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An Agent Based Simulation for Testing the Emergence of Meaning

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Abstract: To understand the essence of meaning is a crucial point to build intelligent systems. It is proposed that meaning emerges if an agent starts to distinguish objects or events that have positive or negative impact on survival and to prefer desirable and avoid undesirable states. In this paper a simulation is proposed to evaluate whether it is possible that from a random initial configuration with the help of an evolutionary process an evaluation system emerges that helps an agent to distinguish and gather energy rich resources and to avoid dangerous matter.
Keywords: Meaning, agents, artificial life, evolutionary computation.

1. Introduction

For humans and other living organisms the surrounding environment has some meaning. Everything an organism senses signifies something to it: food, fight, reproduction [15]. The understanding of the essence of meaning seems to be a fundamental question to build artificial intelligent systems that would be able to communicate with humans using a language. A language consists of symbols and rules for manipulating these symbols. Meaning is associated with the symbols that stand for entities in the world. Symbols are arbitrary and there is no relation between the shape of the symbol and the object or event the symbol refers to. In semantics some more complex languages are used to describe the meaning of symbols.

Harnad raised a question how an arbitrary symbol system can be grounded in the other meaningless symbols and how words actually get their meaning [12] and names this problem a symbol grounding problem. To solve the problem an overview of different approaches is given by Taddeo and Floridi [21]. All the approaches ground the symbols through sensorimotor capacities of an agent. But the non-representational approach expects there is no need to use symbolic representation for grounding and the meaning is grounded in the environment, e.g., the physical grounding hypothesis proposed by Brooks [2].

The relationship between the symbol and the object or the event in the world does not explain why such a phenomenon as meaning arises. An approach to explain the meaning is the control metaphor proposed by Cisek and it based on the idea that organisms behave so that they could get the right stimulus [5]. Objects and events mean to the agent whether they support survival or not and whether they enable to achieve desirable or avoid undesirable state (simply by making a distinction between good and bad). In this paper the results of the simulation are presented that test whether from a random initial configuration and with the help of an evolutionary process such a control loop, making a distinction between good and bad, can emerge.

In this paper some basic introduction to the study of meaning is given. Thereafter an experiment is composed and executed to test the hypothesis that meaning can arise through an evolutionary process. Finally, the results of the simulations are discussed.

2. Study of Meaning

The meaning has been a philosophical issue but has now turned more to be as a scientific issue without having some mythical background. According to the classical approach, the meaning is a relationship between the things (signs) and their meaning (what they intend, express or signify). In semantics a more complicated language is used to describe the meaning, e.g., a semantic lexicon system WordNet [17]. The database consists of words and their mutual relations.

To solve the symbol grounding problem Harnad expects that the symbols and their meaning can be grounded if reference between objects or events and symbols is built up [12] [13]. Harnad's model consists of three kinds of representation: iconic representation – receiving sensory signals, categorical representation – recognition of a certain pattern and symbolic representation – assigning a symbol.

Cisek [5] is critical of the Harnad's solutions and turns back to the beginning of life. There are several theories how the first living pieces of matter came into existence, like 'autocatalytic sets' escribed by Kaufman [16]. The self retaining cycle is the basis of life. It corresponds to a definition called the NASA definition of life: life is a self-sustained chemical system capable of undergoing Darwinian evolution [19]. The main property of the living system ensures that the conditions to continue their existence are met. The living systems should keep certain critical variables within an acceptable range and this mechanism is called "homeostasis". The variables are kept in the desired range by feedback loops forming a control cycle. If a certain variable is out of the desired range a cascade of chemical reactions follows that brings the system back to the desired situation and the trigger of the reactions ceases. It is also a trigger for a motivational system and enables to make decisions.

For example, several hours after eating the blood sugar level drops and it activates certain neuronal activity. Activation of the pertinent innate pattern makes the brain alter the body state so that the probability for correction can be increased [7]. You feel hungry and that makes you take steps to get some food. After eating the blood sugar level increases and the feeling of satiety follows.

The control cycles also help an organism to classify things or events as “good” or “bad” because of their possible impact on survival [7]. And the things are categorized as good or bad and the process of defining new good and bad things grows exponentially. The internal and external signals are triggers of a certain response or behavioral pattern. Animals distinguish inherently some input; some of them are “desirable” and some “undesirable” [5]. The desirable situations are preferred, like a full stomach, and undesirable are avoidable, like danger. Such a distinction gives the meaning to the perception–whether the perceived object or event enables to achieve a favorable situation or must be avoided. Control is gained by studying the regularities within the environment that define reliable rules of interaction.

Cisek states that in the living systems the meaning comes long before symbols because organisms have interacted with their living environment long before they started using symbols. An object or event in the surrounding environment affords something for an organism [10] and means for one organism something different than for the other. The meaning of an object or event depends on what it makes possible.

3. Experiment Design

Previously described solution to the origin of meaning needs some testing whether it is possible that such cycles arise which distinguish good from bad and motivate organisms to move towards good things that give them resources and energy. The test is inspired by the idea that cycles can arise from a random configuration of non-living matter which prefer moving towards some energy sources and avoid dangerous matter. For testing aspects from artificial life and evolutionary computing are combined.

Sun has proposed a solution that uses an evolutionary approach to solve the symbol grounding problem that uses a two-level learning [20]. The first level is like evolutionary learning using a trial-and-error approach and the second stage is fine tuning to produce the best possible behavior. This approach is based on the reinforcement learning principle where a good choice is rewarded and a bad choice is punished. Taddeo and Floridi [21] have criticized the evolutionary approach to solve the symbol grounding problem. They argue that a programmer generates the goal of the evolutionary system and therefore the “natural” selection process follows the programmer’s intentions. As life is a self-organizing system and develops following the laws of evolution and natural selection the evolutionary approach might offer the most promising solution to the symbol grounding problem. To avoid the critics of intentionality the simulation must be based on natural laws.

Biological systems are defined to exhibit the self-organizing phenomenon [4]. The self-organizing systems can be regarded as open systems, it means the energy and matter is flowing through them [18]. A fundamental starting point to design the experiment is that organisms or agents need some energy to function. Consumption of energy is an important factor because it is needed to keep an entropy level of a living organism low. Without continuous flow of additional energy and resources the process will reach equilibrium when all the stored resources are used. If an organism is successful to find new energy sources, he will survive and otherwise he dies out.

The simulation is based on the idea that energy-driven networks of small molecules were the initiators of life. Shapiro supports the theory of metabolism first and argues that life began as a combination of simple organic molecules that stored information for duplication and passing it to their descendants [19]. Multiplication took place through catalyzed reaction cycles and some external source of energy was needed. Based on the Shapiro's assumptions the simulation was constructed as a very simple one and agents have only simple drives to gather external sources of energy and to replicate.

Based on those presumptions an agent based simulation has been built. The aim of the simulation is to test whether it is possible that first, a random configuration occurs which allows to recognize energy sources, and second, a system starting from a random configuration is able to reconfigure and to adapt the surrounding environment and generate rules to distinguish good things from bad ones. It is a test to assess whether it is possible that control cycles supporting an organism’s ability to distinguish good from bad can arise.

3.1 Simulation Environment

The simulation consists of a world where initially a number of agents and resources are distributed randomly. The agents have an ability to move, distinguish things in the surrounding environment and reproduce. There is a rule in the world that an agent needs some energy to live and to reproduce and without energy an agent dies. An agent can consume both good things and bad things. A good thing gives him n units additional energy and a bad thing speeds up energy consumption. The value of internal energy decreases at each step of simulation. When an agent reproduces half of the good and bad resources are given to his offspring.

The simulation presupposes that agents have an ability to perceive resources occupying the neighboring area. An agent has weighted values to determine which resources and moving directions to prefer. The set of weights determining behavior of an agent is called a configuration. Initially all the weights have a random value and it is presupposed that agents can prefer an arbitrary resource which is the trial-and-error approach. During the simulations the weights are changed. If the value of internal energy of an agent is increased, the weight related to the consumed resource is increased and at the same time the weights of the other resources are decreased. It is the other way round when the energy decreases. The simulation uses a gradual learning because it is presupposed that even the trial-and-error approach can lead the system to the desired state but it takes more time.

Time in the simulation is discrete. At each step an agent evaluates the surrounding environment, makes decisions which direction to move and consumes resources. To make a decision the weight value of the resource and half of the weight value of the direction are summed up and the direction with the highest value is selected. At the end of each step the used resources are restored and replaced randomly on the world.

4. Experiments

To test the hypothesis several experiments were performed. All the experiments were made in the world with the size of 20 x 15 units (Fig. 1). The initial number of agents was 10. With each world 10 tests were performed. The simulation ended when it had performed 300 steps or all the agents had become dead.

Fig. 1. A simulation. (Legend: ■ - agent, ■ - good, ■ - bad).

The results of the tests are given in Table 1, which defines the number of good and bad things, the energetic value of good and bad things and the results of the experiments.

Table 1. The results of the tests.

Number of good	Number of bad	Good energetic value	Bad energetic value	No of successful experiments	Average number of steps
20	20	4	-1	1	42.8
20	20	6	-6	0	30.9
20	20	8	-8	0	15.9
30	30	4	-1	4	132.5
30	30	6	-6	7	214.3
30	30	8	-8	3	101.6
30	10	4	-1	7	215.5
30	10	6	-6	7	231.9
30	10	8	-8	5	172.1

Next several observations and generalizations of the performed simulations will be given. The world needed certain energetic density to keep the agents living. It can be calculated by the probability to find a new energy source within a certain time limit. As a result the configuration preferring energy rich resources appeared quite frequently. The probability of survival of such a configuration was higher when the energetic density of the world was high. The natural selection was pitiless and all the configurations preferring something else than energy rich resources usually died out.

The population of agents was successful when the whole population acquired a similar behavior and started to move in the same direction as a wave. The population growth seems to be connected to the Bak-Sneppen model [1]. A certain small change in a configuration was needed to make the number of agents grow very rapidly until it reached the equilibrium with the available resources (Fig. 2).

From the initial population only a few species remained and usually they acquired similar behavior. If several sub-populations acquired different behavioral pattern, they started to compete for the energy sources and the size of the population remained cyclic.

Usually the use of negative energy sources ceased during the simulation because all the organisms that preferred to consume bad things died out and only agents preferring good things survived. If the energetic value of the world was high, quite often the use of bad things did not cease because the agents had enough energy available to compensate the additional expense.

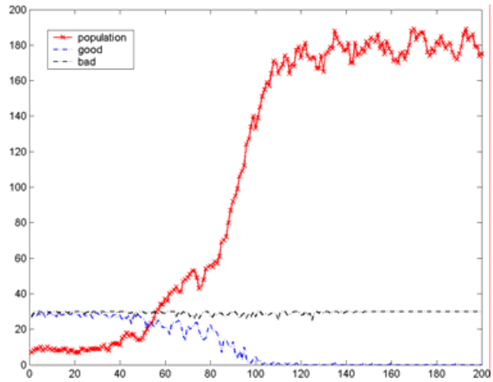

Fig. 2. A typical graph of the simulation of a successful population.

5. Conclusions and Discussion

The results of the simulations indicated firstly that it is possible that a random initial configuration determining an agent's behavior may have an ability to recognize energy rich resources and secondly that a configuration recognizing and distinguishing good resources from bad ones can emerge through an evolutionary process. It might give some indication of starting a process that is the precursor of the meaning.

The experiment was very simple but proved that a configuration distinguishing good from bad can possibly emerge. As Brooks noticed there is no need for the world model [2] and the best world model is the world itself. There are several regularities in the world and an agent must remember what those regularities may result in and whether their outcome is desirable or undesirable. An object or event in the world means to an agent a certain possibility to satisfy his needs. Why was the first stone axe created – because it increased the possibility that an animal had been caught and it meant more food and less hunger. The tool was sharpened and improved to increase the probability that the desired state was achieved. Again, things can afford something in a sense of the theory of affordances [10]. An agent selects an action that allows the most probable way to achieve the desired state. The weights defining probabilistic relations between the action and the achieved state are changed through the interactions with the surrounding environment and the meaning can be regarded as a process. Events or objects can be recognized and classified and thereby conceptualized. Agents use a conceptual instead of symbolic representation.

The symbol grounding problem becomes easier if a concept approach is used [8]. In the theory of conceptual spaces [11] the properties of a concept are defined by a number of quality dimensions, which also represent a semantic information, and symbols are high level representation of concepts. But in this theory a value dimension is missing that might be an important factor to create meaning. Meaning is defined by the value of the relationship between an individual and his environment [22].

An object or event in the surrounding environment may be connected to several concepts and have different meaning depending on the situation, e.g., a daily use of a cup – it can be used to drink coffee, but also to keep flowers or to use for some other purposes. An agent usually, routinely, reflexively uses an object in its everyday life as it can be used [20]. When the context changes, also the meaning changes, e.g., when a human is thirsty, a cup means a tool for helping drinking and reducing thirst, when one has some flowers a cup enables to use it as a vase. The cup remains the same but its meaning changes. When the concept is analyzed, the values or feelings associated with it are changed like the Damasio's waterbed metaphor [7]. The process of meaning may work so that the relationship between a desired state, a conceptual representation of the environment and possible actions is continuously formed and evaluated.

The performed simulations gave some indication that from a random initial state a configuration can emerge that is able to survive and reproduce. To have a successful configuration a variety of initial states are needed but the nature had enough time to test different initial conditions. Once a successful configuration was found it turned out to be unstoppable when there was a continuous flow of additional energy and resources. Changes in the configuration could help an agent to adapt with the changing environment. Despite the different origin the agents exhibited similar behavior and it can be said that life is the same everywhere, it's only the faces that are different. Actually life can be taken as a whole and organisms are only components of it. Different organisms are different representations of the same life. Life tends to keep itself existing therefore it tries to invade different areas and has a wide variation.

Brooks argues that living systems are composed of non-living atoms and there is an unknown gap between the living and non-living matter [3]. Here the solution has been tested that might help to cross the gap. The solution may be in the new control approach where the system tries to achieve the desired state. From a random configuration the control cycles arise that keep the parameters of a system in a desired range. It also offers an explanation for the basis of the motivational system of a living organism. Hawkins has proposed that a human brain deals with predicting [14] and so do all the other living organisms – they predicting sequences and regularities in the surrounding world. The goal of such predicting is to select one of the actions made possible by the environment that has the best payoff [6]. Edelman argues that a living organism becomes conscious of the surrounding environment if the perception is connected to the value category memory [9]. The value system and the memorized previous experience generate a probabilistic view whether and how a certain desired state can be achieved. There seems to be three components that a living system might have – the motivational, evaluative, and predictive component. The motivational component explains why a system continuously acts in the changing surrounding environment and why it is motivated to act. A steady analysis whether the situation is desirable or not and whether it needs some correction to ensure the agent's existence is the basis of motivation. The evaluative component evaluates what the surrounding environment can afford and what it means to an agent in the terms of survival. The predictive component gives the best probable solutions how to reach desirable situations based on the previous experience of the regularities in the world stored in the memory system. Through continuous evolution or learning the parameters are changed to increase the probability of survival. The more adaptive and successful an agent is the more intelligent it seems to be.

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