A behaviorist knowledge representation

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Abstract: In this paper we propose a behaviorist representation of knowledge imagined like a three level structure. The first level is a strategically level the second is a tactical level and the third is an operational level. The first level is necessary for the problem solution the second for the solution implementation and the last for the solution execution. Each level feedback information which are used in (learning) developing the previous level. The paper presents also a case study about such a structure designed for an autonomous car.

Key-Words: Artificial intelligence, Knowledge representation, Behavior

1 Introduction

The sixty year history of Artificial Intelligence (AI) can be structured in three predominant approaches. The first approach during (1950-1960) is known as weak method problem solving and is represented by the Logic Theorist (Newell and Simon 1956, 1963). Based on logical deduction methods this first theme has been able to prove mathematical theorems but failed in commune sense judgments modeling. It has been proved that a single heuristic can not be used in all problems solving.

The second approach during from 1970- until nowadays is known as the strong method problem solving. This theme used explicit knowledge of a particular domain. Expert systems are one of the results of this approach. The third approach is known like agent based approach to intelligence (Brooks 1987, Clark 1997). This theme avoids the requirement of having any centralized knowledge base or general inference scheme.

In using strong method the following assumptions about the nature of intelligence are made (Brian Smith 1985): knowledge can be represented propositionally and the behavior of the system can be seen as formally caused by the propositions in the knowledge base.

The semantic of predicate calculus and the nature of human understanding have been the mains researches directions in all mentioned approaches.

One of the attempts to model the semantic structures is the Schank’s (1974) conceptual definition theory. The same author designs the scripts (1977), which are structured representation describing stereotyped sequence of events in a particular context. Minsky (1975) have developed the concept of frame: a static data structure used to represent well- understood stereotyped situations.

More modern representation used in natural language program are the John Sowa’s (1984) conceptual graph and the Brook’s (1991) alternative the subsumption three level architecture for robots. It is important to mention that for Brooks the intelligence is the product of the interaction between an appropriately designed system and its environment. Our idea starts fro this point: the need to design a system which allows interaction – in a specific way - with the environment and learn from these interactions. By specific way we understand an interaction based on known behaviors collections. By learning from the mentioned interaction we understand the possibility to develop the behaviors collections.

Our paper is structured in the following parts: a conceptual description of the proposed three levels knowledge representation diagram, followed by a state case where a part of this diagram have been designed and used for an autonomous car application; conclusions and future work intentions will end the paper.

2 The behaviorist knowledge representation

Present paper proposes a three level knowledge representation consisting from the following parts (see figure 1):

- The strategically level, who transform the user goal in to a strategy. In fact this is a problem solver engine composed from a hypothesis database, a procedure which choose the best hypothesis and transform it in to a strategically solution. In order to allow the learning process this level contains procedures needed for new hypothesis construction.
The tactical level. The function of this level is to transform the strategically solution into a tactical solution. For this reason a behavior database is queried for solution. A behavior is a network of actions used to implement a part of the strategy. Step by step the tactical solution becomes a network obtained from dynamical linked behaviors. In order to allow learning this level contains procedures needed for new behavior construction.

The operational level. The function of this level is to manage the tactical solution. More precisely to trigger and control each action from the mentioned network and to read the sensors. If the sensors confirm the control solution the operational level will continue the tactical solution if not new tactical solution are need.

From the proposed diagram (see figure 1) it can be seen that the goal (task, problem) is transformed into a hypothesis by a Strategically solution block, which operate also with the Hypothesis Database, - a collection of strategically solutions – the Tactical Report block – information about the failure of the tactical solutions – and the New Hypothesis block – a procedure which construct new hypothesis.

The selected hypothesis will generate a behaviors network into a Tactical solution block. For this reason the mentioned block is also linked with: the Behaviors Database – a collection of behaviors - the Sensor Fusion block – a set of information of the environment – and the New Behaviors block – a procedure used to generate new behaviors.

The current behavior contains a set of actions which are triggered by Control solution block.

The proposed diagram contains all the three level of information processing: the abduction – where from several hypotheses the best is selected – the deduction - where the Goal is transformed into a hypothesis or where the hypothesis is transformed into a behavior – and the induction – used in new behaviors or new hypothesis constructions.

In the next section a case study is presented where a part of this diagram was designed to control of the ACC autonomous car [16].

3 Case study: the autonomous car control system

Because the following case study is related to an autonomous car control system design, some discussions about other ideas are necessary. From the references ([1],[8]) we know that the “Driver’s Behaviour” model is used in the simulation field [3], [4] and also in autonomous or mixed manual and autonomous field [2]. The first researches on the subject start in 1950 [3] and begin with the “Skill-based driving model”. continue with the “Motivational model” which considers the drivers emotional state (from this class we can enumerate the “Risk compensation”; “Risk avoidance” and “Risk threshold models”) and in the last years is developed in a “Hierarchical control structure” (by Milchon). The “Hierarchical control structure” divides driving into three levels of control: a strategic
level which establishes the goal of the driving; a tactical level which finds the solution to accomplish the goal; an operational level that implements this solution on the low level control of the vehicle. Behind this “Hierarchical control structure” many scientific papers consider and develop problems like: “Longitudinal behaviors models” [2]; “Lateral behaviors model” [5], [1]; “Brake behavior” [2] etc. The solutions of these problems are varied: “Linear optimal Control”, “Heuristic human driver models”, “Adaptive control strategy”, “Neuronal Network and fuzzy logic”, “Mental models”, etc. Architectures which model de human behaviour are presented in [3] and [4]. Some conclusions about these briefly overviews are the following:

- In the scientific literature referring to “Driver Behaviour Model” we have found several results which can be adapted and used in the ACC robot control;
- Recent works accept the Milchon three levels architecture;
- Many papers are focusing in developing the tactical level where the program must find the solutions in condition of changeable driving circumstance.

Our idea starts from this point: we consider that is more suitable to model, and implement the “human driver decisions act” than the “human driver actions”, an for this reason we have used the diagram presented in figure 1.

To obtain the human driver behavior a preliminary analyze must answer to the following questions: “how a common driver acts, or what is a driving behavior?”; “can we obtain some fundamental true about this behavior and use them in our construction?” and more “can we identify tools to transpose this behavior in soft?”

To answer to the first question we must give the definition of the “behaviour” by underlining the semantic characteristics of “Driving behaviour”. First it is important to establish the category tree of this word: from [15] we have \( \{ \text{act} \rightarrow \text{activity} \rightarrow \text{behaviour}, \text{practice},...\} \). According to this the behaviour is: “an action or a set of actions performed by a person under specified circumstances that reveal some skill, knowledge or attitude”. From the scientific literature which concern the driving behaviour ([1]...[8]) and from our experience the driving behaviour has a special character. To describe this character we focus on the word “custom” which is from the same category tree \( \{ \text{act} \rightarrow \text{activity} \rightarrow \text{practice} \rightarrow \text{custom},...\} \) and which is defined like: “accepted or habitual practice”. In many situations these customs have a special nature: automatism: any reaction that occurs automatically without conscious thought or reflection. Now we can present what we understand by “Driving Behaviour”: an action or a set of actions performed by a person under driving circumstances, action which tend to be transformed in customs and even in automatisms; in fact the “Driving Behaviour” is composed from a collection of behaviors (the driver’s behaviour when he makes the ignition, the driver’s behaviour when he stops the car,...).

From the same theoretical and practical research, we establish the following “fundamental truth” for the “Driving Behaviour”:

- A priori the driver establishes the current driving goal;
- A behaviour is a set of actions;
- These behaviors are linked together creating a system which allows to obtain solutions in the driving circumstance;
- The translation from one behaviour to other is triggered by brow casting an event;
- This system is developed by learning - experience;
- Behaviors presume decisions with an incomplete set of information;
- In time, these set of actions tend to be transformed in customs and automatisms.

These propositions are in accord with the well known three level architecture of Milchon: the strategically level where the driver establishes his goal, the tactical level where the driver finds the solution to accomplish the goal and the operational level where the driver implements these solutions. Using these propositions we can focus on the tactical level and model (approximate) the “Driving Behaviour” by a collection of high linked programs (behaviors) which are stored in a memory. The decision to run a certain program is made by a Tactical Solution program. This decision is based on the goal of driving and acknowledging about the environment (driving circumstance). Each program (behaviour) is a succession of instructions (action) which impose parameters and trigger actuators.

For a better understanding of this concept we will compare it with the well know Lego toys concept where several buildings (goals) can be made (solve the driving circumstance) using a finite type of bricks (program - behaviour). Using this analogy we will underline that it is very important to provide the interconnections of the bricks, and have an appropriate collection of them.

After we have answer to the analyze questions a graphical representation of all these results will make our concept more understandable (see figure 2). Some explanations are necessary:
The strategically level, where the robot must transform his goal into a hypothesis is replaced with an interface where the human operator imposes the hypothesis;

The Tactical Solution analyzes the hypothesis in the driving circumstances which are obtained from the sensors; the result of this process is the status vector of the robot (the desired position, velocity, etc.) and the decision to run certain program from the “Behaviors” subsystem;

The “Output Interface” allows to the human operator to read the state vector and the errors of the robot and also memorizes the robot state history;

The “Actuators Communications” outputs data to the microcontrollers of each actuator;

The “Sensors” inputs data from the sensors.

To build the “Behaviors” subsystem it is important to imagine the structure of the programs (bricks). Understanding that this subsystem can, and will, be enriched in figure 3 we proposed three different structures, named: “basic behaviors”, “error behaviour” and “simple behaviour”. The main differences between these bricks are the connection type (P previous, N next, E error, QI quick in, QO quick out) and also the direction of information flow.

The decisions, about which brick must be connected, are made by the Tactical Solution. This program compares the goal of the robot with the driving circumstance; establishes the status vector and enables the brick which must run. After these decisions the program continues to compare the robot goal with driving circumstance. If the result is acceptable, nothing is changed (the same brick is run), in contrary, a “Crisis” or a “Failure” event is brown caste. “Crisis” means that a new behaviour is needed, so the status vector as well as the brick is changed. “Failure” means that we don’t have solutions (behaviors) to solve the problem and we must stop safely the robot. We present these processes by using the diagram represented in figure 4.
Conclusions about the program architecture are necessary:

- The structure of the program is a three levels type structure;
- In this case the goal of the robot is imposed by the human operator via the “Input interface”;
- The tactical level finds solution, linking several programs (bricks). A brick is a succession of action; an action sets up parameters and trigger actuators;
- The human behaviour approximation consist in modeling the human decision process and not the human acting process;
- There are two control loops:
  - A high level control solved by the **Tactical Solution**: goal (robot status) versus robot performance (robot state),
  - Operational level control, low level control solved by each actuator microcontroller, desired value versus current value.

![Diagram](image)

**Figure 5**
The ACC control program

This paper presents only partial results on our control program construction. The control program is made in Matlab and use the xPC toolbox. We have started by creating the communication tools, via CANopen network, between the actuators, sensors and the control program. Using these tools we have created the operational level.

The next step was the “Behaviors” subsystem composed by several “bricks” which allows to: start the car; stop the car; perform emergency brakes; follow a desired trajectory etc. Based on this architecture, the control program plotted in figure 5, past successfully the experimental test.

4. Conclusions

Present work continues the research program, of the human knowledge, finance from CNCSIS 842/2009 project, by proposing a knowledge representation diagram. The starting idea is that intelligence is based on appropriate designed system and on interactions with environment. This is a three level diagram formed from a strategically, tactical and operational levels.

The functions of these levels are: to transform the goal in to a strategically solution, to transform this solution in to a tactical solution consisting on a behaviors network and to interact with the environment. Each of the three mains human mental process: abduction deduction and induction are modeled with this diagram.

The second part of the paper present a case study. The ACC autonomous car control system construction is inspired from the proposed diagram. We must underline that it was designed only a part of the mentioned diagram.

Future research works will focus on designing the procedures who allows the new behaviors and hypothesis design.

**References:**


