Applying a natural intelligence pattern in cognitive robots

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Abstract

Human brain was always a mysterious subject to explore, as it has still got lots to be discovered, and a good topic to be studied in many aspects, by different branches of science. In other hand, one of the biggest concerns of the future generation of Artificial Intelligence (AI) is to build robots who can think like human. To achieve this AI engineers used the theories inspired by human intelligent, which were suggested by well-known psychologists, to improve the intelligence systems. To control this complicated system they can gain a lot of benefits from studying how human mind works.

In this article, cognitive robots, which were equipped to a system that was built based on human brain's function, searched in a virtual environment and tried to survive for longer. To build the cognitive system for these robots, the psychoanalysis theory of Sigmund Freud (id, ego, and super-ego) was used. And at the end, the surviving period of cognitive robots and normal robots in similar environments were compared. The results of these simulations proved that cognitive robots had more chances of surviving.

Keywords: *Cognitive robotic, Artificial Intelligence, Natural intelligence.*

1. Introduction

TO get benefit from technology in our lives, we need to understand and learn all aspects of human life, specifically the needs and problems. To adapt technology with human needs, study of a wide range of different branches of science is necessary. Cognitive science is a collection of a wide range of knowledge which is aimed to describe and assemble the cognitive abilities of all living things and the mechanisms of their brains' functions. To solve a problem and make a decision, human should understand their surroundings, first. Then, with this information and the experience(s) or skill(s) gained prior to this, he could act properly towards the situation. It's assumed that the structure of an automated system must be designed with thousands of sensors to be able to process new data and make a suitable decision. 'Error! Reference source not found [1].

A collection of Epistemology, Cognitive Neuro Science, Cognitive Psychology, and Artificial Intelligent create Cognitive Science, which is one of this generation scientific approaches and very useful for human needs. In other hand, Robotics as a technologic dependant of AI, is a perception which consists of mechanics, computer sciences, and electronics control. Robotics plus cognitive sciences together make a new branch of science called cognitive robotics. Cognitive Robotics, uses living organisms' and human brains function in its calculation algorithms.

One of the main applications of Cognitive sciences is in AI (building of human-like computers). From their point of view, human mind is a kind of computer that sends the information received from its sensors (e.g. vision) to its processing centre (mind) and as the result of this process we talk or walk, and so on.

The behaving patterns that had been inspired from human intelligence, would be a great help for engineers to improve the systems. Specifically, the way that human mind could control complicated matters suggests new ways to scientists.

In articles [2], [3] shown that a wide range of sciences could come to help engineers to understand how human brain works such as psychology, psychotherapy, cognitive sciences, and neuro sciences. Many researchers in AI are investigating the patterns of natural intelligence, in order to apply them in automated robots [5].

In article [4], a Memory-based theory is used to discover brain functions and prove that memory is the base and root of any kind of intelligence either natural or artificial. They also believe that most of the unsolved problems in computer fields, software engineering, informatics and AI are because of not understanding the mechanisms of natural intelligence, and cognitive functions of brain.
In [6] has shown the theoretical improvements in the mechanisms of AI and Natural Intelligence (NI). As well, the classification of intelligence and the role of information in development of brain functions were studied. They've expanded a general intelligence model which will help describing the developed mechanisms of natural intelligence.

2. Topic Plan

The simulation of human and other living organism brain pattern and its behaviour model in a virtual environment has been always a topic of interest for scientists and their researches, as much that we can see some of those results in modernising our industries and their affects in our lives, too. In order to follow human cognitive structure, our research was based on a psychological framework. Pursuing this, we chose a suitable model of NI among the suggested ones, and designed our cognitive robots in a virtual environment accordingly. Our NI model is from a cognitive field of psychology in which the different aspect of personality, perception, excitement, intension, and physical reactions of a person and his adaption with the environment, was studied.
Sigmund Freud, the founder of psychoanalysis, says that personality is consisted three elements which together control human behaviour. His theory would be discussed in other sections of this article.
The plan of this article was simulation of the behaviour of cognitive robots, with NI pattern, in a virtual environment. The designed cognitive robots searched their surroundings and in order to survive for longer, they needed to use the energy supplies from their virtual environment, otherwise their energy level reduced too much and they would be eliminated. The cognitive robots were equipped with Learning Automata (LA), which helped them making decision by recognizing their situation in their surroundings in each episode. But in other hand, normal robots had no LA available, so they moved randomly and tried to survive for longer.
Later, the virtual environment, LAs, decision making algorithms (based on Freud's theory) would be discussed in details.

2.1 The Design of Virtual Ecosystem

The simulated surroundings were sectioned in two zones, Rocky zone (or dangerous zone), and Flat zone (or safe zone). These two zones were exactly the same size, and the two zones had been separated by a hazardous boarder. Since the Rocky zone was dangerous, the amount of energy used in it, was twice the energy level used in a safe zone.
The other difference between these two zones was the number of energy pack spread in them, which was more in the dangerous zone.
The robots are built randomly, with the same level of energy (the highest level of energy), in the Safe zone. They are obliged to search in the zone and try to survive for longer in the environment. Eventually, with each movement, the robot will lose one energy unit in Safe zone, and two energy units in Rocky (dangerous) zone. When a robot gets 1 energy pack, its energy level reaches to its highest level. But, if its energy level drops to zero, it will get eliminated.
Two groups of robots (cognitive and normal), with similar situation, search the virtual environment. At the end, the average of their (the two groups) surviving time will be compared together.
The first group, which involves normal robots that have no decision making ability, move randomly in the virtual environment and never enter Rocky zone. This means that they constantly use/lose less energy in each episode. In other hand, they have less chance of using energy packs, since number of energy packs are more in the dangerous/Rocky zone.
The other group, that has cognitive robots, with the mechanism of decision making (according to Freud's theory), will act suitably to their surroundings. Opposite of the first group, this group of robots (cognitive) based on their ability of decision making, try to learn about their surroundings and which action's best to apply in each situation, so, they could survive longer.

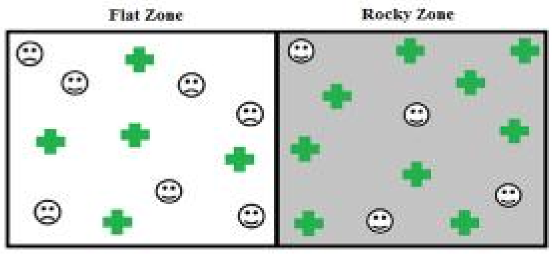

Fig. 1 Virtual ecosystem

2.2 Learning Automata (LA)

The Learning Automata are abstract models. They act randomly in the environment, and are able to up to date their actions based on the information they've got from outside (environment). This feature helps them to improve their functions. A LA can do limited number of actions.

Each chosen action, is studied by the virtual environment, and responded with a reward (for correct action), or a fine (for wrong action). LA uses this respond, and chooses its next action [7], [8].
In simpler words, a learning automata is an abstract model that randomly chooses one of its limited actions and enforce it to the environment. And the environment studies this action, and sends the result with a relayed signal to LA. Then, with this data, LA up to dates its information, and chooses its next action. Following diagram shows this relationship between LA and the environment.

Fig. 2 Relationship between LA and environment

There are two types of LAs: Fixed structure, and Variable structure. We have used the variable type in our research. To get more detailed information about these two types, refer to the articles of [9], [10], [11], please.

2.3 Robots' Decision Making, Based on Freud's Theory

A natural Intelligence (NI) model is actually a pattern of human or any other living organisms' natural behaviours, and the consequences of cognitive behaviour follows this model, as well. As mentioned before Freud's psychoanalysis theory was used as an outline for our designed cognitive robots actions.
According to what has been suggested in this theory, the structure of human personality is built up three elements, the 'id', the 'ego', and the 'super-ego'. These three aspects of personality in dealing together, create the complicated human behaviours (refer to the fig. 3).

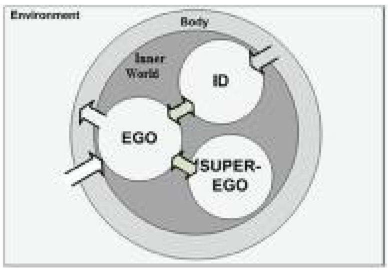

Fig. 3.Information flow between world modules [12]

'id' is presented from birth, 'ego' is responsible for dealing with reality, and 'super-ego' is all of our inner moral standards and ideals that we acquire from both our parents and our society.
'id' is driven by the pleasure principle, which strives for immediate gratification of all desires, wants, and needs. If these needs are not satisfied immediately, the result is a state anxiety or tension. So, 'id' tries to resolve this tension created by the pleasure principle through the primary process, which means learning to find a suitable method to satisfy the needs.
Based on this description, cognitive robots start moving in their surroundings at first, and as their energy level drops due to each movement, and getting fined by the environment time to time, they learn that their movements should be in a way that by using the available energy packs, when necessary, be able to survive for longer. In this article, 'needs' of robots are defined as 'wanting to use the energy packs', and if this needs weren't satisfied, the robots would go to their tense mode/state.
'super-ego' is the aspect of civilization of personality, and holds all the ideals and moral standards which are gained from parents and society. It also provides guidelines for making judgements (our sense of right and wrong). The robots, also, based on this description, and through their consecutive episodes, by the Learning Automata, will learn that their energy level shouldn't drop drastically, otherwise they will get eliminated. However, to follow the moral standards, as soon as they receive an energy pack , they shouldn't use it, and they should keep it for when they are in tense/excitement mode/state (it's not ideal for robots to use energy in their normal/steady mode). Ideally, robots should not go for risky movements when they are in their normal/steady mode. According to the description of 'super-ego' in Freud's theory, the robots could get advantage from other robots' experiences as well.
Also, Freud explained 'ego' is resulted from personal experiences, and is the executive centre as well as decision making one. The 'ego' strives to satisfy 'id's desires, and ensures that the impulses of 'id' can be expressed in a manner acceptable in the real world (super-ego). It plays a middle person role and makes the final decision. Following this pattern, our designed robots learn that from its experiences from its surroundings, choose suitable actions; this is done by LAs. So, robots based on available LAs and their actions' probability ratios, decide what action to choose next.
A cognitive robot, in its surviving period (from highest level of energy to zero energy), experiences two conditions, according to Freud's theory. We called them Normal and Excited/Tensed conditions. When, a robot's energy level goes lower than a certain amount, its normal condition changes to tensed condition. This is shown with a cognitive index. In tense condition, a robot gets more risky, and is able to make better decisions in critical conditions.

3. Proposed Solution

In this article, the robots start searching/ valuating their surroundings synchronously, and they are able to 5 actions in each episode. They can choose to be steady (fixed) in any condition that they think it's giving a better result, but they will lose one or two units of their energy level depends on which zone they are in.

There is a noticeable difference between functioning of a cognitive robot and a normal robot's ; a normal robot will never risk its (energy level) in order to survive longer, so it never enters an unsafe/unsecure zone. But, in other hand, a cognitive robot, because of being equipped to LA(which follows NI and Freud's theory) , risks its life so it can reduce the tension occurred in its system, and enters the Rocky zone (dangerous zone) . This means instead of choosing the ideals by their 'super-ego' , the decision making element (ego), will go more for whatever needs 'id' element asking for.

The cognitive robots, can up to date the probability of their actions (up/down, right/left, fix) by the help of this LA. So, can gradually improve their functions and increase their surviving chance in the virtual environment. Based on Freud's theory, the robots get rewarded, or fined, depends on the movement (action). We'll go in more details later.

When the robots are built, the probability of any of these 5 actions is the same as others, because they have not experienced the reaction of the environment, yet (reward, or fine). As you can observe the following table the addition of the probabilities of these 5 actions, is equal to 1 in the beginning of their movement, Please refer to (1).

Table 1: probability of each action in the beginning

Action	Probability
Up	0.2
Right	0.2
Left	0.2
Down	0.2
Fix	0.2

Sum of Probability (action) = P (up) + P (right) + P (down) + P (left) + P (fix) = 1; (1)

A cognitive robot will choose an action randomly, an action with a higher probability, has a higher chance to be chosen next, but in the beginning of the movement (search) it will go for an action randomly and investigate its surroundings. As the result a robot receives back a reward or fine for each action chosen, and this information and the new probability (sum of these new probabilities will be equal to 1, at all time) will be recorded for later use. This will be continuously done in each iteration, until all the robots are eliminated from the virtual environment.

3.1 The Algorithm of Up to Dating the Probability of the Actions in Learning Automata

* If an action got a reward (=0) as its result, in each LA, its probability ratio would be increased, in other words the rest of actions ratios would get decreased.
* If the result was a fine (=1), then the probability ratio would be decreased in that LA for that action, and wise versa for the rest of actions.

Please refer (2):

$$P_j(n+1)=\begin{cases} P_j(n)+(1-\beta)\left[a\left(1-P_j(n)\right)\right]-\beta\left[(b)P_j(n)\right] & \text{if } j=i \\ P_j(n)-(1-\beta)\left[(a)\ P_j(n)\ \right]+\beta\left[\frac{b}{r-1}-(b)P_j(n)\right] & \text{if } j\neq i \end{cases}$$

In this algorithm, the variables are as follow:
P(n) : the probability of an action in n times
P(n+1) : the probability of an action in n+1 times (or the probability of an action after up to dating)
β : the reaction or reply of the environment to the robot's action*
β = 0 means reward
β = 1 means fine
a: reward index
b: fine index
r: number of defined actions for a robot
* Environment rewards or fines based on some rules which follow Freud's theory of psychoanalysis.

3.2 How Cognitive Robots Acquire Information from their environment

Each robot depended on its vision boundary (radius) was equipped to sensors, that enabled it to recognize the contents (information) from their neighbourhood surroundings. So, each robot in its presence in the virtual environment could recognise:

- The zone it was in (Safe/Rocky)
- Its state based on its energy level (normal/excited)
- The zones its neighbours were in (Safe/Rocky)
- The contents of its neighbourhood (a robot/an energy pack/a barrier/or nothing)

These abilities together were what made a Learning Automata for a robot. Robots made many LAs in their surviving time, and save them in their memories. They could up to date their LAs in each episode. There were 5 actions (up/down, right/left, and fix) available for each LA, and each action was allocated with a probability ratio. As a robot faced an experienced situation, it referred to its list of LAs, and chose a suitable LA, then followed that

LA actions based on their probabilities. So, this way they made a suitable movement/action, and learned gradually how to increase their chance of surviving.
In each episode, instead of any action the robot has chosen, it has experienced a situation in its surrounding, so, one LA would be produced. If robot has not experienced such situation before, there would be a new LA built, and added to the list of LAs in robot's memory. As well, the respond of the environment to such experience (based on the rules introduced) would provide up to dating of probability ratio of actions for the LA.
But if a robot has already got that specific LA in its list, It wouldn't add it again, instead, its experiences would be used in deciding what action to take, and this way robot has got the chance of increasing its experience (knowledge of decision making), and as the result increasing its surviving time. That's how Freud believed in the feedbacks a person has received from the society, which would effect his/her actions later on, and help his/her to adapt better to the society. He also believed that parents' rewards or punishment has the same affects on their child's behaviour.
For example a child who has been praised for a good behaviour, by his parents; his super-ego has recorded it as an ideal reaction, so in a similar situation, it would be much easier for him to decide what to do, based on his experience (ego). That's exactly the same for our designed cognitive robots in the virtual environment.

3.3 How LAs Built in Robots

There are many different of ways to build LAs in robots. In this article, three methods were discussed and experienced.
In all the three methods the same zones and the same actions were introduced. They (based on their functions) were called: State based, Model based, and State based with vision radius.

Method 1: State based
LA was designed based on the robot's state, situation and the four surrounding neighbours of the robot. Robot could sense its surroundings with its sensors.

Method 2: Model based
In this method, plus the sate of the robot and its neighbourhood information, the axial positions of the robot ,in each episode, were recorded as one of the fields of LA.
So, when robot didn't know much about its surroundings but had its axial positions, tried to collect other information about that environment gradually, which resulted in better decision making, and action.
One of this method's defects was being slow due to its massive number of LAs.

Method 3: State based with vision radius
In this method the proposed algorithm was improved when the vision radius of the robots increased. Here, as well as the first method, the state of robot and its neighbouring information (but not the axial positions) were available for the robots with the difference of giving the four neighbours, 4 points, that helped the robots to choose an action based on those points. This method has provided a better result at the end.
This pointing system worked this way:
The highest point was given to energy supply packs, and the rest got points based on the how far they've been from the energy pack. That meant the points were reduced if they were further from the energy pack. It was calculated by the following three equations (3,4,5):

Max Point = 2 r+1 (3)
Distance = |(NodeX – ResourceX)| + |(NodeY – ResourceY)| (4)
Node Point = Max Point / 2 Distance (5)

In which:
r : vision radius
Max Point : highest point
Node Point :the point given to each neighbouring side
Distance : the distance of the side from energy pack
(NodeX, NodeY) : the axial position of each side that has earned a point
(ResourceX, ResourceY) : the axial of an energy pack
The interesting thing was that each side's point was sum of all other points it had earned from different supplies. And there would be no points for the sides which were away from the vision radius. So, the robot could find an energy pack faster.
In this method, in each episode, a Learning Automata was built with the above features. Its privilege to the other two methods was that the robots had a wider view of their surroundings, which helped them in decision making (ego), and having better results.
If a vision radius of 1, 2, or 3 was available for the robots, they could recognise the contents of their neighbouring units with the help of their sensors. (fig.4)

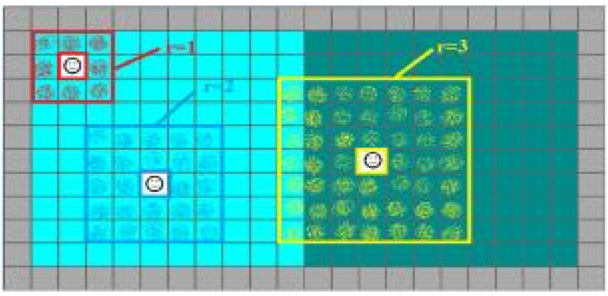

Fig. 4 vision radius of 1, 2, and 3

3.4 The Rules of Giving Rewards or Fine to a Robot by Its Surroundings

Rule 1: If a wrong action was chosen, the robot could have got fine e.g. went up, where was a barrier. (Super-ego (the social aspect of behaviour) has built up, and ego recorded the experiences gained from the surrounding.)

Rule 2: If an energy supply was used where the robot was in its normal state, there would be fine applied. (id was trying to fulfil its pleasure aspects where it contradicted the ideal of super-ego, so ego took control over id and balances achieved)

Rule 3: If the robot chose a movement that leaded to an energy pack, a reward would be given to the robot. (The robot has learned that being next to an energy pack could satisfy its needs faster at the time of tension, which meant ego was collecting information from the environment)

Rule 4: If a robot in its normal state, went to Rocky zone from Safe zone, would have got fine. (Risking when it was not necessary, leaded to fine. Ego was learning about the motives.)

Rule 5: If a robot in its normal state, chose to move to Safe zone, Would have earned rewards. (In Safe zone, less energy would be lost, so ego has learned how to adapt or compromise.)

Rule 6: If a robot was in tense/excited state, and used its energy supply pack, would have got rewarded. (Ego must have reduced the tension of id by using the available sources.)

Rule 7: If a robot was in tense state and though having energy supply available, not use it, would have got fined. (ego neglected id's needs and as the result recorded the information about this incident/ experience.)

3.5 The Results of the Simulation

To study the suggested algorithms, five robots with maximum level of energy (200 units) were put in an environment with 25 energy supply packs, with ratio of 80% (energy packs in Rocky zone)to 20% (energy packs in Safe zone) plus reward index of 0.8 , fine index of 0.7, and excitement index of 0.5.
In 4 methods and 60 iterations, the average of robots' surviving time was calculated. In the fourth method, a vision radius of 3 was provided for robots, which meant a better view to the environment and to the energy supply packs, and also a better decision making.
The results of these 60 continuous iterations and robots' life time in the environment are shown in fig. 5.

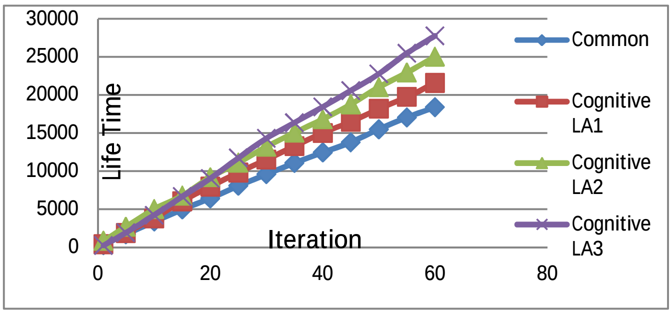

Fig. 5 Total of robots' life time in test

As it was shown in the graph, after 60 iterations, cognitive robot had a better chance of surviving comparing to a normal robot, which meant a robot with the privilege of decision making ability (LA) would act more suitable and acceptable to its surroundings. Among cognitive robots, those used third method had better results, and that was because of having a wider vision radius which leaded to better decision makings and better actions.

In this test, cognitive robots with method one(state-based), showed less efficiency comparing to those used method two (model-base), where had more robots available in the environment, and as the result more information recorded and more experiences gained to help decision making process.

4. Conclusions

This article tried Freud's psychoanalysis theory (id, ego, super-ego) to suggest a suitable behaviour model for cognitive robots. And this theory was simulated in a way that robots could make decisions to choose an action (which look better and closer to reality) based on their experiences from the environment. The cognitive robots used these algorithms to search their surroundings and gain some information so that they could survive for longer. To achieve this knowledge and make a decision, cognitive robots used LAs and the responds (fine, or reward) of their environment based on Freud's theory.

For simulation, three methods were suggested and robots' decision making power were studied and compared together. The results showed that cognitive robots (which were given the factor of sensing and decision making, to look closer to human) adapted themselves easier to the environment, and after a few iterations, they learned (by making better decisions in critical moments) how to survive longer comparing to normal robots. Though their (cognitive robots) risking approaches to critical situation, sometimes, caused trouble for them, and didn't result well, overall, comparing to normal robots, they produced much better outcomes according to the observations done.

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