Ontological Network System Construction from the Interaction between Robots and Human

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Abstract: We propose ontology for an agent communication with human and other agents according to environmental information (situation). Recently, various types of robots and information tools are developed and used. But now, the system is still promoted and developed by human. The system is not able to build interaction between human. The agent process information led by a single robot, and is not able to utilize relationship with human or other agents. We consider the informational aspects of intimacy recognition technology, and information transport and sharing. Therefore, we focus attention on ontology technology. Human can communicate with other, estimating the situation and the body language. This is because human has ontology. In this research, ontology is composed of Conceptual Fuzzy Sets. Conceptual Fuzzy Sets can combine separate concepts one by one, and form a whole concept. The agent created the ontology from observed human motion and situation, communication by human or other agents using ontology. In this paper, we show the composition of ontology from the interaction between human and agent, and experiment of the communication with robot using ontology.

Keywords: ontology, robot, intelligent agent

1 Introduction

Recently, Internet Electronic Superhighway has become common in general homes. The new various types of information devices and systems, pet robots and so on, are created to cover up human life. Yet, the system is promoted and developed by human. However, the system cannot build interaction between human. The agent processes information by itself cannot utilize relationship with human or other agents. We consider the informational aspects of intimacy (recognition technology, and information transport and sharing). Therefore, we focus attention on ontology technology. Human can communicate with other, estimating the situation and the body language. This is because human has ontology. In this research, ontology is composed of Conceptual Fuzzy Sets. Conceptual Fuzzy Sets can combine separate concepts one by one, and form a whole concept. The agent created the ontology from observed human motion and situation, communication by human or other agents using ontology. In this paper, we show the composition of ontology from the interaction between human and agent, and experiment of the communication with robot using ontology.

2 Intelligent Agent

2.1 Action Recognition of Human

Robot recognizes human's command using human hand motion information from iSpace by Fuzzy Associative Memory. In order not to change the estimation of the motion length, we normalize the motion detection in tune with distance between human as shown in Figure 2. In the symbiosis of human and robot, the robot should understand specific instruction as well as non-specific instructions given by human. In this research, Fuzzy Associative Memory [7] is used, which the robot can understand instructions that are conveyed directly by the human as well as those that come from the human's environment. Fuzzy Associative Memory is composed of a front layer of fuzzy rule (If layer) and a back layer (Then layer). The rule layer is set by one node, which represents one rule. The fuzzy rule can be expressed by using the composition of the BAM (Bi-directional Associative Memory) between the If layer and the Then layer (Figure 3).
2.2 Composition of agent

Figure 5 shows the composition of an agent, in the system we constructed. This is based on the intellectual hierarchical model of Rasmussen [3]. To approach human, we use multi-agent robots as examples of robot cooperation. A robot needs the hierarchical knowledge to process a macro level and a micro level in parallel. Estimating of the situation and the plan of operation perform the macro level processes. The micro level processes perform the feature calculation from sensor information, and concrete action generation. Therefore we use Rasmussen model in this research. Rasmussen groups divide human actions into three hierarchical categories: first for knowledge-based actions, second for rule-based actions, third for skill-based actions.

In this model, an agent is composed of three layers: a group intelligence layer, a high layer, and a low layer. The group intelligence layer includes ontology. In this layer, ontology recognize human intention by which considerate the user's command from the high layer's and situation of other agent's condition, and decide action of the high layer's (instance). The high layer contains the knowledge of commands from the user and corresponds with a lot of attributes by the Fuzzy Association Memory as shown in section 2.1, and the knowledge of robot action as "instance". We did not study on the lower layer. However, the lower layer contains the knowledge needed to decide on the right action by the agent based on the information from the group intelligence and high layers, because this agent is the one that recognizes the human intention.

3 Ontology

3.1 About Ontology

The term "ontology" means a "systematic theory of existence" which show human common basis in the study of philosophy. In the field of artificial intelligence, the research for ontology has been performed to study the problem of "Share of knowledge" and "Construction of the knowledge base" as shown in left side of Figure 6. The knowledge processing system constructs the knowledge base of the targeted field by using ontology. By studying
the targeted concept, a contribution to knowledge sharing can be expected as a result. On the other hand, human has common basis, such as mirror neuron, which ‘own’ action neuron was activated by observing other human motion like a mirror. Although human can communicate by gesture and so on, even with different cultures and languages as shown in Figure 7. We propose new type ontology which is on the extension line as shown in Figure 6. Our purpose is to establish human communication system between different cultures and languages. This ontology is able to get the relation from communication between human and agent. We call this ontology bottom up ontology. We construct agent’s common basis by the bottom up ontology. The ontology is composed of Conceptual Fuzzy Sets (CFS) [6] that has the dispersive expression of concept.

The label of a fuzzy set' represents the name of a concept. 'The fuzzy set' represents the meaning of the concept. According to the theory of meaning representation from the proposal by Wittgenstein [8], the various meanings for a label (word) may be represented by other labels (words). Thus grades of activations, which show the degree of compatibility between different labels, can be assigned. The distributed knowledge called Conceptual Fuzzy Sets (CFS) is shown in Figure 8. Since the distribution changes depends on the activated labels indicating the conditions, the activation result from the CFS, displays a context-dependent meaning. The CFS can represent not only logical knowledge, but also illogical knowledge.

Figure 8: Image of conceptual fuzzy sets in associative memories

In this article we constructed CFS using BAM (Bidirectional Associative Memories) [1] because of the clarity of constraints for their utilization. The associations in BAM reverberations are carried out according to equation (1).

\[ Y_t = \phi(M \cdot X_t) \]
\[ X_{t+1} = \phi(M^T \cdot Y_t) \]

where, \( X_t = [x_1, x_2, ..., x_n]^T \), \( Y_t = [y_1, y_2, ..., y_n]^T \) are activation vectors on \( x \) and \( y \) layers at the reverberation step \( t \), and \( \phi(\cdot) \) is a sigmoid function of each neuron. The correlation matrices \( M \) and \( M^T \) are given by equation (2). \( \beta \) is an association parameter.

\[ M = \beta \sum_{i=1}^{N} y_i x_i^T \]
\[ M^T = \beta \sum_{i=1}^{N} x_i y_i^T \]

The association matrices \( M_e \) are given by eq(3)-eq(6).

\[ M_e = a(M + B) \]
\[ a = \frac{2][max\{m_{ij}\} - min\{m_{ij}\}]}{3} \]
\[ B = \begin{pmatrix} -c & \ldots & -c \\ \vdots & \ddots & \vdots \\ -c & \ldots & -c \end{pmatrix} \]
\[ c = \frac{1}{mn} \sum m_{ij} \]

A Complex CFS is realized by composing several pieces of associative memory structured individually. Further composition of pieces of knowledge makes the representation of the concept context dependent. In this procedure the constraints of associative memories are very important.

If \( C_1, C_2, \ldots, C_n \) denote individual CFSs and \( M_1, M_2, \ldots, M_n \) are their corresponding correlation matrices then we can combine them to obtain a CFS \( C \), whose correlation matrix \( M \) is given by equation (7).

\[ M = norm[M_1 + M_2 + \ldots + M_n] \]
Where $\text{norm}[\ldots]$ stands for normalizing process for the maximum and minimum value in $M_1 + M_2 + \ldots + M_n$. When the human recollects abstraction concept, the human depends on context. As shown in Figure 9, when you hear the word "guppy", "cat", you may imagine that they are talking about pet. So you recollect pet in your brain. When cat and guppy are stimulated in this CFS, upper class concept, "pet", ignites. Tuna is less realize. It is disregarded, because it is nonexistent in great activity value. Similarly, for example, in the lower part, when "tuna" and "guppy" are stimulated, the upper class concept "fish" ignites. CFS can form general concept by combination of the other words at all times.

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Depending on a situation, human motion has different meanings. In order to recognize human motion's command by considering situation, ontology is constructed by CFS. CFS is able to express a motion with many different meanings.

### 3.3 Construction of Ontology

The ontology of constructing an interface for human-robot interaction is shown in Figure 10, Figure 11 and Figure 12.

**<Step 1>**
Observation of human and experiment is based on agent's ontology composed by CFS (Figure 10, Figure 12-Step1). This ontology is the easiest prototype. Sharing information and synthesis composes intelligent agent. Many operations can be stored in one "instance".

**<Step 2>**
Using input ontology by human, and by corresponding agent, we compose the ontology for human (Figure 11, Figure 12-Step2).

**<Step 3>**
Construct a new ontology by using a new "instance". If other agents have ontologies with the same patterns, a new ontology is constructed by synthesizing ontologies with the same pattern (Figure 12-Step 3). Now we are researching on a robot autonomously developed into a new ontology, using reinforcement learning or chaotic evolution. So in this paper, we experimented using basic ontology up to step2 (Figure 11)
4 Ontology for Information Sharing

Ontology systematizes the concept of 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 (Figure 13). And on a common abstract base, the agents of different mechanism can share information.

Figure 14 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" corresponds 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 [9]. We think that this sharing method is important for some agents and humans to interact smoothly.

5 Experiment and result

Two robots, ROB 1 and ROB 2, study different instances in different environments (situations). If ROB 2 is in the same situation as ROB 1, ROB 2 doesn’t have the instance for this situation. Then, ROB 1, which has this instance, shares it with ROB 2. In this way, ROB 2 can easily obtain the necessary instance without studying. (Figure 15)

If ontology of intelligent agent is used between human, it studies the instance of situation, human operation and sharing of information. A multi-agent system can be constructed in which agents need not to spend a lot of time learning, and to communicate easily with user.

In this paper, the robot use mobile robot 'LABO-3', in Figure 16, made in AAI, which put on note PC, camera, and wireless modem. Note PC takes change in robot intelligence, camera get state of human and wireless modem is used for conversation between robots. We experiment three situations. All situations, we use two robots, ROB1 and ROB2.
< Situation - 1 > Both robots can watch human face and hand. The information from face position, robots detect distance of human. Robot decides its own behavior using human's command and information of human distance by ontology. So nearest robot will follow human order, and approach human (Figure 17).

< Situation - 2 > ROB2 is nearer to human than ROB1. But there is a block in front of ROB2. Therefore ROB2 cannot seek human, so it cannot read human distance and understand the command. ROB2 knows not to move. ROB1 on the other side can see human face and hand. ROB1 knows ROB2's situation through the ontology. ROB1 follow human order (Figure 18).

< Situation - 3 > ROB1 is nearer to human than ROB2. ROB2 can see human's face and hand. ROB1 can see human's face, but cannot see his hand. Therefore ROB1 can find out the distance to human, but cannot find out the human's command. ROB1 and ROB2 share information of human's command through the ontology. So ROB1 receives order of common information between robots. ROB1 approaches human, based on the rule that nearer robot approaches human (Figure 19).
6 Conclusion

We proposed the ontology as the system for human recognition purposes, and showed the effectiveness of the agent system. It is constructed in order to become more intelligent by the ontology and that automatically recognizes the purpose of humans by the intuitive interface such as movements of hands or faces. The action pattern for the symbiosis of a human and a robot was shown in a real machine experiment. To promote sharing acquisition knowledge among agents in different situation, 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. We are now researching the ontological sharing between the robots and each different mechanism.

References


