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Ontological Robot System for Communication

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Abstract
The robot has recently emerged as a factor in the daily lives of humans, taking the form of a mechanical pet or similar source of entertainment. A robot system that is designed to co-exist with humans, i.e., a coexistence-type robot system, is important to be "it exists in various environments with the person, and robot system by which the interaction of a physical, informational emotion with the person etc. was valued". When studying the impact of intimacy in the human/robot relationship, we have to examine the problems that can arise as a result of physical intimacy (coordination on safety in the hardware side and a soft side). Furthermore, We should also consider the informational aspects of intimacy (recognition technology, and information transport and sharing).
This paper reports the interim results of the research of a system configuration that enhances the physical intimacy relationship in the symbiosis of the human and the robot.

Keywords
Ontology, Multi-platform robotics, Communication

INTRODUCTION
The symbiosis of the human existence and the intelligent robot assumes that the robot is capable of being safely integrated into the human environment. That is, an intelligent robot can be endowed with autonomy and the capacity to interact intimately with humans. Human nature is such that when we are not working, we like to indulge in leisure-time activities. These activities and their characteristics vary depending on one's life style. An intelligent robot must be capable of subjectively understanding human nature to interact safely. We describe here a system we designed that provides a robot with an autonomous function and a learning function. The good actions of the robot were learned from interaction between human and robots, and it was experimented in the real machine robot. The good actions that satisfy both human and robots are acquired from human's subjective evaluation as well as the emotion of the robot.
We studied the resulting human and robot symbiosis using the system composed. The learning method used is different from a general reinforcement learning method though it assumes that reinforcement learning is fundamental.
In a word, a reinforced signal depends on the evaluation of a human and the value of the robot, and the value changes by simulated feelings of the robot. Moreover, a smooth communication was enabled by sharing the studied action with other agents according to an environmental information situation.

SYSTEM OUTLINE
The outline of the system configuration of the intelligent robot we designed is shown below (Fig. 1).

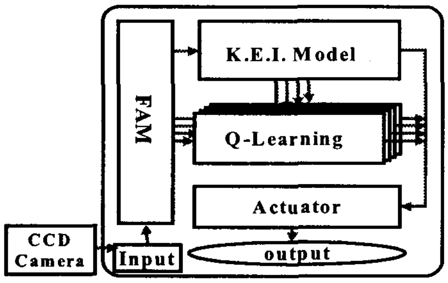

Figure 1. System outline

The basis of the system used in this research is the Rasmussen model, which is comprised of a three-layer structure.
The information generated by a human's action is provided to the robot by a CCD camera (Fig. 2).

Figure. 2: Experiment robot

The robot and human positional information is provided by CCD camera mounted above on the ceiling.
The system that was developed from this research is composed of three intelligent systems.

1. Action (gesture) recognition of human and expression of robot emotion. (Autonomous action support)
   Fuzzy Associative Memory (FAM) Model of Knowledge, Emotion, and Intention (K.E.I. Model)
2. Learning action pattern of Robot Q-Learning algorithm
3. Sharing of acquired knowledge Network Robotics using Ontology for human

In this paper, we explain each intelligent system sequentially.

ACTION RECOGNITION OF HUMAN

In the symbiosis of human and robot, the robot should understand specific instruction as well as non-specific instructions given by a human. In this research, Fuzzy Associative Memory (FAM) is used so the robot can understand instructions that are conveyed directly by the human as well as those that come from the human's environment. FAM is composed of a front layer of fuzzy rule (If layer) and a back layer (Then layer). The rule layer by which one node represents one rule is set. The fuzzy rule is expressible by using the composition of the BAM (Bi-directional Associative Memory) between the If layer and the Then layer. (Fig. 3)

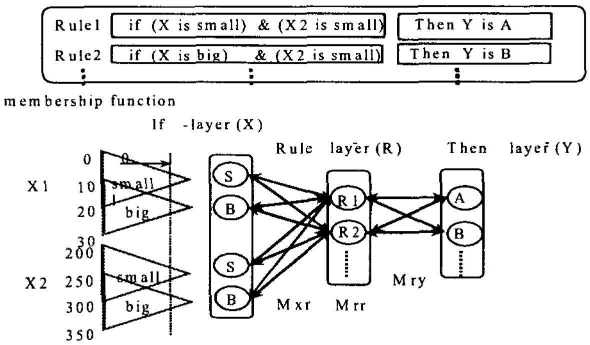

Figure 3.FAM

In this study, Intelligent Space software (ISpace) was used to recognize the position of the human's hand and the position of the robot. ISpace can recognize a user's skin color (color information) and the position information of human and the robot. (Fig. 4) The human's hand position obtained by ISpace is treated as time series data. The value of the point of inflection is processed by FAM, and it is then inferred what the operation is being observed.

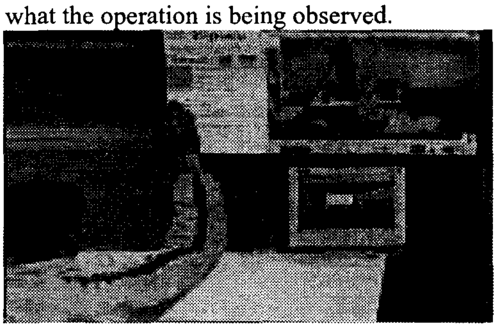

Figure. 4: Intelligent Space

EXPRESSION OF ROBOT EMOTION

K.E.I. (Knowledge, Emotion, and Intention) is used to express feelings in the robot. As for the robot, the action performed to obtain the necessary information by its own feelings becomes possible by constructing the feeling and the intention into an intellectual robot, even in the absence of input from the external environment. For instance, when the feeling of an intellectual robot becomes "Worry", paying attention to the human and performing an action that confirms the man presence become possible.

The engineering-like model of the K.E.I. is composed of the Rasmussen model of 3 layers of 'macro-knowledge, micro-knowledge, and local loop'. "Emotion" is a layer to express the agent emotion toward the human. "Intention" is a layer to express the intention of the agent movement. The K.E.I. model added the layer of "Emotion" and "Intention" to the macro-knowledge. (Fig. 5) When the modeling is based on the norm of humans, the hierarchical model of the Rasmussen model is known to be effective when used to building an intelligent model.

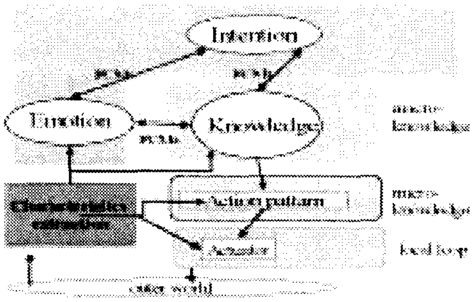

Figure. 5: The K.E.I. model

The recognized human action (gesture) is input to the macro-knowledge. Thus, the robot has the emotions to complement the action. Adding intention to the emotion and the robot acts upon them.

Then, the value is set for each node, and the result of the simulation is shown.The following feelings patterns are assumed as an example.

1. Troublesome --- Anxiety --- Approach --- Forward
2. Anger --- Fear --- Leave --- Avoid

A series of such patterns (causal relation) quantitized for a movement that are based on guesses are called the emotion pattern. (Fig. 6) For example, the emotion pattern included in the macro-knowledge is shown in Fig. 5. The causal relation of each node space is composed of fuzzy cognitive maps. (FCMs).

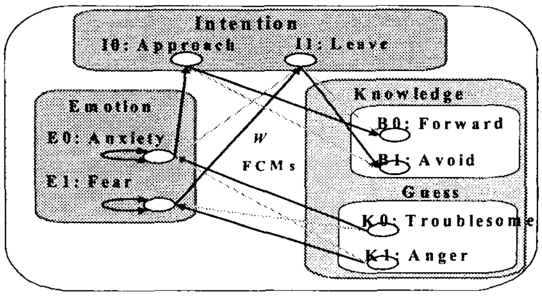

Figure 6. Emotion pattern

Guess Node: Troublesome [K0], Anger [K1].
Emotion Node: Anxiety [E0], Fear [E1].
Intention Node: Approach [I0], Leave [I1].
Movement Node: Forward [B0], Avoid [B1].

The weight of each node space is made ω. The value of ω is adjusted so that the relations of each node space become suitable. The emotion node is made to have the causal relation given to oneself.
(It is assumed that it inputs the weight on feelings feeding back.) The purpose is to remain the express on emotions influenced. The weight between each node was set and the result of the simulation is shown below (Fig.7)

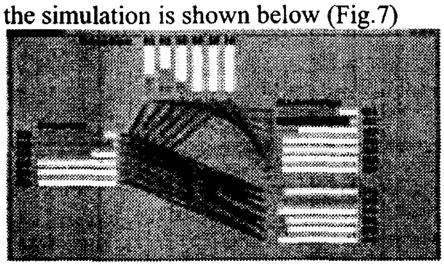

Figure 7. Experiment real image

SYMBIOTIC LEARNING OF ROBOT ACTION PATTERN

The action of the robot, "Forward" and "Avoidance", is determined by the K.E.I. model, the result of various patterns are thought. Then, the algorithm of Q-Learning is used for pattern recall of the determined movement and learning.
In general, the reward of reinforcement learning is given by a reinforced signal from the external world. However, we are using the symbiotic learning method with the human and the robot in this research. In a word, the learning method embodies both the autonomy and intimacy toward the robot. As a method, the rewards depend on both the human and the robot values. The reward received from a human is a reward that is based on the human's subjective evaluation. The value is subject to change for each person and situation. And the reward received by the robot depends on the emotions of the robot (emotion node grade of K.E.I. model). In a word, the grade of emotions that are simulated by varying human actions (gestures) gives the evaluation value. For instance, when the robot is worrying about a particular human, it approaches the human, if the action is inappropriate, the reward of the robot is subtracted from the value with a high emotion node. The symbiotic learning process of the human and the robot is done, thusly the action pattern satisfying both is learned (Fig.8).

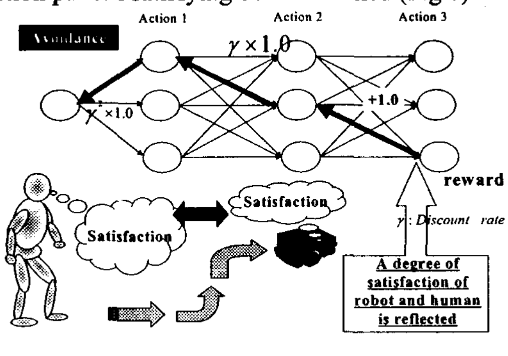

Figure 8. Symbiotic learning process of human and robot

Ontology

The original meaning of Ontology is a "systematic theory of existence" that is based the study philosophy.
Philosophically aiming to arrange everything in the systematic world, it is called Ontology. Ontology in the artificial intelligence research field is defined as a "Specified rule in the making of a concept'".
The research into ontology has been performed to study the problem of "Share of knowledge" and "Construction of the knowledge base" in the field of the knowledge processing.
The knowledge processing system constructs the knowledge base of the targeted world by using Ontology (Fig.9).
A contribution to knowledge sharing can be expected to result by studying the targeted concept. The ontology proposed here is of the knowledge-construction type and is used to communicate to the human and the system.
This ontology is called a bottom-up ontology. Ontology is composed of Conceptual Fuzzy Sets (CFS) that has the dispersive express of concept.

Ontology for information sharing

Ontology systematizes the concept to the object.
Therefore, a common structure is expected to be formed between the human and some agents. In a word, technological ontology enables some agents to cooperate naturally with human (Fig.9). And on a common abstract base, the agents of a different mechanism can share information.
Figure 10 shows the ontology used by this research. This ontology is composed of the ontology from the human to the agent and the ontology from the agent to human. The agent has the instance corresponding to the instruction of human and the situation. This instance is acquired by the symbiotic learning. Each agent learns symbiotically according to each situation. The knowledge acquired by a certain situation is shared with other agents that are in the same situation. We think that this sharing method is important for some agents and humans to interact smoothly.

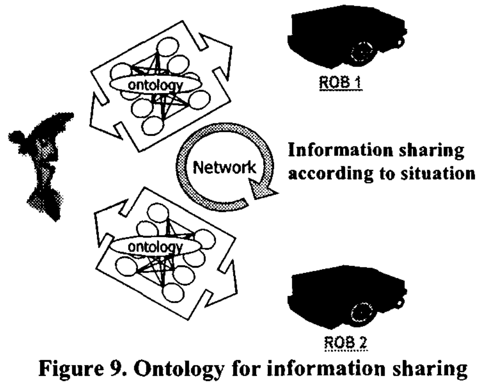

Figure 9. Ontology for information sharing

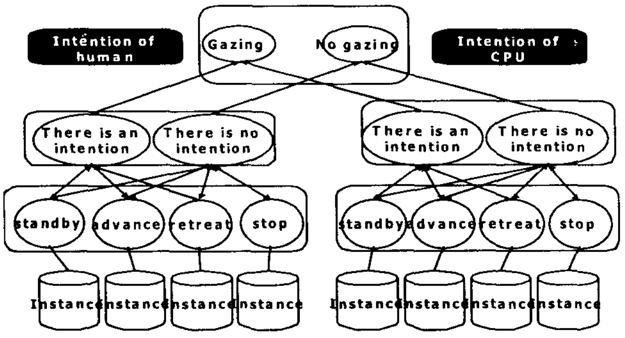

Figure 10. Composition of ontology

The knowledge sharing experiment was as follows. (Figs.11 and 12)
The situation in this experiment is

1.ROB1 is near man. ROB2 is away from man.
2.Human pays attention to ROB1, and directs ROB1.

In such the situation, the action of the robot was learned by using the symbiotic learning method (Fig.11).
The upper robot is ROB1 in Fig.11 and the lower one is ROB2.
In the reverse situation, each item of knowledge could be shared in the sharing of the acquisition knowledge experiment of each robot.
The reversed situation is

1.ROB2 is near man. ROB1 is away from man.
2.Human pays attention to ROB2, and directs ROB2. (Fig.12)

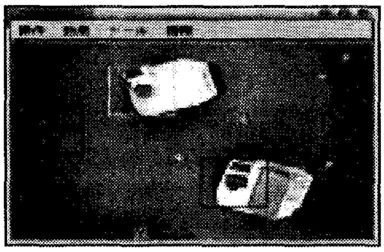

Fig. 11: Learning experiment by different situation

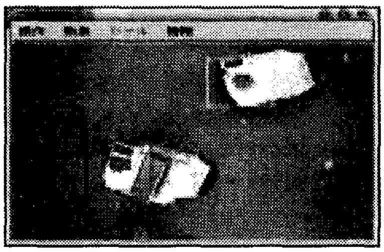

Fig. 12: Experiment after situation is reversed

CONCLUSION

We reported a demonstration of a robot initiating a voluntary action that was achieved by using the K.E.I. Model. The reward that was dependent on a value for the human and the robot that were both given by using Q-Learning. The action pattern for the symbiosis of a human and a robot was shown in a real machine experiment. Moreover, to promote sharing with agents in the acquisition knowledge in accord with a given situation, an ontology was composed. As a result, this system showed its suitability to be used as a multi-agent system that can correspond to many situations smoothly.
Moreover, we are researching about the ontological sharing between the robots with each different mechanism. (Fig.13)

Fig. 13: Robots with each different mechanism

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