A Conscious Robot that can Venture into an Unknown Environment in search of Pleasure

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Abstract
A "conscious system that can venture into an unknown environment" has been proposed. This study models the process of consciousness of a person who is going into an unknown environment. First, we assumed that to go into an unknown environment, the person needs to be curious about that environment and assured of its safety. Curiosity is a tendency to become interested in unknown phenomena and draw information from them. We consider that to acquire the behavior of going into an unknown environment (curiosity behavior), firstly the person needs in some way to go through many experiences of pleasure in unknown environments and increase curiosity and interest in such environments. To enter an unknown environment the person must also be assured that the environment is safe. We have developed a conscious system that can venture into an unknown environment and tested whether a robot can voluntarily enter an unknown environment.

Keywords: conscious robot, venture, unknown environment, curiosity, pleasure

1 Introduction

In recent years, the progress of robot technology has brought about the development of many human-like robots, known as humanoid robots. Humanoid robots have advanced functions, and they are expected to play active roles in the future.

As future issues, humanoid robots will be required to possess an understanding of the human mind and human-like behavior in order to have more intimate communication with humans. As such, what is that human mind and human-like quality? The authors consider these to be phenomena that arise from the "consciousness" of humans. Various studies have been conducted on consciousness, but there is still no clear theory about human consciousness. For this reason, the authors speculated that human consciousness became "consciousness" through the complicated activity of advanced functions, and thought that, first of all, it was important to grasp the mechanism that lies at the root of consciousness. And the authors defined consciousness using a simple paradigm.

In this study, we define consciousness as follows: "consciousness is generated by the consistency of cognition and behavior" (Takeno, 2012). Then, using a system model that is devised based on that theory, called a MoNAD (Module of Nerves for Advanced Dynamics), we aim to achieve the functions of human consciousness and also to understand human consciousness in the process.

2 Mechanism of Searching the Unknown

The authors considered the process of consciousness that occurs when humans "venture into an unknown environment in search of something pleasant" and modeled that process.

Basically, something "unknown" is thought to cause an unpleasant sensation in humans (Leon, 1957). As such, unknown environments should also cause unpleasantness to humans.

Humans often feel uncomfortable because of emotions, such as pain or solitude, resulting from physical changes and external stimuli. However, the authors consider an "unknown environment" to be a source of particular unpleasantness, and this is because the unknown environment is brought about by the cognition of the external environment. Reason is what determines the behavior taken upon the cognition of this external environment and the logical judgment performed from the information obtained from the environment. The authors think that there is one source of unpleasantness in this "logical judgment" here. And therefore, we think that the unpleasantness caused by an unknown environment is brought about by reason. In order for humans to venture into an unknown environment, it is necessary to change the behavior that is determined by reason.

In addition, while the unknown produces a feeling that is initially uncomfortable to humans, if they are given the opportunity to know the unknown after that, the authors think that this is an opportunity for humans to change toward a feeling of pleasantness regarding the unknown. We speculate that by repeating experiences in which unknowns can become known, humans gradually become able to represent unknown subjects. This would seem to be the development of a sort of curiosity concept.

Curiosity is commonly said to be an interest in unknown events, and that there is a tendency to derive information from them (Della, 2014). We may presume that the interest in an unknown environment arises due to human curiosity, and that it serves to aid the desire to move forward in an unknown environment. However, although interest in an unknown environment may arise due to human curiosity, there is a doubt as to whether that alone will lead the human to the act of actually entering the unknown environment. Here we consider the relationship between "death," which is an example of an unknown event, and curiosity. Although curiosity may lead to an interest in death, it seems that no one dies from an interest in death. From this example, in order for humans to challenge the unknown, we think that, in addition to the interest generated by curiosity, something different is necessary.

The authors think that that is the "growth of curiosity in the unknown." As humans receive pleasure related to unknown events, their curiosity about the unknown events grows and their interest in them grows. The authors thought that curiosity will grow to challenge unknown events when crossing certain lines.

The authors also believe that there is another important factor that enables humans to move into an unknown environment. That is securing a safe environment. If unpleasantness should occur in an unknown environment, as long as one has secured a safe environment beforehand, that will be a place that you can escape to. In this way, we thought that securing a safe environment — a place where one could escape to — would become a spiritual support and make it easy to move forward into an unknown environment.

Based on the above points, the hypothesis of the mechanism by which humans venture into an unknown environment as proposed by the authors is as follows. "When humans encounter an unknown

environment, they are interested in the environment due to their curiosity, but in the case of a robot, reason will stop the robot's forward movement and prevent it from moving forward into the unknown environment. To be able to proceed into an unknown environment it is necessary to have a growing curiosity caused by pleasure associated with the unknown environment. It is also necessary to secure a safe environment that can be a place to escape to when unpleasantness occurs in an unknown environment. Only after this growth in curiosity and securing a safe environment can humans proceed into an unknown environment."

3 Conscious System that Ventures into Unknown Environments

In this study we use a consciousness module called a "MoNAD," which stands for Module of Nerves for Advanced Dynamics. The MoNAD is a model that is composed of neural networks and achieves consciousness functions. We have also constructed a conscious system by using multiple MoNADs. Our conscious system consists of three subsystems, the "Reason subsystem," "Emotion & Feeling subsystem," and "Association subsystem." In the Reason subsystem, the state of the conscious system itself in the external environment is determined based on information input from the environment, and emotion and feelings are represented in the Emotion & Feeling subsystem. The role of the Association system is to arbitrate (i.e., settle) the information of the Reason subsystem and the information of the Emotion & Feeling subsystem.

Our conscious system that can venture into unknown environments roughly consists of six MoNADs. The Reason subsystem consists of the reason MoNAD (Re), safety MoNAD (Sa), curiosity MoNAD (Cu), and search MoNAD (Se). The Emotion & Feeling subsystem consists of the pleasant MoNAD (P) and unpleasant MoNAD (UP). We do not use the MoNADs in the emotion subsystem in this study. Incidentally, Re is the part that would intelligently make judgments in humans. Sa confirms safety. Cu mimics human curiosity. Se searches for unknown environments and makes them known. P represents pleasure. UP represents unpleasantness. This conscious system that can venture into unknown environments is shown in the figure below.

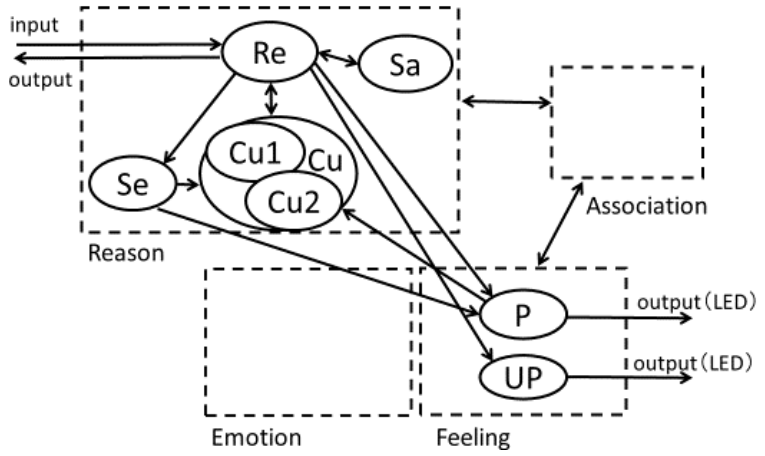

Figure 1: Conscious system that ventures into unknown environments

In our experiment, the robot judges whether to move forward or stop (rationally) depending on the external situation. Also, information input from Cu and Sa becomes judgment information for the behavior decision.

Sa confirms the safety. In this study, we assume that safety is secured when the current position of the robot is a known place.

If the next location to move to from the current position of the robot is unknown, Cu issues a go forward signal or a stop signal. Cu uses two MoNADs, Cu1 and Cu2, to represent the growth of curiosity. Since in the initial state Cu1 is weakly interested in the unknown environment, Cu1 outputs a signal stopping the forward movement of the robot with respect to Re. As Cu1 grows with the experience of receiving pleasure in the unknown environment, Cu1 is set to switch to Cu2. Cu2 outputs a go forward signal when recognizing an unknown environment.

Se is the MoNAD that enables the robot itself to be conscious of the known environment and the unknown environment. Se recognizes the present location of the robot itself in the experimental environment using a one-dimensional array M[k] (where k is an integer) that is set in the conscious system. That is, M is the environment map of the robot. At the start of the experiment, M[0]=1 is set as the initial value, and the other array elements are set to 0. Element 1 means that the position k of M is a known environment. Element 0 corresponds to an unknown environment.

P represents a "pleasant" state. In this study, the robot represents a current pleasant state (p0) when its present location is a known location and when the unknown environment is made known by a forced forward movement. There are cases in which the environment in front of the robot may be a known place or an unknown place, but if the robot judges that the environment in front of it is a place that will bring it pleasure, even if that is an unknown place, a future pleasant state (p1) is represented.

UP represents an "unpleasant" state. In this study, the robot represents a current unpleasant state (up0) when its current location is unknown. And when the environment in front of the robot is unknown, a future unpleasant state (up1) is represented.

All of the MoNADs perform in advance the initial learning that is necessary for the experiments, and the learning method uses back propagation.

4 Robot Experiments

The conscious system as described in the previous chapter was mounted on a robot and experiments were conducted. In these experiments, we used the "e-puck," a commercial small robot.

The robot has LEDs on its exterior. In our experiments, the LEDs corresponding to the emotions represented by the robot light up. We used four LEDs in our experiments (Fig. 2).

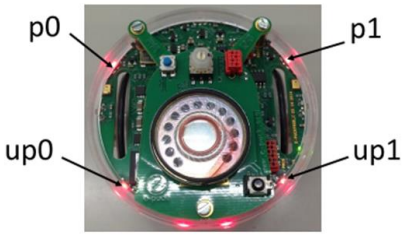

Figure 2: Layout and meanings of the LEDs on the small robot
(p0: pleasant state of current location, p1: future pleasant state,
up0: unpleasant state of current location, up1: future unpleasant state)

All of the LEDs are red.

In our experiments, the robot uses the environment map M to move forward or stop. The actual distance between M[k] and M[k+1] in the experimental environment is approximately 10 cm.

We begin the experiment by placing the robot on a flat surface. First, we set the area (M[0]=1) where the robot is placed (this is a 10 cm × 10 cm wide region, and the position is M[0]), and we set the area

(M[1]) in front of the robot, which is where the robot will move to, to an unknown area (M[1]=0). Since the area in front of the robot is an unknown area, the feeling MoNAD UP represents an unpleasant state (up1) and the robot does not move forward. As mentioned above, in order for the robot to move forward into the unknown area by itself, it is necessary for it to know the unknown environment first, to experience pleasure, and for its curiosity Cu to grow. However, the robot can not experience pleasure as it is. Therefore, the experimenter forcibly pushes the robot by hand and moves it 10 cm forward from its current position M[0] into the unknown area M[1]. Through this process, the system activates the search MoNAD Se to correspond to an unknown environment and sets the information (M[1]=0) of the unknown area to be known information (M[1]=1). The robot can feel pleasure in a known environment, so when it knows an unknown area, the robot has more opportunities to feel pleasure.

Through the process of experiencing a pleasant state for about n times (n=4 in an experiments), the robot's curiosity can grow adequately and the robot can move forward into an unknown environment voluntarily. In our experiment, the distance the robot can travel in one movement is 10 cm, and for every 10 cm of movement forward, if the place is an unknown environment, the robot changes it to a known environment. Then, the robot judges whether the next area that it will move to 10 cm forward is unknown or already known.

We will describe the state of the experiment.

First of all, the robot is stopped with an unknown area (for example, M[k+1]) in front of it. Since the robot's current position M[k] is already known as described above, p0 is represented, and since the area M[k+1] (hereinafter referred to as the "next area") to move to is unknown, up1 is represented. (Figure 3 a)

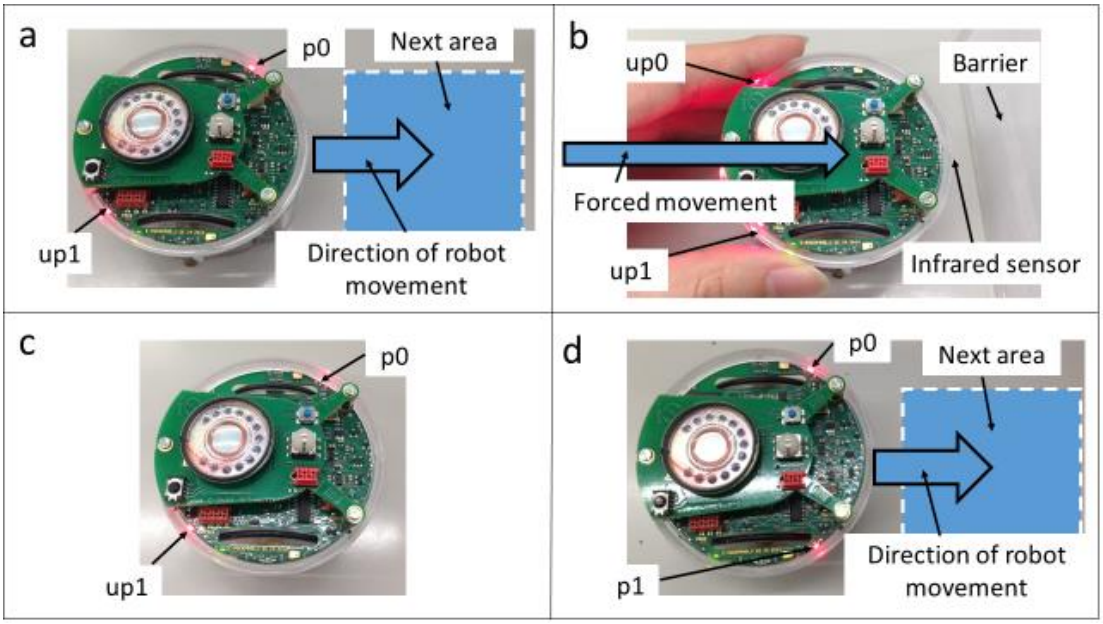

Figure 3: State of the experiment

a: represent p0, up1 for an unknown area,

b: represent up0, up1 when forced to move forward to an unknown area,

c: represent p0, up1 when successfully making an unknown area known,

d: represent p0, p1 with the unknown area in front.

Next, the robot is pushed by hand to forcibly move it forward to that area because the robot can not move forward voluntarily (because of the M[k+1]=0 information indicating that the area in front of the robot is unknown). The robot can recognize whether it has been forcibly moved forward (due to a change in the sensor value of the infrared sensor installed in the traveling direction of the robot). Therefore, the experimenter temporarily places a barrier 10 cm away from the robot in the direction of travel as an expedient measure. The barrier is removed immediately after a forced movement forward.

Since the robot has entered an unknown environment (e.g., M[k+1]), the robot represents up0. Also, since the next area (M[k+2]) for the robot to move into continues to be unknown, the robot represents up1. (Fig. 3 b)

Since the robot did not assume that it had intruded into an unknown area at this time, Se operates and changes the unknown area (M[k+1]) into known information (M[k+1]=1). At this time, since the robot took an unknown environment to be a known environment, the robot represents p0. However, the representation of up1 remains unchanged. (Fig. 3 c) This means that the robot is in a state where it is not yet able to venture voluntarily into the unknown environment because its curiosity Cu has not grown enough at the moment. Therefore, the robot stops with the unknown area (M[k+2] in this case) immediately in front of it. However, by forcibly experiencing the feeling of pleasure at this time, the robot's curiosity Cu gradually starts growing.

The experimenter needs to forcibly move the robot forward to an unknown environment several times until the robot can move forward voluntarily. As a result, the curiosity Cu of the robot gradually grows.

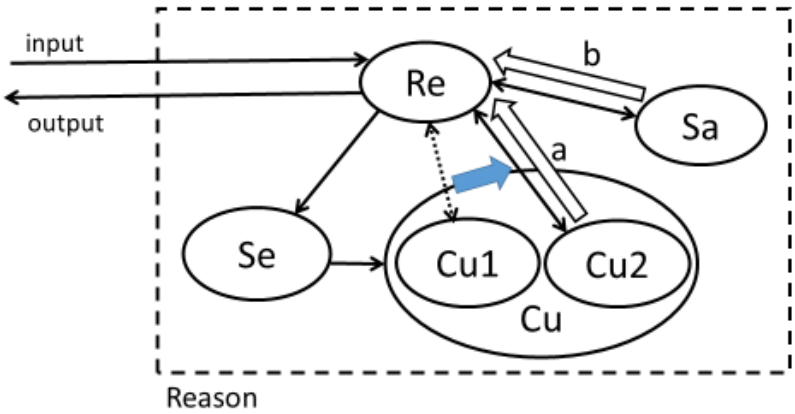

Figure 4: Reason subsystem when curiosity has grown adequately, a safe environment is secured, and an unknown area is located immediately in front of the robot

When the robot experiences pleasure from knowing an unknown area about 4 times, Cu switches from Cu1 to Cu2. This process represents the growth of curiosity. In this experiment, the procedure for switching from Cu1 to Cu2 uses a procedural method in which the ratio z increases as the number of iterations (n) is increased by repeating the pleasant experience received by forcibly moving the robot forward (z=n*20%). Essentially, the method of MoNAD's genesis is suitable for the generation and growth of Cu, but that will be a task for the future.

Figure 4 shows the state of the robot's reason subsystem with Cu1 switched to Cu2 (when curiosity has grown sufficiently) and the state when Sa has secured a safe environment and the unknown area is immediately in front of the robot. "Cu 2" instructs the robot to move forward with respect to Re (Fig. 4, a). In addition, Sa confirms the safety and transmits the information that safety is secured to Re (Fig 4, b). At this time, the robot can represent p1. That is, since the next area to be moved into is unknown, the robot initially represents an unpleasant state, but the robot changes that area to a pleasant state through the process of Cu growth as described above. As a result, this robot, which represented p1 immediately in front of an unknown area, voluntarily moved forward into that unknown area. (Fig. 3 d)

5 Considerations

This experiment was conducted 10 times, and in all of the experiments the robot was able to voluntarily venture into unknown areas. This experiment was the first demonstration of "a robot equipped with a conscious system that voluntarily ventured into unknown areas."

In this paper, the authors first consider the mechanism of searching the unknown by humans, and in order for humans to be able to voluntarily venture into an unknown environment, the authors have confirmed and determined that the growth of curiosity and the securing of a safe environment are important factors.

Based on this consideration, the authors developed a conscious system using MoNAD consciousness modules. This is a "conscious system that voluntarily ventures into unknown environments." Then, we performed experiments by installing the conscious system on a robot and demonstrated that the robot voluntarily ventured into unknown environments. The authors pointed out that this demonstration shows that the growth of curiosity and the securing of a safe environment are important factors when humans voluntarily venture into unknown environments.

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