Development of a humanoid head using a conscious system

J. Takeno
Robot Science Laboratory, School of Science and Technology, Meiji University
Kanagawa, Japan
e-mail: g.matsuzaki.49@gmail.com, juntakeno@gmail.com

G. Matsuzaki
Robot Science Laboratory, School of Science and Technology, Meiji University
Kanagawa, Japan
e-mail: g.matsuzaki.49@gmail.com, juntakeno@gmail.com

Abstract[1]

The authors developed a humanoid head robot that has an artificial spine of almost the same shape as the human spinal structure. The objective of using this humanoid head is to have the robot acquire the same consciousness as humans. The authors define the origin of human consciousness to be the "consistency of cognition and behavior." A consciousness program developed based on this definition was loaded on the robot in an attempt to validate the legitimacy of the conscious system. The aim is the achievement of self-recognition in a robot with a physical structure based closely on human anatomy by having the robot perform imitation behavior using the conscious system in conjunction with the humanoid head. The study also aimed to deepen comprehension of human consciousness and to further develop the conscious system model.

1. Introduction

In contemporary Japan the birthrate is declining and the population is aging. A workforce shortfall is expected to become a future problem in time [1]. As a solution, robots are expected to be capable of substituting for human labor in various fields including nursing and welfare services.

The authors think that the important factors for robots working in human society are that they should be humanoid in form and should be capable of consciousness similar to that of humans. A humanoid has almost the same physical structure and sensory organs as a human, so humans can be expected to be able to communicate with such robots in the same manner as they do with other humans. Robots are expected to be able to integrate information on their own status and information on the external world and be self-aware to make autonomous decisions. Humans perform such activities using the functions of human consciousness. We think that it should be possible to develop a robot that can handle the complexities of human society if it were able to possess consciousness.

For this research, we developed the humanoid head robot resembling the physical and sensory structure of humans. While it is still not thoroughly understood, we define human consciousness more specifically, and simulate and incorporate this consciousness in the humanoid head. Through these processes, we hope to justify our proposed definition of consciousness and aim at a more thorough resolution and comprehension of consciousness. We are attempting to reproduce a flow of consciousness on a computer to achieve capability of communication and judgment. Ultimately, using this new technology we aim to construct the foundations of a robot that has the potential to become more useful in human society.

2. Chapter 1 Structure of the humanoid head

2.1. Head portion

The humanoid head developed in this research simulates the skeletal structure of the human head and neck. The head is the same size as a human head, but the neck is approx. 30% thicker than a human neck due to mechanical considerations. Aluminum is used as the material for its durability and hardness. (Fig. 1)

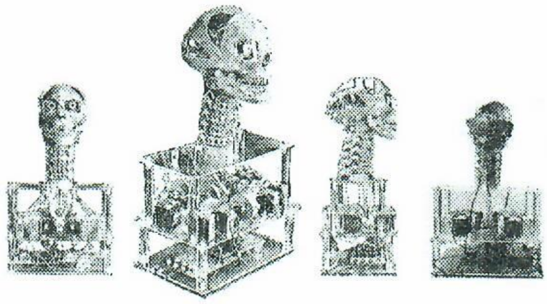

Fig. 1. Humanoid head

The height from the base of the neck to the top of the head is approx. 300 mm and the weight is approx. 3 kg.
A vision unit is mounted in the head to obtain visual information on the external environment. The neck

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consists of 7 cervical vertebrae in the same configuration as the cervical portion of the human spine. Wire is used for the muscles of the cervical region, and a flexible silicon resin is used between the vertebrae. This structure makes it possible to perform flexible and nimble movements. The overall humanoid head system comprises the head portion consisting of the skeleton and motors that moves the skeleton, the computer that processes data, and the vision processing portion. The data processing computer processes action data for controlling the motors, image data and sensory data.

Humans communicate with others not only orally but also through their actions. The humanoid head can move in three-dimensional space using its artificial cervical spine and motors, for instance nodding, thus it can perform the same communication gestures as humans with its head and neck.

2.2. Control method

The movements of the humanoid head are controlled by positioning it with three coordinate systems: vertical inclination (flexion, extension), right or left inclination (side bending), and right or left turning (rotation). These movements can be performed in almost the same way as the basic movements of the human cervical region. A set of motors and wires are built into the humanoid head to simulate the movements of 16 muscles. Thus, there are 16 sets of discrete three-dimensional functions of f (x, y, z). We repeated interpolation processing of each function using the interpolation polynomial of Lagrange based on the movement reference point and calculated the approximate function. Using this calculation, the robot is actually able to move its head in most of the directions that humans are physically capable of turning their heads. In this calculation, x is a parameter of rotation, y is flexion and extension, and z is the side bending.

2.3. Vision system

The vision system is equipped in the humanoid head to obtain visual information on the robot's external environment. The vision unit uses 2 sets of small cameras and the general purpose RoboVision is used for processing.

3 Conscious system

3.1. Consciousness

In general terms, consciousness is the state where one understands what oneself and others are doing and acts accordingly based on that cognition.

In this research, we base our definition of consciousness on the principle that the "consistency of cognition and behavior is the origin of consciousness," as stated in the thinking of various philosophers, and reported on brain science, such as mirror neurons, and in medical cases including imitation behavior.

3.2. MoNAD

We developed a consciousness module, the Module of Nerves for Advanced Dynamics (MoNAD), based on our definition of consciousness. MoNAD is a model for artificial consciousness functions, and it consists of neural networks. Various states of artificial consciousness can be attained when consciousness modules with various functions are linked to each other to form a hierarchical structure. [2].

3.3. Comparison of MoNAD and former models

Former models that perform cognition and behavior in artificial intelligence or robots are mechatronics based. Information that is input is then output via the route of the "cognition system", "judgment part" and "behavior system part." Cognition and behavior are processed in series, and information is processed sequentially.

In the case of a mechatronics model, the data that is output corresponds to the data that is input, however this is very different from the information processing that is performed in the human brain. Moreover, there is no internal circulation of the information as there is in the MoNAD, thus it is not possible to explain advanced cognition functions such as expectation, thought, self-cognition and representation. Therefore, as a model with consistent cognition and behavior, MoNAD represents a better model than the mechatronics model for the purpose of achieving consciousness in a robot.

3.4. Robot using a conscious system

The system we call a conscious system is configured by stratifying multiple MoNADs according to roles such as "reason system," "emotion & feelings system," and "association system."

The legitimacy of the conscious system using MoNADs has been validated in previous research [3][4]. However, consciousness has a close relationship with the human body, so it is necessary to demonstrate within the environment of a physical body just like the human body. We have therefore attempted to validate the conscious system using the humanoid head in this research.

4. Experiment with imitation behavior using a robot

The imitation conscious system imitates the behavior of the target human using visual information. The system receives information, for example what sort of position or posture the humanoid head is currently in, from the conscious system of the drive system. Then it outputs the behavior for the humanoid head to perform using the information obtained through the drive system and visual information. However, the robot is not just following orders sequentially. When the humanoid head moves, a pleasant or unpleasant emotion occurs and information is circulated internally, and judgments are made. This gives a representation of what sort of behavior the humanoid head is performing or whether any abnormality has occurred, and this is conveyed to the conscious system as feedback information.

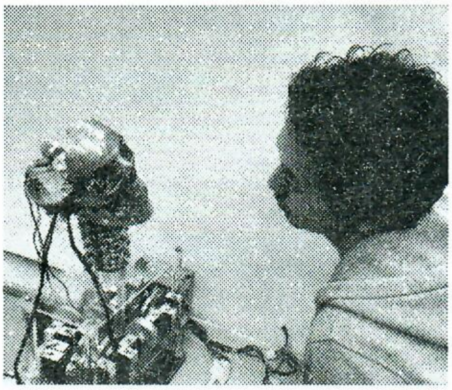

Fig. 2. Experiment of imitation by robot

We use RoboVision, a dedicated computer for processing visual information, to process the positional information of the object, without using the conscious system at present. With this method, the color of the object to be tracked is specified, and the image is simplified into two values based on the color. We calculate the center of gravity in the range split into two values and use the result as positional information for the object being tracked. The center of gravity is expressed as two-dimensional coordinates. We set the coordinates related to the horizontal direction as y and the coordinates related to the vertical direction as x. In this experiment, we achieved imitation by setting the threshold using the color of human skin and tracking the obtained center of gravity coordinates (x, y).

Figure 3 shows the conscious system configuration for performing the imitation behavior. When somatosensory information from the humanoid head or external information from the vision system is input, the conscious system represents the result of cognition or behavior or emotion.

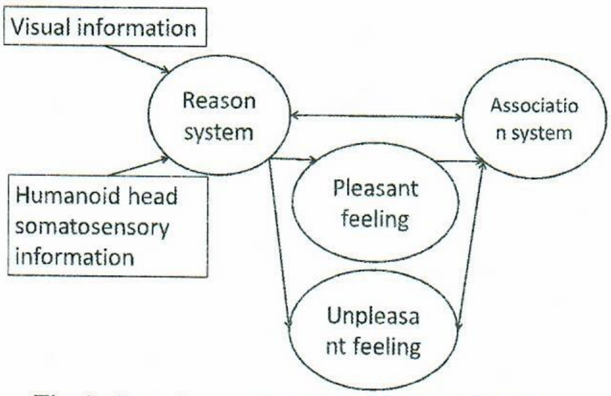

Fig. 3. Conscious system for imitation behavior

5. Experiments

We incorporated this conscious system for imitation in the humanoid head and made it perform imitation (Fig.4). The following is the internal information on the representation of the humanoid head over time. The behavior of the human is shown in ①.

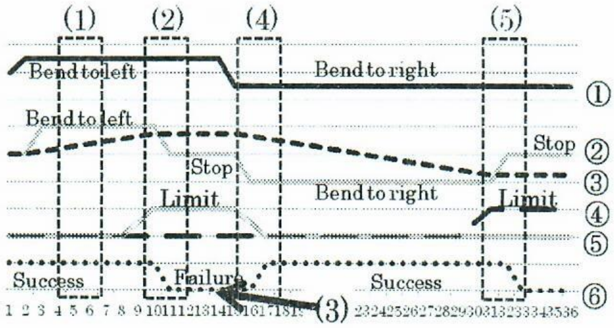

Fig. 4 Experimental result of conscious system for imitation (Side bending degree of human, Side bending degree of humanoid head, Cognition representation for humanoid head behavior, Unpleasant: limit of side bend for humanoid head on the right side, Unpleasant: limit of side bend for humanoid head on the left side, Cognition representation of the imitation behavior)

The time series in Fig. 4 shows that the humanoid head bends its neck to the left to imitate the target human's bending his neck to the left as viewed from the humanoid head. In this situation, the imitation is successfully performed. As the target human to be imitated continues bending to the left gradually, the humanoid head also keeps bending to the left to imitate the behavior (Fig. 4(1)).

The artificial cervical spine has a narrower range of bending movement than the cervical spine of a human, so as bending to the left continues, the humanoid head reaches the limitation of the bending range before the human. The internal status of the humanoid head at that time is shown in Fig. 4 (2). Though the target human can bend his cervical spine further to the left, the humanoid head generates an unpleasant feeling arising from the limitation of its movement range, so we changed its behavior so that it stops bending at that point. At this time, the imitation fails, and the humanoid head cognizes the failure of the imitation behavior itself (Fig. 4 (3)).

After that, when the target human stops bending to the left and starts bending to the right, the humanoid head also starts bending its cervical spine to the right to imitate. The internal status of the humanoid head at this time is shown in Fig. 4 (4). When bending to the right continues up to the limitation of the bending movement range, an unpleasant feeling is generated again, so we changed its behavior so that it stops bending at that point. This is shown in Fig. 4 (5).

The result of this experiment shows that the humanoid head was conscious of its own behavior and that of the target human to be imitated using the conscious system and successfully generated behavior from cognition accordingly. Furthermore, the robot could recognize "unpleasant" feelings and change its behavior.

Because the humanoid head was able to comprehend itself and another (the human it was imitating) and generate behavior from cognition accordingly, we think that we have succeeded in achieving the fundamental functions that will become the source for its consciousness. We believe this experiment is effective in demonstrating the legitimacy of our conscious system and forms the basis for the future development of our conscious system.

6. Conclusion and Results

- Our initial experiments utilized multiple MoNADs, and the humanoid head performed the imitation behavior by implementing this as the conscious system.

- As a result, the humanoid head performed the imitation behavior using information on the target human to be imitated and somatosensory information on its own status. When an unpleasant feeling arose from the somatosensory system, the humanoid head changed its behavior according to the representation.

- We can say that the humanoid head communicates information including its own current state, the behavior that the target human is performing, and whether it succeeds in imitation as representation and understands the status. This can be interpreted in no other way than that the robot is simultaneously capable of cognizing its own status and external status and subsequently generating a behavioral response.

- In this research we mounted our conscious system in a humanoid head created to emulate the human skeletal and muscle structure and successfully performed an imitation behavior experiment. We believe that this experiment effectively demonstrates the legitimacy of our conscious system and is the foundation for the future development of the conscious system.

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