Likewise the experiment 1, hierarchical cluster analysis is performed using the similarity measure standardized Euclidean distance. Reason of using the standardized Euclidean distance is the numerical scale of the variables found in similarity table. Average, wards's, single and complete linkage methods are applied to cross validate the results. Clustering structure does not find to be different as compared to the results of experiment 1. In all dendorgrams seven different categories are found as in experiment one. Figures 4.10, 4.11 and 4.12 shows the results of single linkage, ward's and average method. Dendrogram prepared by ward's method gives compact clustering structure.

To compare a model of the similarity behavior to actual behavior in the dendorgram plotted above, we measured cophenetic correlation coefficient for all clustering methods. ρ values (0.970 for average linkage method, 0.9439 for ward method and 0.9565 for Single linkage) are very close to one shows that dendrograms plotted from all methods shows a good fit model of similarity behavior.

Likewise in experiment one, seven to nine individual groups are created by par-

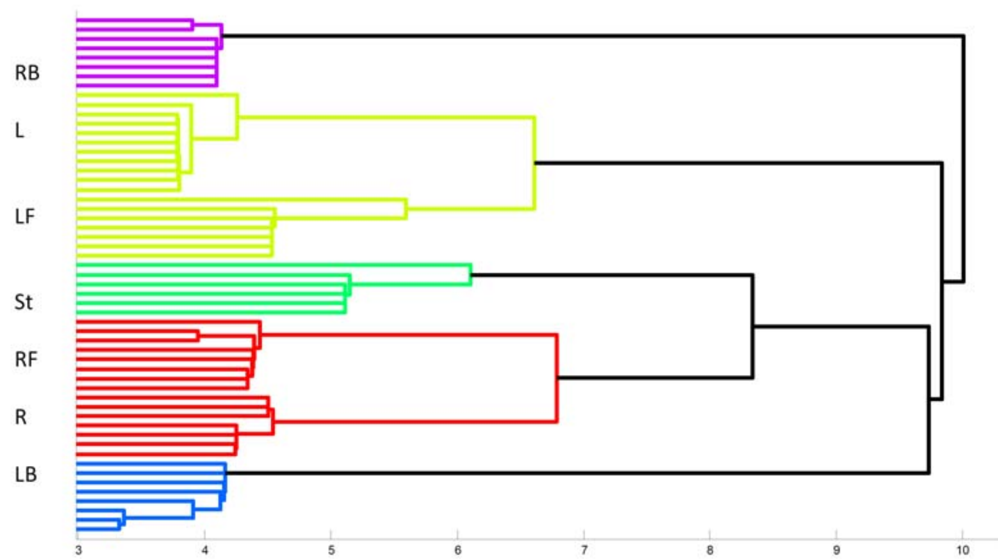


Figure 4.10: Dendrogram generated using Single linkage method (Task 2 of Experiment 2)

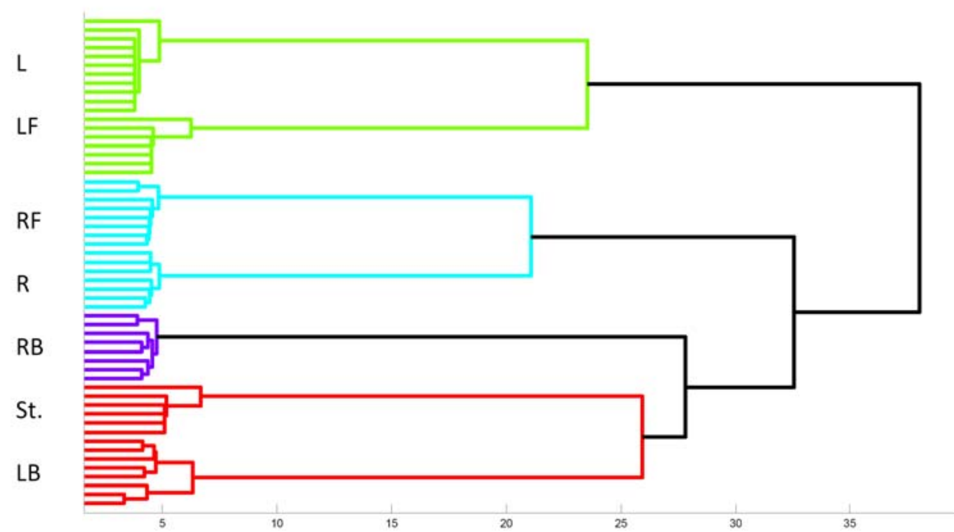


Figure 4.11: Dendrogram generated using Ward's method (Task 2 of Experiment 2)

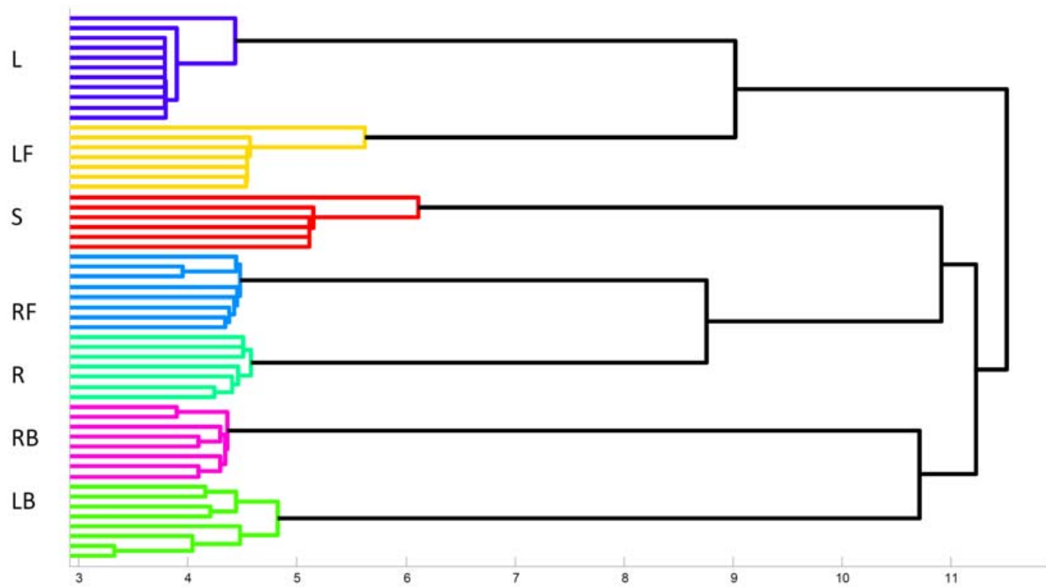


Figure 4.12: Dendrogram generated using Average linkage method (Task 2 of Experiment 2)

ticipants. As an example, for a participant who created seven individual groups; nach links (left), nack rechts (right), immer gerade aus (straight), nach richts oben (right front), nach links oben (left front), rechts nach hinten abbiegen (Right back), links nach hinten abbiegen (Left back). We also find the description of Right front and left front sectors as biegt leicht nach links ab (turn slightly left), biegt leicht nach rechts ab (turn slightly right). Another seven individual groups created by a participant also described in the following way; nach Osten (East), nach Westen (West), nach Norden (North), nach Südosten (Southeast), Südwesten (Southwest), Nordosten (Northeast), Nordwest (northwest).

4.3 General Discussion

The results of experiment 1 on scale 1 (bike and city) show that NTPP is playing a dominant role. Although NTPP is grouped with TPP and TPP-II but in many cases, it is grouped individually. It could be because of the selection of the domain which enables participants to treat this relation as city centre. One justification of this statement might be the status of NTPP in the second experiment with a different scale *i.e.* bike and park where mostly NTPP is grouped with the TPP and TPP-II relations instead of grouped separately. The experiment results are the same as Klippel (2009) that TPP, TPP-II and NTPP are conceptually very close but it is also find that NTPP is mostly categorized single in scale 1, where as in scale 2 *i.e.* bike and park NTPP grouping is found to more with TPP and TPP-II relations. it can be assumed that participants are considering the NTPP relation specifically as city centre in case of scale one which can be shown by their linguistic description they created. While in case of scale 2, mostly it is not treated as specifically.

In both experiments, we find that DC, EC are found close as they are grouped together. Another finding of the study is that DCII and ECII relations are also found in one group but separate from the group formed by DC and EC relations. This shows that DC and EC are treated as the starting point of the path followed by bike and DCII and ECII are assumed as end of the bike path. It is also examine that DC and EC grouping does not make a difference in our selected domain of scale. One reason could be the design and construction of the stimuli and participants assumed that bike path is started only from starting region. It would be an interesting question what would be the results if we have different starting region for different paths of bike.

Weighting the edges in a neighborhood graph (schwering, 2007, Klippel, 2009) is important approach to reflect cognitive perception about the different movement patterns. Fusion coefficient is measured to assign the weights. Fusion coefficient is the measure of the horizontal axis. It is clearly seen in figure 20 of experiment 1 that fusion coefficient for the clusters of DC and EC is 5.594 shows the closeness of the relations and similarly fusion coefficient for cluster TPP, TPPII and NTPP is 5.465 reveals a conceptual closeness between these relations. On the contrary, the fusion coefficient for DC/EC and PO/POII is 10.34, shows a higher dissimilarity. In case of scale two, Figure 26 shows the fusion coefficient for the clusters TPP, TPPII and NTPP is 5.625. It shows conceptual closeness between these relations.

Similarly, fusion coefficient for cluster joining the DC and EC is 6.573. On the contrary the fusion coefficient for clusters DC/EC and PO/PO-II is 12 gives result of higher dissimilarities among these variables.

In the second task of both experiments, the grouping behavior of different direction turns seems not affected by influence of scale. It is found that participants created seven to nine individual groups. The right and left turn angular boundaries are varying in different groups. It is also observed that no participant grouped perpendicular axis alone and is grouped with more than 4 icons. It is also scrutinized angles around 73° to 106° are mostly perceived as right turns and angles around 247° to 286° as left turns. It means that the demarcation of front and back plane is not found which is similar to the results of 'non linguistic awareness experiment 2, the research conducted by Klippel in 2007. Beside, right and left front parts are identified. Angles around (112° -163°) are assumed as right front turns while angles around (196° to 247°) are perceived as left front turns. Furthermore, Back turns and sharp back turns distinction is also recognized which was not expected. It might be because of the technical study background of participants. In sharp direction turns bike is assumed that bike is coming back to its starting position which participants justified in their verbal labeling.

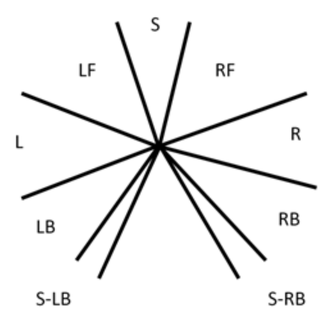


Figure 4.13: Direction Model

Chapter 5

Conclusion

5.1 Research Findings

Qualitative spatial reasoning is frequently used by human beings to understand, investigate and draw results and conclusions in the spatial environment where information is usually available in qualitative form. Topology has a significant role in distinguishing movement paths and has distinguishable perceptual characteristics. It is discussed in detail that how topological relations differentiate the different movement pattern, additionally this research is also focused the influence of scale to characterize the different movement pattern. Two experiments were conducted on two different scale i.e bike and city and bike and park. Nine relations (Klippel, 2009) are followed and applied on a domain with two different scales. One of the most important finding of this study is the difference in the conceptualization of topological relation between two scales. Results conclude that scale has an important role in conceptualization of different topological relations. Non-tangential proper part (NTPP) conceptualization is different in both scales. In case of scale 1 (bike and city), this relation is conceptualized as city centre in human minds and mostly grouped alone. While in case of scale 2 (bike and park) its conceptualization is completely different and mostly grouped with TPP and TPP-II relations. Another important finding of this study is the similar grouping behavior of the TPP, TPP-II and NTPP relations. Additionally, DC and EC are conceptually similar and do not make any difference of characterizing in both scales. In conclusion we found four distinct groups in case of scale 1 and three in case of scale two which is because of the grouping of NTPP. The result of the grouping is found to be more similar to the research conducted by Klippel (2009) but found to be different from the study conducted by Lu and Harter, who showed that humans have the proclivity toward simplification in constructing different temporal relations. Directional relations conceptualization is also a most important aspect of spatial reasoning. We examined influence of scale on the categorization of the direction turns when they are grouped into similarity basis but do not find the diverse results. It is clearly seen from the results that direction turns right, left, front, back and even sharp turns are distinguished and indicate the awareness about the different direction categories in human mind. This research does not find difference in categorization of different direction turn when experienced on two different scales *i.e.* bike and city and bike and park, one factor could be the design of the material and another might be strong technical background of the participants.

5.2 Future Work

This study gives a variety of linguistic descriptions and vocabulary used by human beings to conceptualize the topological and directional relations. On the basis of these various possibilities, a linguistic analysis can be done. The experiments results show that all participants have different technical study back ground. Participants with non technical backgrounds might produce different results. An important issue can involve that this research does not deal in depth about the specific application on small, medium and large scale of environment (Downs and Stea, 1977 & Ittelson, 1973) but only assess the influence of two different scale on the categorization of different movement patterns and directional turns, it would be desirable to assess the similarity and influence on the cognitive classes with specific small, medium and large scale domain. A Similarity assessment with a different stimuli design can also be carried out for comparison. Different design of stimuli might give different result.

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Appendix A

Appendix 1

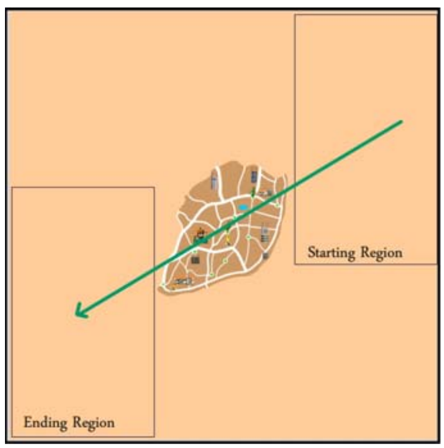

Figure A.1: Second path of bike (animated icon) passing through the city

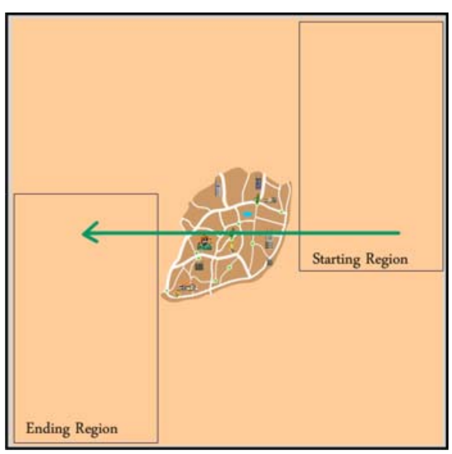

Figure A.2: Third path of bike (animated icon) passing through the city

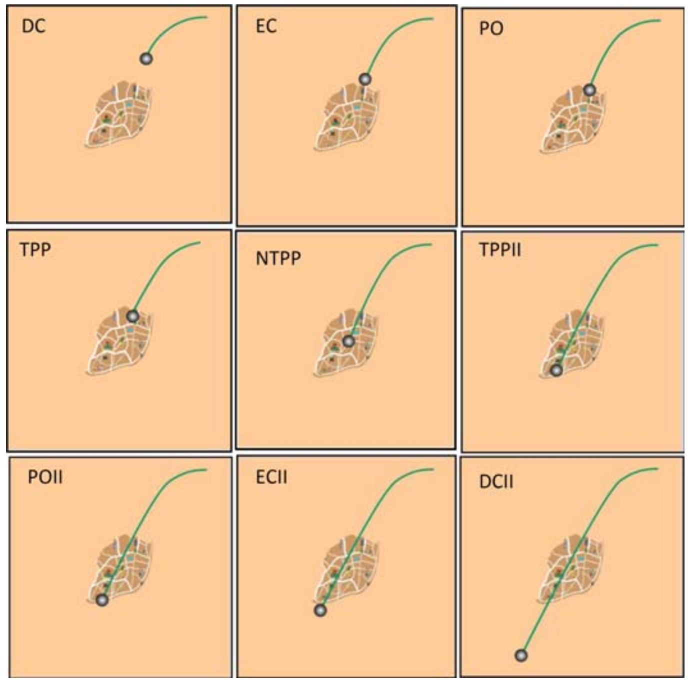

Figure A.3: 9 Different position of bike (path 1)

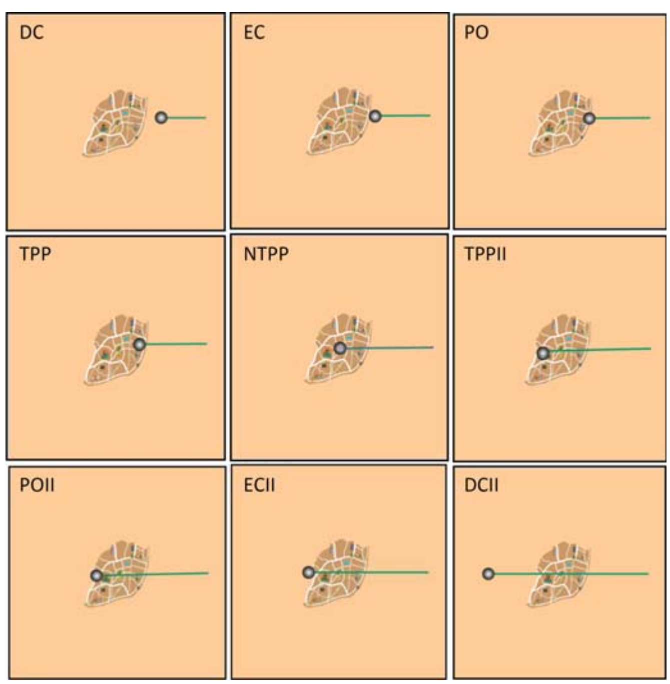

Figure A.4: 9 Different position of bike(path 3)

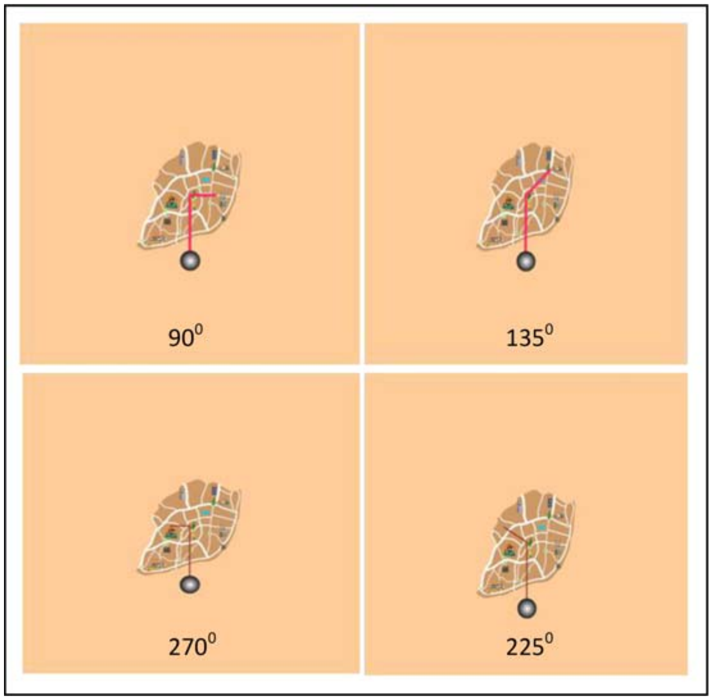

Figure A.5: Different direction paths of bike (Exp. 1, scale 1)

Figure A.6: Path 1 (bike passing through the park)

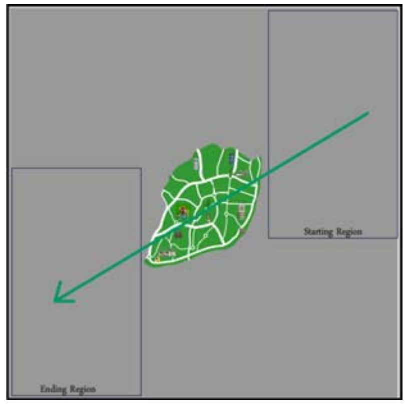

Figure A.7: Path 2 (bike passing through the park)

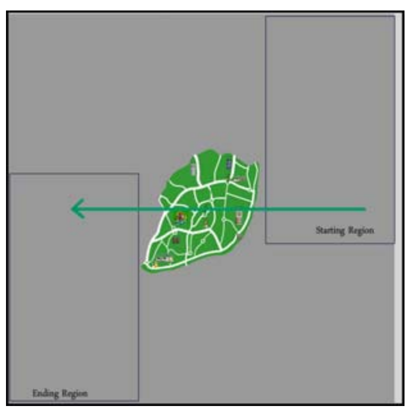

Figure A.8: Path 3 (bike passing through the park)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
1		0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20	0	20	0	20
2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0
3	0	0		0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	20	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	20	0	0	0	0	20	0	0	0
4	0	0	0		0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	20	0	0	0	0	20	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	20	0	0	0	20	0
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6	0	0	0	0	0		0	0	0	0	0	0	0	0	20	0	0	15	0	0	0	0	20	0	0	0	0	15	0	0	0	0	15	0	0	0	0	15	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0
7	20	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20	0	20	0	0
8	0	0	0	0	0	0	0		0	0	0	0	20	20	0	0	0	0	9	0	0	0	0	20	0	0	0	0	20	20	0	0	0	20	0	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
9	0	0	20	0	0	0	0	0		0	0	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	20	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	20	0	0	0	0	20	0	0	0
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52	0	0	20	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	20	0	0	0	0	0	20	0	0	0	20	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	20	0	0	0	0		0	0	0
53	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20	0		0	20
54	0	0	0	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	20	0	0	0	0	20	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	20	0	0	0		0
55	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20	0	20	0	

Table A.1: Similarity matrix of direction turns (Exp.1, scale 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
1		0	0	0	0	0	20	3	0	0	0	0	4	3	0	0	0	0	18	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	0	0	0	4	0	0	20	0	20	0	20
2	0		0	0	0	0	0	1	0	0	0	0	0	1	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0
3	0	0		4	0	0	0	0	20	4	0	11	0	0	0	0	0	0	0	4	20	0	0	0	4	4	20	0	0	0	4	0	0	0	0	20	0	0	0	0	4	20	0	0	0	0	20	0	0	4	0	4	0	4	0
4	0	0	4		0	0	0	0	4	20	1	14	0	0	0	0	1	0	0	20	3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0	20	0
5	0	0	0	0		1	0	0	0	0	16	0	0	0	1	0	16	1	0	0	0	16	1	0	0	0	0	1	0	0	0	20	1	0	0	0	17	1	0	0	0	0	0	17	1	0	0	0	20	0	0	0	0	0	0
6	0	0	0	0	1		0	0	0	0	0	0	0	0	20	0	0	17	0	0	0	0	20	0	0	0	0	17	0	0	0	1	17	0	0	0	1	17	0	0	0	0	0	1	17	0	0	0	1	0	0	0	0	0	0
7	20	0	0	0	0	0		3	0	0	0	0	4	3	0	0	0	0	18	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	0	0	0	4	0	0	20	0	20	0	20
8	3	1	0	0	0	0	3		0	0	0	0	19	20	0	1	0	0	5	0	0	0	0	15	0	0	0	0	19	6	0	0	0	19	1	0	0	0	3	19	0	0	1	0	0	1	0	19	0	0	3	0	3	0	3
9	0	0	20	4	0	0	0	0		4	0	9	0	0	0	0	0	0	0	4	19	0	0	0	4	4	20	0	0	0	4	0	0	0	0	20	0	0	0	0	4	20	0	0	0	0	20	0	0	4	0	4	0	4	0
10	0	0	4	20	0	0	0	0	4		1	15	0	0	0	0	1	0	0	20	3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	4	20	0	0	0	0	0	4	0	0	20	0	20	0	20	0
11	0	0	0	1	16	0	0	0	0	1		1	0	0	0	0	20	0	0	1	0	20	0	0	1	1	0	0	0	0	1	15	0	0	0	0	19	0	0	0	1	0	0	19	0	0	0	0	16	1	0	1	0	1	0
12	0	0	11	14	0	0	0	0	9	15	1		0	0	0	0	1	0	0	15	8	1	0	0	15	15	9	0	0	0	15	0	0	0	0	9	0	0	0	0	15	9	0	0	0	0	9	0	0	15	0	15	0	15	0
13	4	0	0	0	0	0	4	19	0	0	0	0		17	0	0	0	0	6	0	0	0	0	16	0	0	0	0	20	5	0	0	0	20	0	0	0	0	4	20	0	0	0	0	0	0	0	20	0	0	4	0	4	0	4
14	3	1	0	0	0	0	3	20	0	0	0	0	17		0	1	0	0	5	0	0	0	0	15	0	0	0	0	19	6	0	0	0	19	1	0	0	0	3	19	0	0	1	0	0	1	0	19	0	0	3	0	3	0	3
15	0	0	0	0	1	20	0	0	0	0	0	0	0	0		0	0	17	0	0	0	0	20	0	0	0	0	17	0	0	0	1	17	0	0	0	1	17	0	0	0	0	0	1	17	0	0	0	1	0	0	0	0	0	0
16	0	20	0	0	0	0	0	1	0	0	20	0	0	1	0		0	0	0	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0
17	0	0	0	1	16	0	0	0	0	1	0	1	0	0	0	0		0	0	1	0	20	0	0	1	1	0	0	0	0	1	16	0	0	0	0	19	0	0	0	1	0	0	19	0	0	0	0	19	1	0	1	0	1	0
18	0	0	0	0	1	17	0	0	0	0	0	0	0	0	17	0	0		0	0	0	0	17	0	0	0	0	20	0	0	0	1	20	0	0	0	1	20	0	0	0	0	0	1	20	0	0	0	1	0	0	0	0	0	0
19	18	0	0	0	0	0	18	5	0	0	1	0	6	5	0	0	0	0		0	0	0	0	8	0	0	0	0	2	0	0	0	0	4	0	0	0	0	18	4	0	0	0	0	0	0	0	4	0	0	20	0	20	0	20
20	0	0	4	20	0	0	0	0	4	20	0	15	0	0	0	0	1	0	0		3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0	20	0
21	0	1	20	3	0	0	0	0	19	3	20	8	0	0	0	1	0	0	0	3		0	0	0	3	3	19	0	0	1	3	0	0	0	1	19	0	0	0	0	3	19	1	0	0	1	19	0	0	3	0	3	0	3	0
22	0	0	0	1	16	0	0	0	0	1	0	1	0	0	0	0	20	0	0	1	0		0	0	1	1	0	0	0	0	1	16	0	0	0	0	19	0	0	0	1	0	0	19	0	0	0	0	16	1	0	1	0	1	0
23	0	0	0	0	1	20	0	0	0	0	0	0	0	0	20	0	0	17	0	0	0	0		0	0	0	0	17	0	0	0	1	16	0	0	0	1	17	0	0	0	0	0	1	17	0	0	0	1	0	0	0	0	0	0
24	9	0	0	0	0	0	8	15	0	0	1	0	16	15	0	0	0	0	8	0	0	0	0		0	0	0	0	16	4	0	0	0	16	0	0	0	0	8	16	0	0	0	0	0	0	0	16	0	0	8	0	8	0	8
25	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	1	0	0		20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0	20	0
26	0	0	4	20	0	0	0	0	4	20	0	15	0	0	0	0	1	0	0	20	3	0	0	0	20		4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0	20	0
27	0	0	20	4	0	0	0	0	20	4	0	9	0	0	0	0	0	0	0	4	19	0	0	0	4	4		0	0	0	4	0	0	0	0	20	0	0	0	0	4	20	0	0	0	0	20	0	0	4	0	4	0	4	0
28	0	0	0	0	1	17	0	0	0	0	0	0	0	0	17	0	0	20	0	0	0	0	17	0	0	0	0		0	0	0	0	20	0	0	0	1	20	0	0	0	0	0	1	20	0	0	0	1	0	0	0	0	0	0
29	4	0	0	0	0	0	4	19	0	0	0	0	20	19	0	0	0	0	2	0	0	0	0	16	0	0	0	0		4	0	0	0	20	0	0	0	0	4	20	0	0	0	0	0	0	0	20	0	0	4	0	4	0	4
30	0	15	0	0	0	0	0	6	0	0	0	0	5	6	0	15	0	0	0	0	1	1	0	4	0	0	0	0	4		0	0	0	5	15	0	0	0	0	5	0	0	15	0	0	15	0	5	0	0	0	0	0	0	0
31	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	0	0	0	20	20	4	0	0	0		0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0	20	0
32	0	0	0	0	20	1	0	0	0	0	15	0	0	0	1	0	16	1	0	0	0	16	1	0	0	0	0	0	0	0	0		0	0	0	0	17	1	0	0	0	0	0	17	1	0	0	0	20	0	0	0	0	0	0
33	0	0	0	0	1	17	0	0	0	0	0	0	0	0	17	0	0	20	0	0	0	0	16	0	0	0	0	20	0	0	0	0		0	0	0	1	20	0	0	0	0	0	1	20	0	0	0	1	0	0	0	0	0	0
34	4	0	0	0	0	0	4	19	0	0	0	0	20	19	0	0	0	0	4	0	0	0	0	16	0	0	0	0	20	5	0	0	0		0	0	0	0	4	20	0	0	0	0	0	0	0	20	0	0	4	0	4	0	4
35	0	20	0	0	0	0	0	1	0	0	0	0	0	1	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0		0	0	0	0	0	0	0	20	0	0	20	0	0	0	0	0	0	0	0	0
36	0	0	20	4	0	0	0	0	20	4	0	9	0	0	0	0	0	0	0	4	19	0	0	0	4	4	20	0	0	0	4	0	0	0	0		0	0	0	0	4	20	0	0	0	0	20	0	0	4	0	4	0	4	0
37	0	0	0	0	17	1	0	0	0	0	19	0	0	0	1	0	19	1	0	0	0	19	1	0	0	0	0	1	0	0	0	17	1	0	0	0		0	0	0	0	0	0	20	1	0	0	0	17	0	0	0	0	0	0
38	0	0	0	0	1	17	0	0	0	0	0	0	0	0	17	0	0	20	0	0	0	0	17	0	0	0	0	20	0	0	0	1	20	0	0	0	0		0	0	0	0	0	1	20	0	0	0	1	0	0	0	0	0	0
39	20	0	0	0	0	0	20	3	0	0	0	0	4	3	0	0	0	0	18	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0		4	0	0	0	0	0	0	0	4	0	0	20	0	20	0	20
40	4	0	0	0	0	0	4	19	0	4	0	0	20	19	0	0	0	0	4	0	0	1	0	16	0	0	0	0	20	5	0	0	0	20	0	0	0	0	4		0	0	0	0	0	0	0	20	0	0	4	0	4	0	4
41	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	0	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0		4	0	0	0	0	4	0	0	20	0	20	0	20	0
42	0	0	20	4	0	0	0	0	20	0	0	9	0	0	0	0	0	0	0	4	19	0	0	0	4	4	20	0	0	0	4	0	0	0	0	20	0	0	0	0	4		0	0	0	0	20	0	0	4	0	4	0	4	0
43	0	20	0	0	0	0	0	1	0	0	0	0	0	1	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0	20	0	0	0	0	0	0	0		0	0	20	0	0	0	0	0	0	0	0	0
44	0	0	0	0	17	1	0	0	0	0	19	0	0	0	1	0	19	1	0	0	0	19	1	0	0	0	0	1	0	0	0	17	1	0	0	0	20	1	0	0	0	0	0		1	0	0	0	17	0	0	0	0	0	0
45	0	0	0	0	1	17	0	0	0	0	0	0	0	0	17	0	0	20	0	0	0	0	17	0	0	0	0	20	0	0	0	1	20	0	0	0	1	20	0	0	0	0	0	1		0	0	0	1	0	0	0	0	0	0
46	0	20	0	0	0	0	0	1	0	0	0	0	0	1	0	20	0	0	0	0	1	0	0	0	0	0	0	0	0	15	0	0	0	0	20	0	0	0	0	0	0	0	20	0	0		0	0	0	0	0	0	0	0	0
47	0	0	20	4	0	0	0	0	20	4	0	9	0	0	0	0	0	0	0	4	19	0	0	0	4	4	20	0	0	0	4	0	0	0	0	20	0	0	0	0	4	20	0	0	0	0		0	0	4	0	4	0	4	0
48	4	0	0	0	0	0	4	19	0	0	0	0	20	19	0	0	0	0	4	0	0	0	0	16	0	0	0	0	20	5	0	0	0	20	0	0	0	0	4	20	0	0	0	0	0	0	0		0	0	4	0	4	0	4
49	0	0	0	0	20	1	0	0	0	0	16	0	0	0	1	0	16	1	0	0	0	16	1	0	0	0	0	1	0	0	0	20	1	0	0	0	17	1	0	0	0	0	0	17	1	0	0	0		0	0	0	0	0	0
50	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0		0	20	0	20	0
51	20	0	0	0	0	0	20	3	0	0	0	0	4	3	0	0	0	0	20	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	0	0	0	4	0	0		0	20	0	20
52	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0		0	20	0
53	20	0	0	0	0	0	20	3	0	0	0	0	4	3	0	0	0	0	20	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	0	0	0	4	0	0	20	0		0	20
54	0	0	4	20	0	0	0	0	4	20	1	15	0	0	0	0	1	0	0	20	3	1	0	0	20	20	4	0	0	0	20	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	4	0	0	20	0	20	0		0
55	20	0	0	0	0	0	20	3	0	0	0	0	4	3	0	0	0	0	20	0	0	0	0	8	0	0	0	0	4	0	0	0	0	4	0	0	0	0	20	4	0	0	0	0	0	0	0	4	0	0	20	0	20	0	

Table A.2: Similarity matrix of direction turns (Exp.2, scale 2)

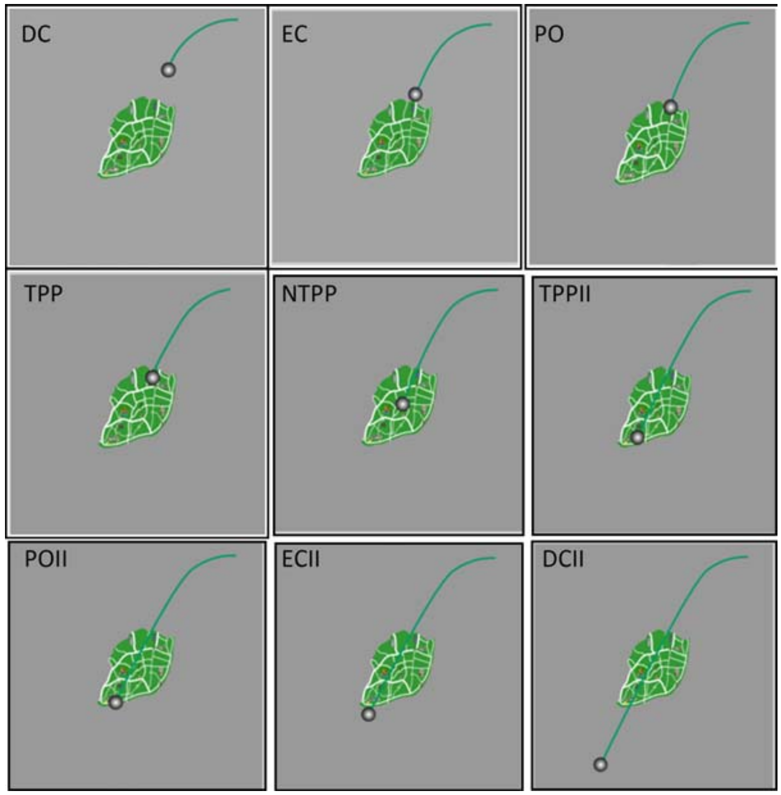

Figure A.9: Nine Different position of bike (path 1)

Variable	Angle	Variable	Angle	Variable	Angle	Variable	Angle
1	95.625	2	168.75	3	213.75	4	275.62
5	332	6	28.125	7	90	8	151.875
9	208.125	10	270	11	315	12	230.625
13	123.75	14	146.25	15	33.75	16	180
17	292.5	18	50.625	19	106.875	20	258.75
21	106.875	22	258.75	23	39.375	24	112.5
25	247.5	26	286.875	27	196.875	28	45
29	140.25	30	157.5	31	241.875	32	326.5
33	56.25	34	118.125	35	174.375	36	225
37	298.125	38	61.875	39	22.5	40	135
41	281.25	42	220.5	43	163.125	44	309.375
45	67.5	46	185.625	47	219.375	48	129.375
49	320.75	50	253.125	51	320.75	52	253.125
53	320.75	54	253.125	55	78.75	-	-

Table A.3: Legend of Simialrity table

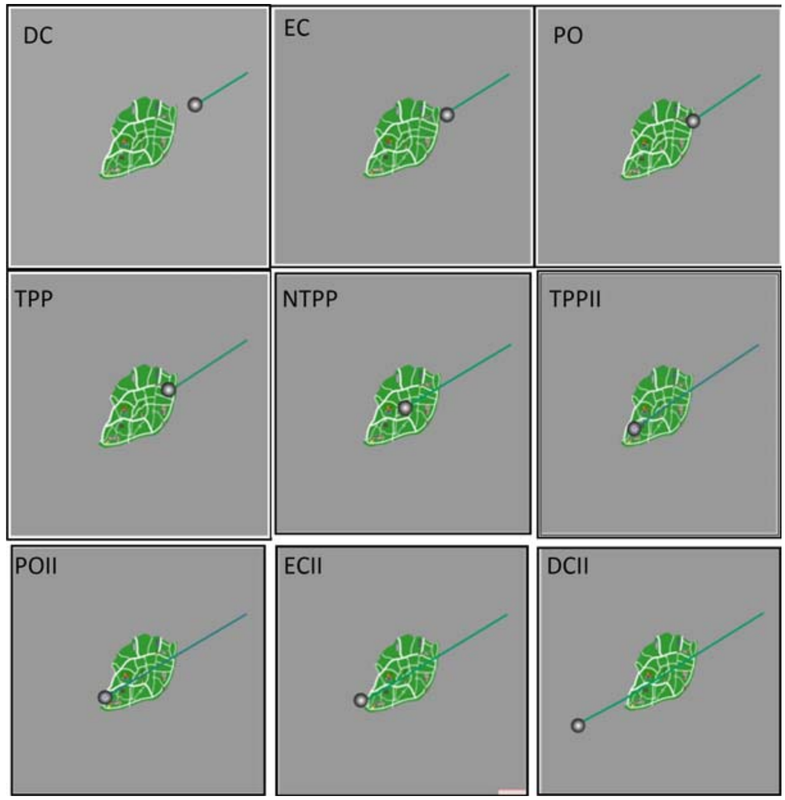

Figure A.10: Nine Different position of bike (path 2)

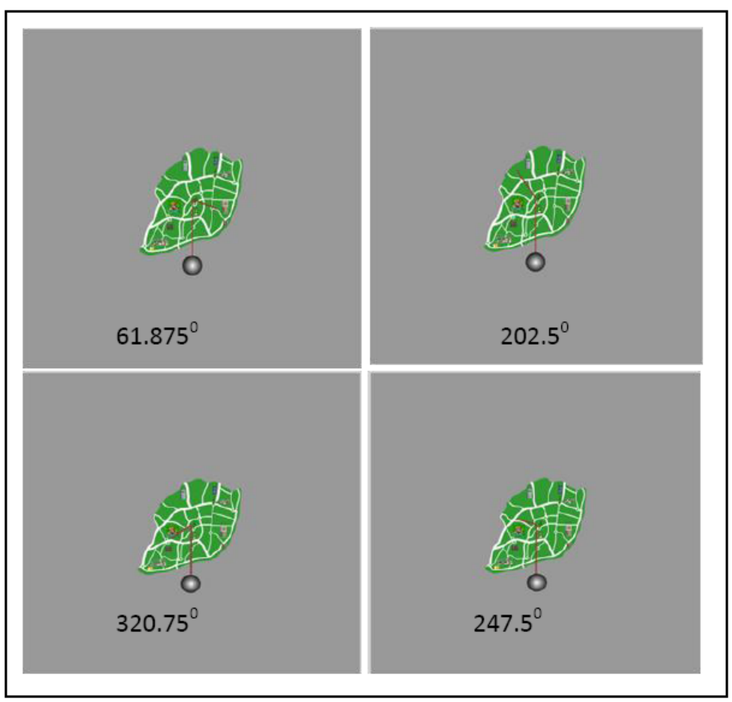

Figure A.11: Different directions of Bike (Exp. 2, scale 2)