Human Robot Interaction with Shared Experiences

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1 Introduction

The research of humanoid robots has a long history. The focus of early efforts was mostly on the dynamics and control of biped walk. Recently, the focus and paradigm have been shifted to realization of intelligent behavior in dairy life environments with supporting ability for humans.

The difficulties in the real world intelligence are existed in treating humans' behavior. Understanding of intention, utterance, and behavior is neccesary for the support of humans' dairy life, however, a long journey is needed for the realization of the "intention understanding". It is also difficult for robots to decide the adequate behavior for "the human's intention".

In this paper, we propose an approach that robots store shared experiences between humans and the robots, and also show that the shared experiences act as an important role for the coexistence of the humans and robots, and for the realization of the support ability of the robots. Enormous amount of shared experiences are effective for the understanding of users under uncertain and incomplete conditions, as well as communication among humans. We propose the importance of the shared experiences for real world intelligence, and show a development research of the infrastructure for the storage of the share experiences and application method.

2 Human Robot Interaction with Shared Experiences

Physical interaction systems between human and machine have proposed such as Oxygen Project [1], Smart Rooms[2], Intelligent Room[3] and so on. The most impressive factor of these systems is the ubiquitous sensors and actuators.

Satoh *et al* also have proposed the "Robotic Room" [4] with the concept of ubiquitous environments. The robotic room has a lot of floor pressure sensors, position and button sensors on home electric appliances, and so on. One of the characteristics of the robotic room is storage of observation result of users' behavior for realization of smart support behaviors for the users. Archives of humans' behavior are represented as the archives of these sensors in the robotic room. As personal behaviors in daily life are infinite in variety, it is difficult to estimate and pre-designe the support behavior. It is said that existent machines are designed with the goal to satisfy 80% of users using only single user model. The storage of behavior between systems and users, that is, the shared experiences can influence to the human machine interaction, because shared experiences enables the system to decide adequate behavior strategy for each person.

The support behavior is important functions for not only such ubiquitous systems but also humanoid systems as a physical agent. In case of humanoid systems, the systems have to make speech and gesture communications differs from the ubiquitous systems. Therefore shared experiences between users and robots become to be more effective in case of humanoids. The advantages of intelligent behavior based on the shared experiences are the followings:

- Acquisition of novel behavior based on observation and imitation of the humans' behavior.
- Complement of users' vague instructions.
- Realization of adaptive interface in order for each user to be satisfied.

3 Expression of share experiences

3.1 Experience storage and stochastic expressions

In this section, a method of storage and expression of the shared experiences are mentioned.

It is desirable that the database is divided into first and second database for the shared experiences. The First database ought to store all information the robot can observes as detailed as possible. Candidates of the first database are;

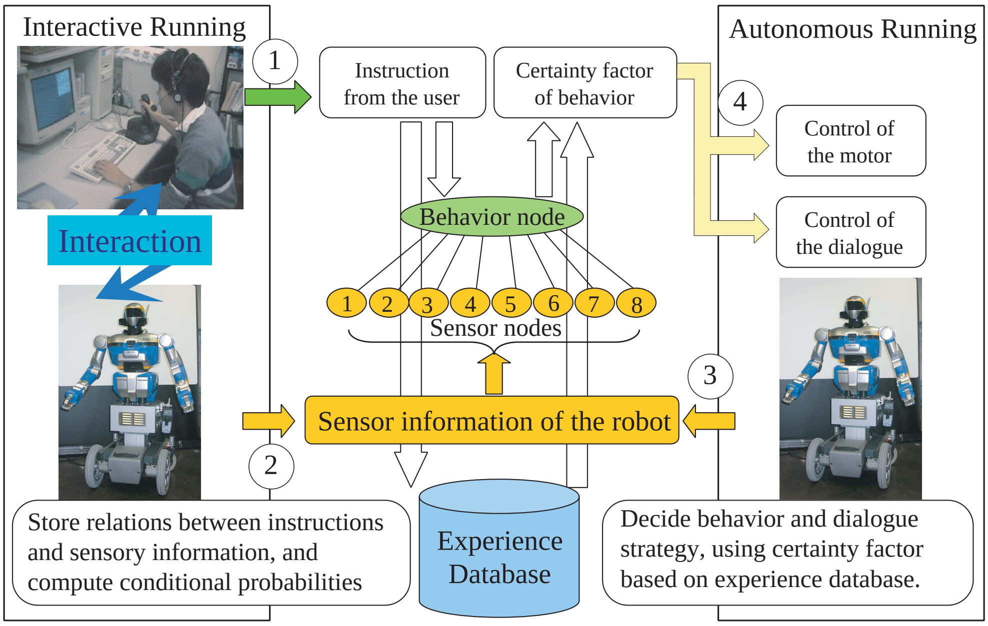

Figure 1: *Overview of the human robot interaction based on shared experiences and its example for behavior decision. 1) The user make a instruction to the robot. 2) The robot store the user's utterance and sensor information. 3) When the robot have to decide an autonomous behavior, the robot ask for the system. 4) Certainty factor for a target behavior shows the behavior decision.*

- Behavior of human.(cf. time-series data of location and joint angles)
- Contents and time of utterances of human.
- All observable status of the robot (location, joint angles, vision data, and so on)
- Environment status such as target object.

Then, the information are transformed into discrete symbolic representations using by conversion rules depend on each task domain. For example, these symbolic representation are necessary for speech communication, for example, explanation of the behavior decision for users. The second database ought to store these symbolic data. Here, the causal relationships between each symbolic information are represented by stochastic method and network structures, which is called as probabilistic models. We adopted Bayesian Networks for such a stochastic representation method.

Bayesian Networks is one of the inference models in which the relationships between causes and effects are represented as probabilities [5]. It is used in various fields such as map acquisition for mobile robots [6][7], diagnosis for help system on personal computers[8], dialogue management[9], and so on. In Bayesian Networks, phenomena are expressed by nodes, and relationships between these phenomena are expressed with links, as shown in Fig.??. Each node has a random variable which expresses the probability of the phenomenon. Relationships between each cause and effect corresponded to each link are expressed by conditional probabilities. Nodes are classified roughly into two kinds: evidence nodes, which correspond to the evidence phenomenon to be used in inference, and hypothetical nodes, which correspond to the object phenomenon to be deduced. In the case of application for robots, an evidence node indicates a sensor of the robot, and a hypothetical node indicates instruction from the user. The behavior node expresses a behav-

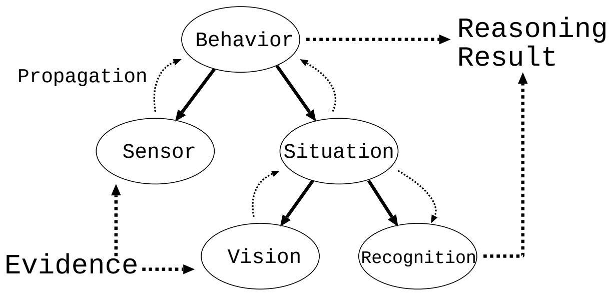

Figure 2: *A Bayesian Network for expression of shared experiences*

ior which will be executed through inference.

A basic process of using Bayesian Networks is followings: (1)The user instructs the robot. (2)The robot stores the user's instruction and sensor inputs while the interaction. (3)Probabilities between each node are computed. (4)When the user doesn't give any instructions, the robot inputs sensor information to sensor nodes, and infers state of instruction nodes. The inference results are output as probability values which correspond to each state of random variables, that is, each proposition. The vector is called the certainty factor, and indicates probability of the state which corresponds to users' instruction. The robot uses the certainty factor in order to decide behaviors and manage dialogue.

3.2 Behavior decision and dialogue management using shared experiences

An overview of the human robot interaction system based on shared experiences is shown in Fig.1. The figure explains an example of behavior decision using shared experiences. The robot usually observes the user's instructions and sensor information, then store the information into the database. When the robot have to decide an behavior by itself, the robot compute a possibility of a target node, that is, the behavior node. The possibility of a node is represented by a vector consists of several probabilities for each proposition.

When a component of the certainty factor vector indicates high value and the rest component indicate low value, the proposition for the component is selected as the plausible behavior. When several component of the vector indicate almost the same value, the robot judges that the current status is a delicate situation, and tries to make a question which is the better selection. Furthermore, when a proposition which indicates highest value differs from the user's instruction, the robot can detect a contradiction, and then make a suggestion with explanation of the reason of the decision[10].

3.3 Communication management using shared experiences

4 COE Humanoid Platform

The important factors of the support behavior based on share experiences are autonomy and reliability with continuous behavior for long term. The problems against the reliability lies on the research on shared experiences for humanoids, because basic biped walk motion have just been available recently, however, complex behaviors such as moving around in a building,

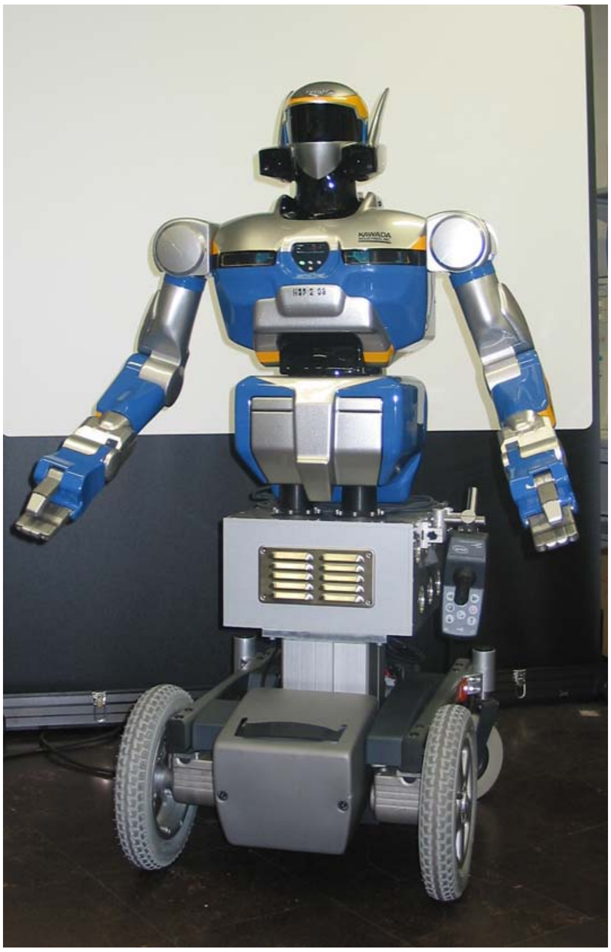

Figure 3: *COE Humanoid Platform*

or carrying buggages, are not gurantied well. We designed a humanoid with wheel unit as lower body for such a problem, and placed the humanoid as a platform for the research of human robot interaction based on share experiences. The overview of the platform is shown in Fig. 3 and Fig.4. One of the concepts of the platform is that the researcher can focus on the intelligence layer without consideration of delicate balance control.

This kind of humanoids with wheel unit have already proposed [11][12]. The differences between those research are continuous act for the storage of shared experiences, and multiple sensors for the plentiful experiences. The following lists are the loaded sensors on the humanoid platform;

- Binocular monochrome cameras for stereo vision.
- A color camera for color image processing.

Figure 4: Interaction between the COE Humanoid Platform

- Four microphones for speech dialogue and sound source orientation.
- A speaker for speech utterance.
- Independence system based on batteries with large capacity and wireless LAN.

The humanoid platform has two batteries of 40[Ah] capacities with a target of continuous act for several hours. The wireless LAN environment enables the robot to send the experience data to a database server.

We have already realized and confirmed the basic performance based on the approach of shared experiences; 1) interactive acquisition of obstacle avoidance behavior[13], 2) narrowing down the candidate object based on users' vague instructions[10], and 3) personal adaptation for action selection[14].

5 Conclusion

In this paper, we proposed the effectiveness of shared experiences for intelligent robots which act in daily life. The experiences are useful for interactive situation such as making communications between users or supporting for users' daily life, rather than autonomous behavior decisions. We also show that stochastic information processing are valid to deal with the shared experiences.

We are planning to evaluate and discuss adequate information for shared experience and criterion for the experience description, for the realization of more complex behavior for daily life support. We believe that the COE humanoid platform will give us an effective research environment.

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