Neural Network Model of Autonomous Agent for Decision Support System

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Abstract One of the trends in the information theory of recent years is a dynamic development of decentralised, intelligent information systems. The systems in question are so complex that the classical methods of describing their dynamics prove to be insufficient. One of the possible ways of describing them is by applying the model of an agent which constitutes an independent entity existing in its own right. The agent has its own inventory of objectives and the ability to interact with the environment and adapt to the changes which take place in this environment. The paper presents the conception of autonomous agent as a cybernetic model of an autonomous system. It is based on psychological and biological phenomena which may be observed in living organisms. The description of the system distinguishes between three basic functional blocks: correlator, homeostat and accumulator; it contains a detailed account of the functions and mutual correlations and interactions.

1. Introduction

A dynamic development as a cybernetic model of an autonomous system is presented. This model was patterned after mental and biological phenomena occurring in living organisms. Decentralised intelligent computer systems is one of the main tendencies in computer science. These systems are complicated to such extent, that classic methods of description of their dynamics become insufficient. One of the possible ways of their description is the application of a model of an agent. The agent constitutes an independent being. The agent has its own list of purposes, an ability to influence its environment, and is adaptable to the changes occurring in the environment. Many authors working in the field of decentralised systems of artificial intelligence assume, that in order to make the agent able to make plans unaided and to performs tasks set, it should be provided with a knowledge. Such knowledge can be subdivided into two basic categories:

- Structural knowledge. Structural knowledge that includes a description of agent's environment, and problems to be solved by the agent. It appears as a rule that the agent knowledge about the environment is not certain or incomplete.

- Decision making knowledge. In order to guarantee that the decisions undertaken by the agent are fully rational, and dependent on the changes occurring in its environment, the agent should be provided with a set of procedures. These procedures should allow the agent to „understand the purpose" while making plans of the scenario of undertaken actions.

For these reasons, depending on the features of the environment of the agent performing the tasks, different types of learning are required to represent the necessary types of agent's knowledge. Many obstacles raised during the implementation of such systems, and during its practical adaptation in a given environment, however.

In the paper the model of an autonomous agent has been presented as a cybernetic model of an autonomous system. This model was patterned after mental and biological phenomena occurring in living organisms.

In the description of the system, three basic functional blocks have been distinguished - a correlator, a homeostat and an accumulator. Their functions are discussed in details and the paths of their interactions are presented. Furthermore implementations of the autonomous agent using artificial neuron networks are included in this paper. The methods of learning used in behavioural psychology (classic conditioning, instrumental conditioning) have been discussed and then adapted for teaching our autonomous agent.

2. Autonomous system

This chapter presents a model of an autonomous system related to the autonomous agent discussed in the paper by M. Mazur. Consequently separate elements of this autonomous system as well as their interactions will be discussed.

The notion of an agent should be identified either with a physical being or with an abstract model. In the case of a physical being, the agent could be understood as a robot which has its own list of tasks to be performed. It should subordinate the implementation of the tasks to the environment, in which it exists, as well as to the internal state. This internal state can be combined with power resources (e.g. battery condition) of the robot, which are necessary for active existence in this environment. In the case of an abstract being, we have in mind a program which should play a role of an expert system.

A controllable system which is able to counteract the loss of controllability, can be called an autonomous system. The system should be equipped with following elements:

- **Effectors**, i.e. elements used to exert an influence on the environment. In the case of a robot they can be its manipulators. When considering the expert system, it is an answer to the question asked. The effectors should be provided with an information influencing possibly the environment within a given period. In order to fulfil this condition, the system should include an information path which consists of following functional blocks: a correlator and receptors.

- **Receptors** are the elements used for taking information from the environment.

- **Correlator** is a sub-system responsible for data processing and storing. The presented system can be compared with organisms living in the natural environment. An equivalent of the correlator block would probably be the cognitive system block, responsible for the learning process of a given organism.

is responsible for distinguishing what is „right" and what is „wrong" for a given organism. The operation of this system can be manifested e.g. in finding pleasure (an awarded prize) or feeling pain (a penalty). Such a block will be called hereinafter a homeostat.

- **Homeostat** is an element used to counteract the flow of information and energy, which reduces the ability to exert influence of the system on the environment. This element is responsible for keeping the state of functional equilibrium of the autonomous system.

A scheme of such type of an autonomous system is presented on Fig. 2.1.

The receptors, alimentators and effectors are functional blocks providing the contact of the system with its environment. The receptors and alimentators are system inputs, while the effectors are system outputs. The correlator, accumulator and homeostat are internal organs of the autonomous system. Gaining information from the environment consists in distinguishing the

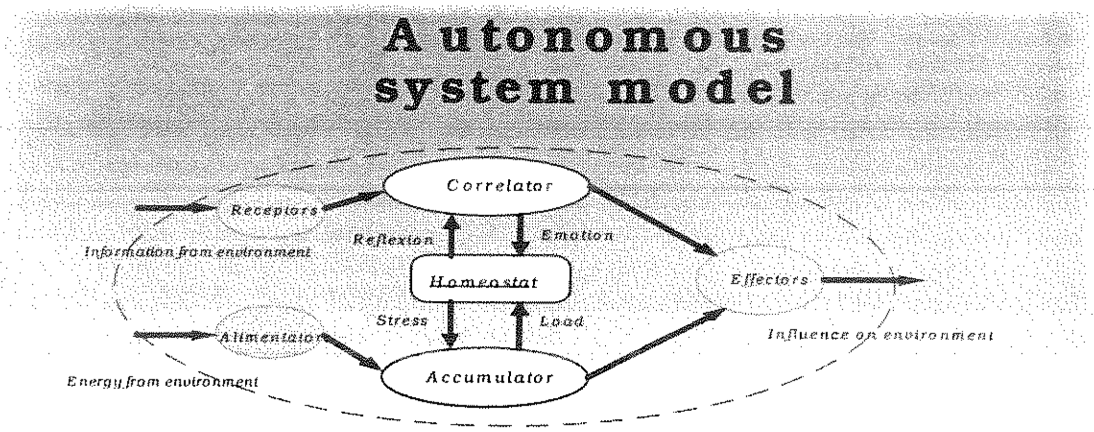

Fig. 2.1

The effectors should also be supplied with energy required for execution of labour necessary to exert the influence on the environment. Therefore another path - the so called power path, is required, to consist of following elements: **alimentators and an accumulator.**

- **Alimentators** are segments used for taking energy from the environment. In the case of a robot, the role of this element is rather obvious, while in the case of an expert system, it requires an explanation. Therefore it can be assumed that no power is required for its existence.

- **Accumulator** block is responsible for keeping and storing the energy.

The autonomous system should be equipped with a block that provides a coupling between the information path (receptors and a correlator) and the power path (an alimentator, an accumulator) of the system. When searching close analogies in natural environment, such a block can be compared with a rewarding system that exists in all the living organisms. This rewarding system

differences in action on the receptors. In order to detect a defined action, a special receptor sensible for this particular type of action and neutral to other ones, is required. A defined type of influence to be exerted on the environment requires a special effector. It is an interaction between the system and its environment. As the information is saved in the correlator, and the energy is kept in the accumulator, they can be used independently on the moment, these data had been gathered.

2.1 Homeostat

The self-control of the autonomous system in the environment is based upon the feedback. As a result, the changes occur not only in the environment but also in the autonomous system itself. The changes introduced into the autonomous system are limited to such values that do not cause the loss of system controllability.

A danger in loosing the controllability is minimal if the state of the autonomous system is far away from both boundaries. Such a state is called *functional* *equilibrium*. The main task of the homeostat is to keep the autonomous system in this state of functional equilibrium.

The greater is the change occurring in the environment, the more intensive will be its influence on the autonomous system via the receptors and alimentators. Also the more intensive will be the action of the accumulator and the correlator on the homeostat. Thus the disturbance of functional equilibrium results indirectly from the changes of the system environment. The homeostat has no contact with the environment. What happens at its input, should be treated as its disturbance. The disturbance can be eliminated by the homeostat. It is possible by means of its direct influence exerted on the accumulator and the correlator. For example if the correlator's and accumulator's action on the homeostat is increasing, then the counteraction of the homeostat on the correlator and the accumulator shall be reduced (and conversely). As a result of such actions, the functional equilibrium of the system is restored. It follows therefore that a negative feedback occurs between the homeostat and correlator as well as between the correlator and homeostat. Some processes can run simultaneously, thus the homeostat should be an element consisting of a lot of mutually combined feedback circuits. Generation of positive feedback in certain circuits is balanced by negative feedback in others.

2.2 Information path of the system

The information path of the autonomous system includes the receptors, a correlator, the effectors as well as the correlator-homeostat feedback.

As it follows from the scheme presented above, the correlator is equipped with two groups of inputs and two groups of outputs:

A **receptor signal** *(Vr)* is entered by a receptor into the correlator,

An **effector signal** *(Ve)* is entered by the correlator into an effector,

A **perturbation signal** *(Vp)* is entered by the correlator into the homeostat,

A **homeostatic signal** *(Vh)* is entered by the homeostat into the correlator.

Regardless of the level of its complication, each correlator should perform following functions:

A. to gain information,

B. to store information,

C. to process the information stored.

The first and second function are rather obvious. However the third one needs an explanation of the point of data processing in the correlator. Creation of an interaction between the correlation elements is called *association* of these elements and - indirectly - of the values of signals appearing at these elements. Taking into consideration all four basic types of correlator signals, following eight types of associations occurring in the correlator can be distinguished:

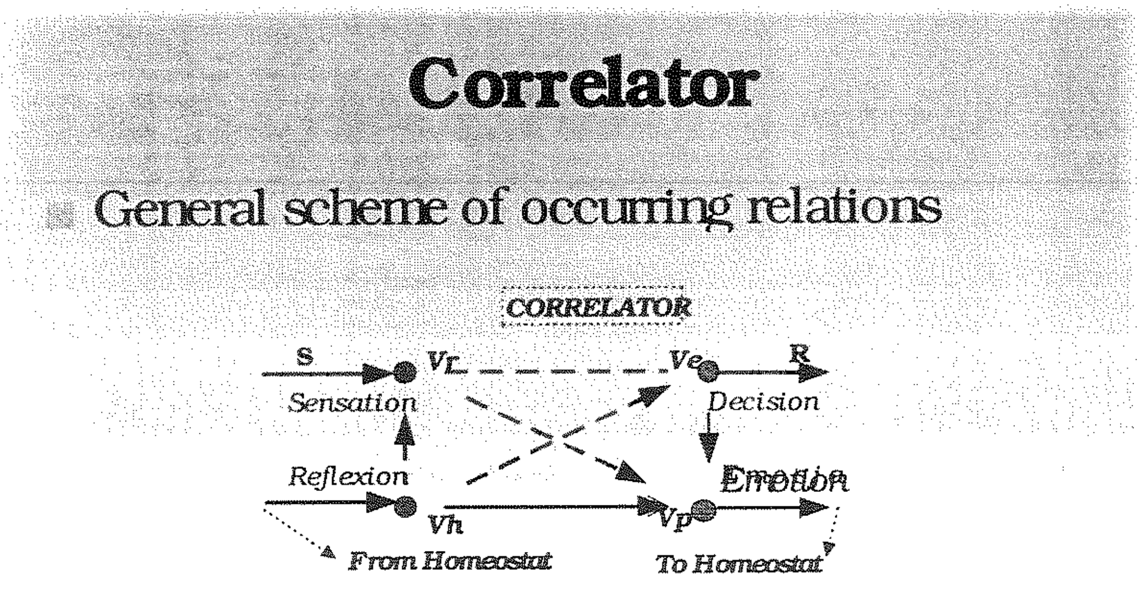

Fig. 2.2

Input - input associations

1. If a sensation *(Vr)* of a stimulus is sufficient to generate a decision and a reaction then an

association with another *(V`r)* stimulus may appear sufficient to generate the same decision as well. An example is the classic experiment carried out by Pavlov.

2. If a sensation *(Vr)* of a stimulus is sufficient to generate a decision and a reaction then also the reflection *(Vh)* leading to the imagination of such stimulus may appear sufficient to generate the same decision and the same reaction as *(Vr)*.

Input - output association

3. A sensation *(Vr)* of a stimulus causes an associated decision *(Ve)* and reaction.
4. A reflection *(Vh)* generates an associated decision *(Ve)* and reaction.
5. A sensation *(Vr)* of a stimulus causes an associated emotion *(Vp)*.
6. A reflection *(Vh)* generates an associated emotion *(Vp)*.

types of associations that give dozens of possible combinations of several associations occurring simultaneously. Furthermore, taking into consideration greater number of correlation elements, i.e. receptors and effectors, respectively, the total number of possible associations might be very large. The terminology defining the relations between correlator's input and output signals has been introduced to describe this model:

- ***Emotion*** is an action of the correlator on the homeostat. In particular two basic cases of emotion can be distinguished:
  1. ***Aversion***, i.e. emotion consisting in an amplification of the disturbing signal *(Vp)*,
  2. ***Attraction***, i.e. emotion consisting in a reduction of the disturbing signal *(Vp)*,
- ***Reflection*** is an action of the homeostat on the correlator; following options occur:
  1. ***Disapproval***, i.e. reflection consisting in

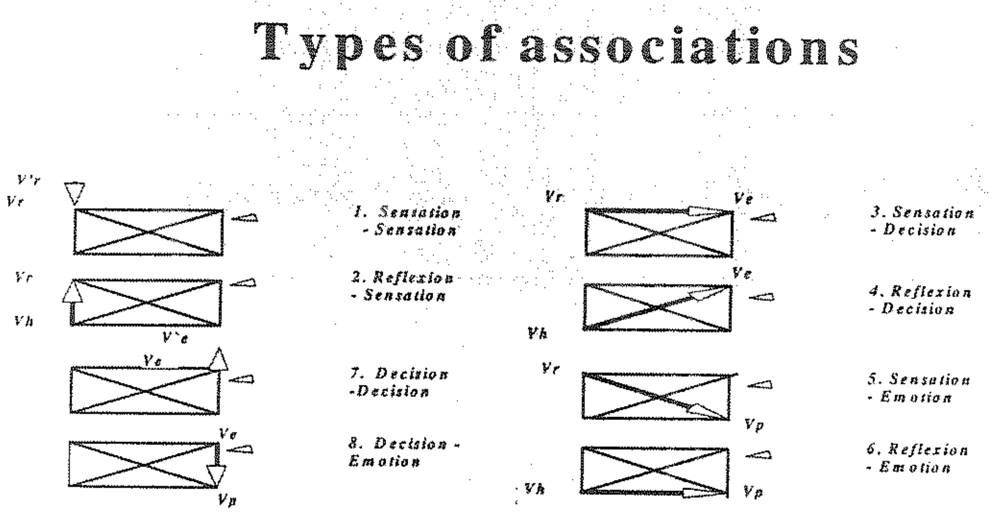

Fig. 2.3

Output - output association

7. If the sensation of a stimulus is sufficient to generate a decision *(Ve)* and a reaction then it may also be sufficient to generate an associated decision *(V`e)*.
8. If the sensation of a stimulus is sufficient to generate a decision *(Ve)* and a reaction then it may also be sufficient to generate an associated emotion *(Vp)*.

Fig. 2.3 presents all the possible association types that can take place in the correlator.

As it is visible, in the case of a correlator containing one receptor, and one effector only, there exist eight possible

reduction of the homeostatic signal *(Vh)*,

2. ***Approval***, i.e. reflection consisting in amplification of the homeostatic signal *(Vh)*.

2.3 Power path of the system

The power area of the autonomous system includes deriving energy from the environment through the alimentators with homeostat's co-action and giving energy out, into the environment, through the effectors. The interactions between the accumulator and homeostat take place within the power area of the system. The accumulator influences the homeostat by introducing into it a signal, defined as a *load* (Fig. 2.1). Following cases of such influence can be distinguished: ***Overload***, i.e. increase of the load, ***Relieve***, i.e. reduction of the load.

The homeostat influences the accumulator by introducing into it a signal, defined as a ***stress*** and similarly to the case discussed above, two possibilities may occur: ***Compression***, i.e. increase of the stress, ***Decompression***, i.e. reduction of the stress. The stress is a signal that exerts an influence on energy accumulation. The compression intensifies, and the decompression reduces the conversion of the accumulated energy into the energy useful for consumption by the autonomous system. The load is a signal generated during consumption of the accumulated energy; the compression appears as a result of an increasing consumption of energy by the autonomous system while the decompression is related to the reduced energy consumption.

2.4 Interaction in the system

We are able to discuss the influence of information processes on power ones as well as the influence of the power processes on information. We are going to discuss the behaviour of the autonomous system. The fact that a homeostat is a common organ for both these areas causes following consequences. Firsts of all the information processes exert an effect on power processes through the homeostat and also the power processes influence on the information processes (Fig. 2.1). In particular the following cases can be distinguished:

1. The reflection depends not only on emotion, but also on the signal put into the homeostat by the accumulator, i.e. on the load;
2. The stress depends not only on the load but also on the information processes run in the correlator and in particular - on the perturbation signal *(Vp)*, i.e. on emotion;
3. The emotion exerts an influence not only on reflection but also on the stress;
4. The load exerts an influence not only on the stress but also on the reflection.

The mutual interaction of information and power processes is determined by the rules of homeostat's co-operation with the correlator and the accumulator.

1. The homeostat reverses the action. If the input potential of the homeostat increases, then its output potential decreases. If the input potential of the homeostat decreases then its output potential increases.
2. The correlator and the accumulator transfer the actions. If the input potential increases then also the output potential shall increase.
3. The homeostat influences the correlator and the accumulator in the same way, i.e. it introduces the increasing or decreasing signals to both these blocks.

Basing upon the presented description of interactions, following basic four types of these interactions between the information and power system can be distinguished:

1. Attraction *(inf.)* causes approval *(inf.)* and acceleration of decision *(inf.)* as well as compression *(en.)* and intensification of the reaction *(en.)*.
2. Aversion *(inf.)* causes disapproval *(inf.)* and postponement of decision *(inf.)* as well as decompression *(en.)* and weakening of the reaction *(en.)*.,
3. Decompression *(en.)* causes compression *(en.)* and intensification of the reaction *(en.)* as well as approval *(inf.)* and acceleration of decision *(inf.)*.
4. Overload *(en.)* causes decompression *(en.)* and weakening of the reaction *(en.)* as well as disapproval *(inf.)* and postponement of decision *(inf.)*.

3. Neuron implementation

This section presents an attempt at implementing the system of an autonomous agent using neuron networks. The homeostat is a block consisting of many mutually combined feedback circuits and therefore creation of positive feedback's in one circuit results in generation of counteracting negative feedback in other circuits.

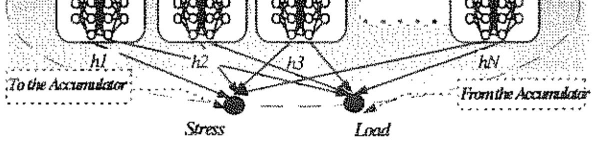

Fig. 3.1

Thus it could be stated that the homeostat oscillating between insufficiencies and excesses operates as a stabiliser of the processes running in the autonomous system. It follows from the above discussion, that a homeostat constitutes a set of elementary homeostatic controlling individual reactions and decisions of the system. Therefore the homeostat can be understood as a set of independent algorithms - in our case a set of independent neuron networks (see Fig. 2.1). An important consequence related to the methods of homeostat learning can be derived. As all the neuron networks entering into the composition of the homeostat are independent to each other, it follows that they can be taught independently to each other using any method. In this model an assumption has been accepted that each decision (an effector) is associated with one reaction. The decisions which can be taken by the agent, are independent to each other. Therefore the number of independent networks (algorithms) included in our homeostat is equal with the number of effectors

Therefore two blocks have been distinguished in a correlator: ***Perception system*** and ***Decision system.***

Perception system

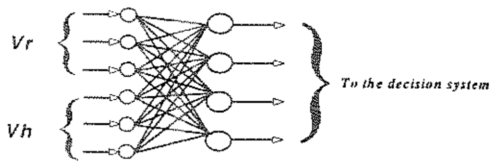

Fig. 3.2

The task of the ***perception system*** is to gain information about the environment through the receptors, generalisation of the information gained in this way and auto-association of stimuli. This system has been implemented by means of a single-layer neuron network (Fig. 3.2). The number of system inputs depends on the number of receptors of the agent. On the other hand, the number of perception system outputs shall depend on the required level of generalisation of the information on the environment, gained by the system. Therefore a learning rule derived from Hebb's laws has been used for learning this system. This method is sometimes called *correlation learning*. Description of this method as well as its properties can be found in commonly available publications on artificial neuron networks and therefore it will not be discussed in this paper. Possible internal structure of the perception system is presented below. The number of *(Vr)* type inputs depends on the number of receptors. On the other hand, the number of *(Vh)* type inputs depends on the number of independent neuron networks entering into the composition of a homeostat (number of system effectors). Such a perception system is presented in Fig. 3.1. Attention should be paid to the fact, that such a structure of the perception system makes the *Vr* value dependent on *Vh* value (Figs 2.2 and 2.3).

The task of the ***decision system*** is to generate the decision signals *(Ve)* for individual effectors of the system. Also in this system all the interactions between the correlator's inputs and outputs should be fulfilled. We have in mind the relations occurring between the signals *(Vr, Vh, Ve)* (Fig. 2.2) .In this case the decision system contains an output layer responsible for generation of output signals for individual effectors of the system as well as a free number of internal layers of the decision system. The structure of the decision system is presented in Fig. 3.3.

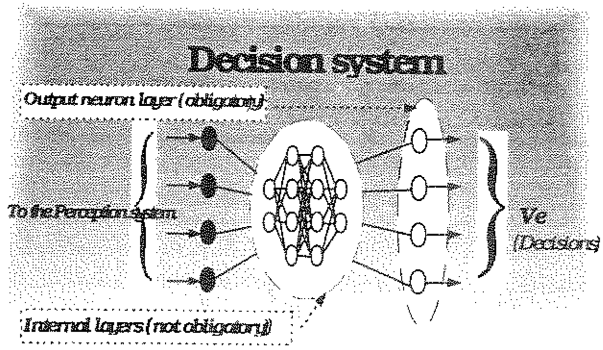

Fig. 3.3

4. Conclusion

The paper presents a model of an autonomous system referred afterwards to the model of an autonomous agent. As an example an implementation of the discussed model using the artificial neuron networks is presented. Furthermore the methods of teaching used in behavioural psychology (classic conditioning, instrumental conditioning) are presented and then adapted for teaching our autonomous agent.

5. References

Demazeau Y., Muler J., Decentralised Artificial Intelligence. in Demazeau Y. *(Ed.)* Decentralised AI. Proceedings of The First European Workshop on Modelling Autonomous Agents in a Multi-Agent World, Cambridge, 1989 England.

Goldberg D. E., Genetic Algorithms in Search, Optimisation and Machine Learning Addison Wesley Publishing Company, Inc. Reading Massachusetts, 1988.

Lizotte M., Moulin M., A Temporal Planning For Modelling Autonomous Agents. *In:* Demazeau Y. *(Ed.)* Decentralised AI . Proceedings of The First European Workshop on Modelling Autonomous Agents in a Multi-Agent World, Cambridge, 1989.

Mazur M., Cybernetyka i charakter, AULA Warszawa, 1996.

Wilensky R., Planning and understanding Addison - Wesley , Reading , Massachusetts, 1983.