A PROPOSED STRUCTURE OF KNOWLEDGE BASED HYBRID INTELLIGENT SYSTEMS FOR SOPHISTICATED ENVIRNOMENTS

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Abstract: The paper deals with a problem of intelligent system's design for complex environments. There is discussed a possibility to integrate several technologies into one basic structure. One possible structure is proposed in order to form a basis for intelligent system that would be able to operate in complex environments. The basic elements of the proposed structure have found their implemented in software system. This software system is shortly presented in the paper. The most important results of experiments are outlined and discussed at the end of the paper. Some possible directions of further research are sketched.

Keywords: Artificial intelligence, knowledge based intelligent systems, hybrid intelligent systems, autonomous intelligent systems, inductive reasoning, deductive reasoning, case based reasoning, associative reasoning.

Introduction

The Artificial intelligence is one of the youngest branches of the modern science.

During a short period of time (lasting only several decades) there have been developed a lot of different technologies and approaches to solve various types of problems existing in the field of artificial intelligence. A complexity of those tasks that can be performed by intelligent systems is growing from year to year. In this paper I would like to keep a closer watch on those intelligent systems that would be able to operate autonomously in complex environments that are close to real world. Obviously, if an intelligent system operates autonomously in a complex environment it needs some kind of environment's model. In spite of model's less complexity it is still quite sophisticated. Though, the basic question is what kind of components is necessary for such an intelligent system in order to maintain and use such a complex environment's model.

Before trying to build a structure of an intelligent system, it is necessary to define the environment in which the system will operate. The basis of such a definition can be found in the assumption that every object (in this case the environment of intelligent system) can be described as a system [Lit.1.] Obviously, a complex environment can be described as a complex system. There are several features that define a complex system [Lit. 2.]:

- uniqueness – usually complex systems are unique or number of similar systems is unweighted.
- hardly predictable – complex systems are very hard to predict. It means that it is hard to calculate the next state of a complex system if the previous states are known.
- an ability to maintain some progress resisting against some outer influence (including influence of the intelligent system).

Of course, any complex system has every general feature of a system such as a set of elements, a set of relations etc [Lit. 3.]

To built a complete model of an environment (complex system) that corresponds to the listed features is either impossible or very expensive. In this case the intelligent system will have incomplete model of environment or will not have it at all. In complex environments usually it is impossible to describe the environment completely. This is caused by a huge space of possible states of environment (or even infinite), expanses or other reasons. It means that an intelligent system in the great part of cases will be using only an incomplete model of environment during its existence.

A very promising way to deal with a complexity and incompleteness is to use some kind of learning mechanisms in order to adjust the intelligent system to new conditions.

A closer watch even on the early methods used in the system theory shows that an analysis of a complex system requires three basic types of reasoning: Deductive, Inductive and Associative [Lit.1,2,3.].

It means that an intelligent system also needs to be able to use all of those reasoning techniques in order to be effective enough.

Basic Features of an Intelligent System

In this section the basic features are outlined and explained according to the previous research activities [Lit.4.].

Summarizing the basic features is:

- an ability to generate a new knowledge from the already existing. This ability can be achieved by means of deductive reasoning. In order to increase an effectiveness a case based reasoning can be used [Lit.5.] Under this feature lies ability to reason logically.
- an ability to learn. This feature can be implemented by means of inductive reasoning. During operation the intelligent system can collect a set of facts through sensing an environment which forms an input for learning.
- an ability to reason associatively. This feature is necessary due to a huge set of possible different situations that the intelligent system can face with. For example, there may be two different situations which can be described by n parameters (n is big enough number) where only k parameters are different (k is small enough number). It is obvious that it is possible to reason about these situations as about similar situations.
- an ability to sense environment. This feature is absolutely necessary for any intelligent system that is built to be more or less autonomous.
- an ability to act. This feature also is necessary for any intelligent system that is designed to do something. If the system (autonomous) is unable to act, it won't be able to achieve its goals.

These features form the basis for an intelligent system that operates in sophisticated environments. According to the features of complex systems that are listed before, any of them can be implemented as it is needed for particular task. The question is how to bind all listed features in one intelligent system.

Obviously, there is a necessity for some kind of integration. There are many good examples of different kinds of integration. For example so called soft computing which combines fuzzy logic with artificial neuron nets [Lit.6.] or Case based reasoning combined with deductive reasoning [Lit.7.].

In order to adjust an intelligent system for some particular tasks different structures can be used [Lit 14].

In this paper I would like to present one of the alternative structures that could be used in order to implement all of the listed features and can form a kernel of an autonomous intelligent system.

Structure of the Intelligent System

According to the list of very basic features there can be outlined the basic modules that correspond to the related reasoning techniques:

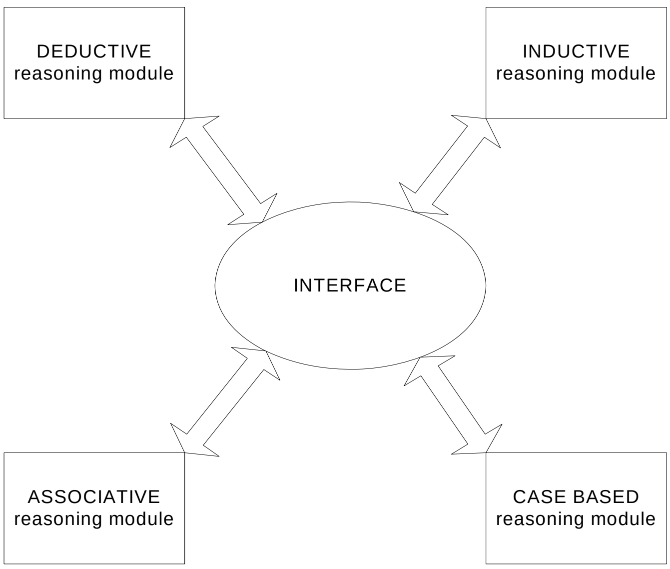

Figure 1. Basic modules

As it is shown in figure 1, there are four basic modules.. As it is said before in complex environments there may be a while of unique situations. To extract (or to learn) any rule an intelligent system needs at lest two equal (or similar – the most part of feature (attributes) are equal) situations. It means that in complex environments a while of situations experienced by an intelligent system may remain unused. Obviously, these unique situations (or cases) may be extremely valuable not only for the intelligent system but also for the researcher that uses the system like it is in medicine. The case based reasoning module is involved to process and use these unique situations.

As it is depicted in figure 1, all of the four modules need some interface to communicate with each other.

Of course, the intelligent system needs additional modules that would supply it with necessary information about the environment and mechanisms to perform some actions. During this research there is developed an alternative structure of the interface that allows combination of four mentioned reasoning techniques. This structure is depicted in the figure 2.

The structure consists of several elements. The fundamental element of whole structure is *object*.

Object. Objects are key elements in the interface structure. They correspond to some kind of entities in the environment (or in the intelligent system). Every object is described with a set of features (attributes). Each feature has some value. As it is depicted in figure 2. objects are linked to each other by associative links. These links form basis for associative reasoning. Two objects are linked if there is any common feature between them. These links can be weighted. The greater weight becomes the more common features are between objects.

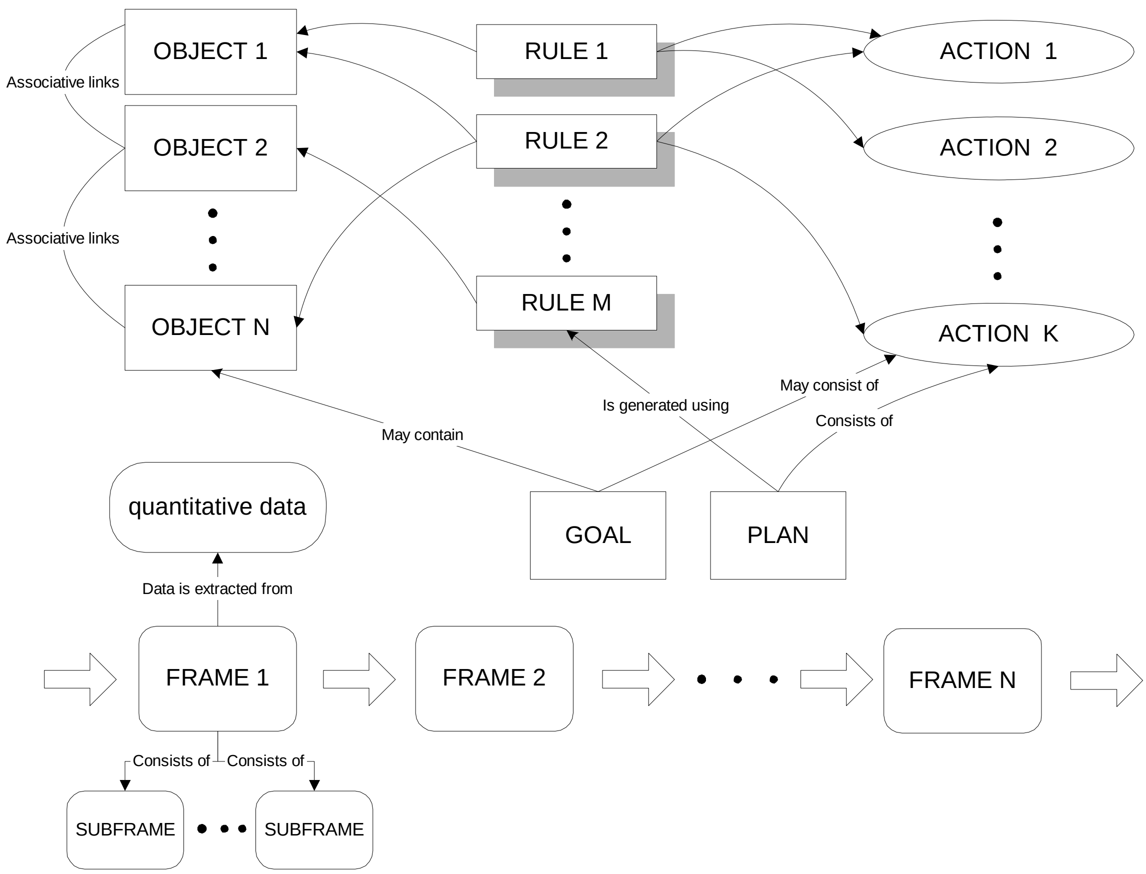

Figure 2. Structure of the interface.

When an intelligent system runs into new situation some subset of objects is activated. These objects map to those entities that the intelligent system currently senses. If there is no rule that can be activated (see below), then the intelligent system may try to activate associated objects where links have some threshold weight. Thus the system can try to reason about objects by using associated rules. The result may be less feasible, but using association between objects the system can run out of the dead end situations. Associative links can spread the “activation” through the whole net of objects if the links among them are strong enough.

A mechanism of associative memory is very useful when the system works with noisy data. This mechanism allows to correct faults of the sensing mechanism [Lit.8.]. For example, if the input vector of the sense which corresponds to some entity has some uncertain or incorrect elements (attributes of object) then the system would not be able to activate any of the objects. In this case associative memory mechanism will activate the closest object [Lit.8.] thus the sensing error will not have significant effect on the reasoning process.

Rules. Rules are any kind of notation that represents causalities. In the practical experimentations were used a well known *if..then* notation. As it is depicted in the figure 2 rules are linked to objects and actions. Each rule may contain a reference to some objects (or its attributes). Therefore if the rule contains such a reference then it is linked to the object. These links help to reduce a searching space and forms a basis for associative reasoning. Each time when the intelligent system receives a new situation, there are activated those objects that are sensed by the system. Linked rules are also activated. The system searches for suitable rules only in the set of activated rules. When system activates objects by using associative links linked rules also are activated thus system can scan also a set of "associated" rules. This ability can significantly improve system's ability to adapt. As it is depicted in figure 2 rules are linked to actions. Rules (for example, those of type *If..Then*) may reference not only to facts but also to actions.

Actions. Actions are some kind of symbolic representation that can be translated by the intelligent system and cause the system to do something. For example "*turn to the right*" causes the system to turn to the right by 90^0.

Actions may be structured in hierarchies. Thus a system can built high level actions that consist of a set of basic actions. For example an action "*open the door*" may consist of two lover level actions: "*unlock the door* " and "*push the door*". High level actions may be formed like scenarios. A scenario can consist of a sequence of lover level actions. It means that rules referencing to the high level actions do not need to reference to each of the basic actions.

The scenarios of actions can be formed as sequence of actions that drive the system to the goal. It means that actions of high level in some way are representation of the positive experience of the system.

Each action consists of three parts: precondition, body and postcondition. Precondition is every factor that should be true before the action is executed. For example, before opening the door it has to be unlocked. Body is a sequence of basic (or lover level) actions. Post conditions are factors that will be true after the execution of action. For example after opening the door, the door will be opened.

2 actions may be sequenced one after another if the following is true:

$$c \in C, C = c' \cup Z ,$$

where c ' – a set of postconditions of the first action
Z – a set of current conditions (known facts)
C – a set of precondition of the second action

Frames. Frames are some kind of data structures that contain the sense array from environment and from the system. It means that frames contain snapshots of the environment's and the system's states.

As it is depicted in figure 2 frames are chained one after another thus forming a historical sequence of the environment's and the system's states. Frames can be structured in hierarchies. Hierarchies help to see values of features that can not be seen in a single snapshot. For example motion trajectories of some object e.c.

Frames are the input for learning (induction module) algorithms. It is obvious that queue of frames can not be infinite due to bounds of hardware equipment. It means that there should be used some "forgetting" mechanism that determines the length of the frame sequence.

Goal. A goal is some kind of a task that has to be done by the system. It can be defined in three ways: as a sequence of actions that should be done, as some particular state that should be achieved or as a combination of actions and states.

Goals can also be structured in hierarchies that determine the priorities of different goals.

Plan. A plan is a sequence of actions that the system is trying to accomplish. It can be formed using both basic and complex actions. After the plan is accomplished it is evaluated depending on whether the goal is achieved or not.

Quantitative data. This element is used to maintain any kind of quantitative data that is needed for the system. For example it can contain certainties about facts or rules, possibilities e.c. A source of quantitative data is the chain of frames.

All of those components together form the interface for the basic modules: Inductive, Deductive, Case based and Associative reasoning.

Fundamental elements of the structure are implemented in experimental software.

Practical Implementation

As it is mentioned above, fundamental elements of the proposed structure are implemented into experimental software.

The implemented elements are: Case based reasoning, Inductive reasoning and Deductive reasoning. Deductive reasoning is implemented as a statement logic module based on rules designed in *if…then* manner. The induction module is implemented using well known algorithm ID3 [Lit.9.] It has its more effective successor C4.5 [Lit.10]. The case based reasoning module is implemented using pairs {situation, action}. Each of such pair has its value which determines how effective it is in particular case. During the planning this value determines which actions are selected if more then one action may be selected.

The environment is implemented as world of rabbits and wolf (domain of pray and hunter). There are defined additional objects “obstacles”. The number of rabbits and obstacles is not specified. The intelligent system is implemented as wolf. Rabbits may be moving or standing at one place. Wolf can catch rabbits. The wolf is moving according to its plan. User can freely change number and place of obstacles and rabbits. The goal can defined and changed at any time.

The intelligent system demonstrates flexibility of the proposed structure. The results of experiments and experience accumulated during the implementation shows that new types of objects can be introduced without changing the proposed structure. The goal can be changed freely.

It means that even being incomplete this structure demonstrates good ability to adapt and to operate

I believe that implementation of the whole structure can give very flexible system that would be able to operate in more complex environments.

Possible Advances and Future Research

Obviously there may be such tasks that can not be done using a single intelligent systems. In other words there may be a task that could be done only by a set of intelligent systems. For example, simulation of real world (battlefields, transport systems e.c.) It means that intelligent system has to be ready to negotiate with other intelligent systems that may be built using different kind of technology. It does not mean that always it is necessary to communicate.

This question is under discussion among researchers working in the field of multiagent systems.

There are different ways to design multiagent system [Lit.11., Lit 12]. In different domains there can be different solutions. Before designing a system for operating in a multiagent environment several questions should be answered.

Some of the basic questions are:

- Will the agents be able to communicate?
- How the agents will communicate to each other.
- What resources they will shared and what resources will stay unshared
- How the conflicts will be solved.
- Of what type the agents will be (competitive, cooperative e.c.)

Only after answering on those questions the intelligent system can be adjusted according to the collected answers.

Referencing to the said above, there may be outlined one of the directions of farther research and experiments – adjustments of the proposed structure in order to allow the intelligent system operate in a heterogeneous communicating multiagent environment. This is the most sophisticated type of multiagent systems [Lit.12.] and the most interesting form the point of view of research. The structure adjusted for such an environment should be able to operate in less complex environments.

One of the most sophisticated problem in such a multiagent environment is communication because every of communication parameter may be variable. It is easy to imagine that two intelligent systems may try to communicate using different knowledge representation schemas, different knowledge, different communication protocols, different type of "conversation" (for example: questioning, answering, argumentation e.c.) or even different physical communication channels (radio frequency, verbal communication e.c.). All said means that it is almost impossible to design an intelligent system that would be able to adjust its communication mechanism to all possible variations. It means that the system should be design for one or few of the possible communication standards. Which one to choose? May be some of the existing standards should be used [Lit.13.]. This question is to be answered only after a deeper analysis. This is the second possible direction of farther research.

In the field of practical research and experimentation the next step is to design an experimental intelligent system that would be an implementation of the whole proposed structure in order to carry out more complex experiments using different environments and different goals.

The other practical experiments that are of my special interest are experiments with some kind of robotic system in order to try the proposed structure in the field of motion control.

Conclusions

Practical experiments show that the proposed structure may be very flexible even in very changing environments with variable goals. It means that it is reasonable to carry out farther research and experiments in order to advance this structure.

Some problems are related with amount of processed data during the reasoning that significantly slows down the whole system.

It means that an optimization of the processes needs to be a part of future activities.

In spite of the quite promising results that are collected during the practical experiments there are still a lot of open questions that should be answered in farther research activities.

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