PLATFORM-BASED TELEOPERATION CONTROL OF SYMBIOTIC HUMAN-ROBOT SYSTEM

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Abstract: This paper presents a platform-based teleoperation control approach of symbiotic human-robot system. With frame-based knowledge representation, features of robots, human-robot interface and cooperative operation of symbiotic human-robot system are defined in the Software Platform of Agents and Knowledge Management (SPAK). By means of this software platform, human can communicate with robots using human-robot interface. Cooperative operation of multiple robots can be implemented by teleoperation control through wireless network. In this paper, platform-based teleoperation control of an actual symbiotic human-robot system comprised of human, humanoid robot (Robovie) and entertainment robot (AIBO) is implemented and the experimental results demonstrate its effectiveness.

1 INTRODUCTION

With the development of robotic techniques, symbiosis of human and robots is proposed for constructing high-intelligent, human-friendly welfare society (H. Ueno, 2002). In such a symbiotic human-robot system, human is just a ordinary member be able to acquire services from robots according to his requests. Robots can understand human intention and act their behaviors for human. In addition, many types of robots with various functions in this system can cooperatively work for a specific task. They are good servers of human and also friendly partners of human. Therefore, it is an attractive and promising topic to construct a symbiotic human-robot system.

However, a symbiotic human-robot system is comprised of many different types of robots and should integrate many kinds of techniques for implementing various complex tasks. In addition, as one of essential conditions, activity of symbiotic human-robot system should be conducted under wireless network. Therefore, many conventional control approaches only in views of a specific robot are not fit for symbiotic human-robot system comprised of many different robots (K.J. Schilling, 1999). In this research, a platform-based teleoperation control approach is proposed in order to implement complex control of symbiotic human-robot system.

In order to implement platform-based teleoperation control of symbiotic human-robot system, regarding various features of robots, human-robot interaction as well as cooperative operation, all of them are defined in the software platform by frame-based knowledge representation. Since the teleoperation control is completely depended on the definition of symbiotic human-robot system in software platform, software platform should comprise of many functions. In our laboratory, a software platform, called Software Platform for Agents and Knowledge Management (SPAK) (V. Ampornaramveth, 2003), is developed recently. This is a powerful platform and can provide great supports to the teleoperation control of symbiotic human-robot system.

The remainder of this paper is organized as follows. In section II, a symbiotic human-robot system is defined in SPAK by frame-based knowledge representation, including features of robots, human-robot interface and cooperative operation. Through wireless network, symbiotic human-robot system is controlled according to the definition of cooperative operation in SPAK in section III. Section IV introduces an actual symbiotic human-robot system comprised of human, humanoid robot (Robovie) and entertainment robot (AIBO) and its experimental results demonstrate the effectiveness of this method.

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2 DEFINITION OF SYMBIOTIC HUMAN-ROBOT SYSTEM IN SOFTWARE PLATFORM

In a symbiotic human-robot system there are many different types of robots. All parts of this system are connected with a wireless network. With human-robot interface developed by many kinds of techniques, such as speech recognition, image analysis, etc., robots can communicate with human and understand human requests. Under the control of SPAK, robots can act their behaviors themselves or perform cooperative operation among them.

SPAK is a frame-based knowledge engineering environment (V. Ampornaramveth, 2003). It provides a central module, which acts as blackboard, knowledge processing brain, memory, and do the judgment, task planning and execution. It also provides software tools necessary for integration of various existing modules over a TCP/IP network. The features of SPAK are "platform-independent" as existing robots and software modules often rely on different platforms or operation systems, "network-aware" as the modules must interact on a network, supporting "software agent" and being "user friendly". SPAK is targeted to be the platform on which a group of coordinative robots (or their agents) operate on top of frame knowledge. As illustrated in Fig.1, SPAK consists of the following software components:

- GUI Interface: A user-friendly graphical interface to the internal knowledge manager and the inference engines. It provides the users direct access to the frame-based knowledge.
- Knowledge Database and Knowledge Manager: This is the SPAK core module which maintains the frame systems as Java class hierarchy, and performs knowledge conversion to/from XML format.
- Inference Engines: Verify and process information from external modules which may result in instantiation or destruction of frame instances in the knowledge manager, and execution of predefined actions.
- JavaScript Interpreter: Interprets JavaScript code which is used for defining condition and procedural slots in a frame. It also provides access to a rich set of standard Java class libraries that can be used for customizing SPAK to a specific application.
- Base Class for Software Agent: Provide basic functionality for developing software agents that reside on networked robots.
- Network Gateway: This is a daemon program allowing networked software agents to access knowledge stored in SPAK. All SPAK network traffics are processed here.

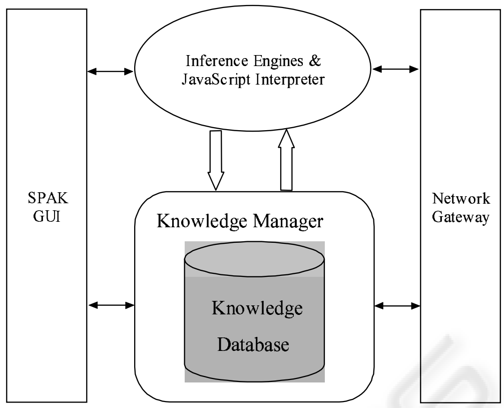

Figure 1: Structure of SPAK.

In order to implement teleoperation control by SPAK, the symbiotic human-robot system should be defined in advance. Its definition is based on the frame-based knowledge representation. It is well known that frame representation systems are currently the primary technology used for large-scale knowledge representation in Artificial Intelligent (AI) (D. Koller, 1998). A frame is a data-structure for representing a stereotyped situation (M. Minsky, 1974). Attached to each frame are several kinds of information. Collections of related frames are linked together into frame-systems. The structure of a frame is consisted of several items, such as name, type, A-kind-of, Descendants, slots, etc. (G. Tairyou, 1998). As the element of a frame, each slot has the following elements, such as name, type, values, conditions, etc.

Using frames and their slots, features of various robots in a symbiotic human-robot system can be defined, which are classified by their types, spatial position, functions, etc. From these features, we can familiar with each type of robot and further find out the robots with identical features. Human-robot interface is also defined, including frames for speech, recognition, etc. In addition, the relationship among robots can be defined. The types of relationship among robots include synchronization, succession, restriction, etc. As we are defining the coordinative control of symbiotic human-robot system for performing a specific task, the knowledge on the relationship among robots will provide sufficient information and simplify the plan procedure. Besides, many possible behaviors are defined, which can be implemented by robots, such as walking, shaking hands, etc. They provide great support to the activities of symbiotic human-robot system.

In SPAK, the frame-based knowledge representation of a symbiotic human-robot system is implemented by means of XML format, as illustrated by Table.1. XML is a markup language for documents containing structured information. With XML format, frame structure as well as its contents written by slots can be defined easily. Particularly, the frame system can be illustrated in the SPAK Graphic User Interface (GUI). In the frame system, all frames are connected by use of ISA relations. The ISA relation means that there has the class and sub-class relation between the upper frame and the lower frame. The lowest frame is an instance of the upper frame. Besides, corresponding to XML file, there is an interpreter to translate XML specification into relative commands.

Table 1: XML format in SPAK

< FRAME >
< NAME >c
< / NAME >
< ISA >c
< / ISA >
< ISINSTANCE >...
< / ISINSTANCE >
< SLOTLIST >
< SLOT >c
< / SLOT >
< SLOT >c
< / SLOT >
c
< / SLOTLIST >
< / FRAME >

The meaning of this format can be explained corresponding to the definition of a frame. Between <FRAME> and < /FRAME> defines a frame. NAME refers to the frame name. ISA refers to the item of ”A-kind-of”. ISINSTANCE refers to the frame type. Between <SLOTLIST> and < /SLOTLIST> defines slots. Each SLOT gives the contents of a slot. The symbol ”c” means here should have some contents. With this XML format, a frame and its slots can be described in detail. Therefore, a symbiotic human-robot system defined by framed-based knowledge representation can be implemented in SPAK by means of XML format.

3 TELEOPERATION CONTROL OF SYMBIOTIC HUMAN-ROBOT SYSTEM

With the definition of symbiotic human-robot system in SPAK, teleoperation control can be implemented. There are three important behaviors which should be conducted in the symbiotic human-robot system by teleoperation control for most of tasks. The first is to realize interaction between human and robots in order to get human requests. In SPAK integrates several techniques for implementing human-robot interface, such as face detection, image recognition, etc. Concerning face detection, by use of ”eyes” of robot, installed by cameras, robot can get the image of human face. With the program of face detection storing in the center computer of robot, robot can recognize human by what it looks. Of course, if it is the first time that robot looks this person, robot can store the enough information about this person’s face in his database by its learning program. As robot looks this person’s face again, he can recognize him at once. Thus it sends the recognition results to SPAK. This result can trigger other actions of robots.

Another technique that robot can use for human-robot interface is by means of speech with human. Robot will firstly store the information on the speech of human. As robot hears the similar speech again, he can recognize this person at once. Regarding these two techniques, SPAK includes the definition of human-robot interface. With this interface, many independent programs for performing various functions in robots, such as image capture, speaking, etc. can coordinative work to implement interaction between robot and human.

The second behavior is to implement cooperative operation. For cooperative operation, firstly, it needs to trigger the activity of symbiotic human-robot system. The simple way is to give a simple command to indicate the beginning of the activity. But actually, there are also many other kinds of ways to trigger activity. One of the most important ways is based on human-robot interaction. Next, the plan of activity of symbiotic human-robot system is necessary for cooperative operation. The plan of activity should obey the relations of all robots. The synchronization relation means that several robots can be operated together at the same time for a specific task. Their control instructions are generated referring to a same time axes. The command in each time sampling period is possible for any robots. The succession relation means that one robot should start its action after another robot finishes its action. The restriction relation means that as one robot is performing a certain action, another robot can not be acting any actions at the same time. The action of one robot will interrupt the action of another robot. If we obey these three relations, even a complex task could be undertaken by coordinative control of symbiotic human-robot system.

In SPAK, the above three relations are implemented by the following patterns. Since features of robots are defined by frames and in SPAK the inference engines for doing forward and backward chaining are defined, the relations can be implemented by inference engines. The feedforward chaining is usually used when a new fact is added to the knowledge base and we want to generate its consequences, which may add new other facts, and trigger further inferences. The backward chaining starts with something we want to prove, find implication facts that would allow us to conclude it. It is used for finding all answers to a question posed to the knowledge base. For these three relations, if the required argument is obtained, a new fact will be generated. Corresponding to this new fact, if there has a synchronization relation, several robots would perform a same task at the same time. If there defines an action of a robot triggered by this fact, the succession relation will be then performed. Similarly, a restriction relation will cause the robot stopping its actions. When we use backward chaining, for a task there will have many actions from various robots if they have cooperative relations.

The third behavior is the control of activity of symbiotic human-robot system. Since different robots have different driving programs, the control of activity of symbiotic human-robot system is actually through the agents defined in SPAK. The agents will convert the control instructions generated in SPAK to the robots. Basically, SPAK will send commands directly to each robot according to its plan of activity of symbiotic human-robot system. Regarding the control of symbiotic human-robot system, feedforward control to robots is not enough to perform the task. Signal feedback from robots is definitely necessary to evaluate the activity of robots as well as instruct the next actions of robots. There are two ways to get the feedback signals on the activity of symbiotic human-robot system. In the environment where human and robots are staying, we setup several cameras as the sensors to capture the status of robots. Based on the human's judgment on the actions of robots, SPAK can adjust its control signals or generate new tasks. Another way to get the feedback signals is by the robots themselves. As robots finished one of their actions, they should send back a response corresponding to their actions. Moreover, since there are many sensors in robot bodies, they could also send some signals detected by these sensors to SPAK, which could be helpful for SPAK to know the status of the activity of symbiotic human-robot system.

Finally, the teleoperation control of symbiotic human-robot system is carried out as the following process. In this system, all components are staying at the state of connection at any time. The actuation of behaviors of this system is from the beginning of human-robot interaction. As robot gets human requests through the interaction, it will send relative information to SPAK. Then, SPAK will plan the action of symbiotic human-robot system according to human request and generate instruction to robots. Robots will offer responses to human. These robots will conduct relative behaviors independently or through cooperative operations for human controlled by SPAK.

4 EXPERIMENT

An actual symbiotic human-robot system is constructed, which is comprised of human, humanoid robot (Robovie), entertainment robot (AIBO), etc., as illustrated by Fig.2. Robovie is developed by Advanced Telecommunications Research Institute International (ATR) of Japan. It is a kind of autonomous communication robots that can communicate and interact with human in our daily environment. It has 11 degrees of freedom and sensors such as an omni-directional camera, pan-tilt zooming cameras, microphone, ultrasonic range sensors, tactile sensors, etc. It also can move by its wheels. Robovie also provides many demo programs for speech, camera vision, motion, etc. Based on the functions of Robovie, we have developed several programs for monitoring the status of all sensors and sending them to SPAK, defining many actions of Robovie as well as instructing Robovie to talk with human. Robovie can be used in the field of education, nursing, medical treatment, etc.

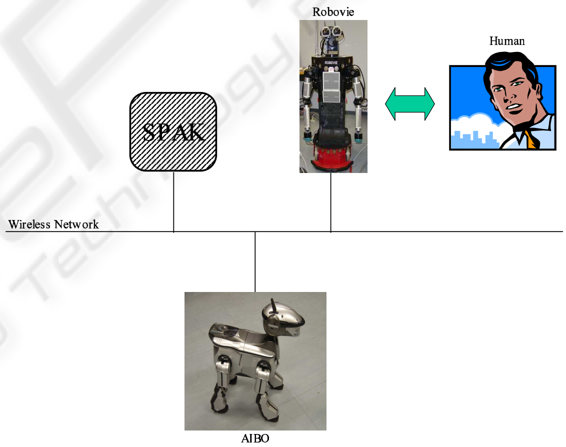

Figure 2: An actual symbiotic human-robot system.

AIBO is a kind of entertainment robots and developed by Sony Co. of Japan. It can provide high degree of autonomous behavior and functionality. In our experimental system, we use AIBO ESP-220, which is able to walk on four legs. It has a total of 16 actuators throughout its body to control its movements, and 19 lights on its head, tail, and elsewhere to express emotions like happiness or anger and reactions to its environment.

As shown in Fig.3, a frame hierarchy written by XML format is defined in SPAK. All frames are connected by their ISA relations. For "Robot" frame, there includes "Robovie" and "AIBO". Related with Robovie, there are many frames about Robovie's components ("Mouth", "Motor", etc), Robovie's sensors and Robovie's behaviors ("FaceDetection",

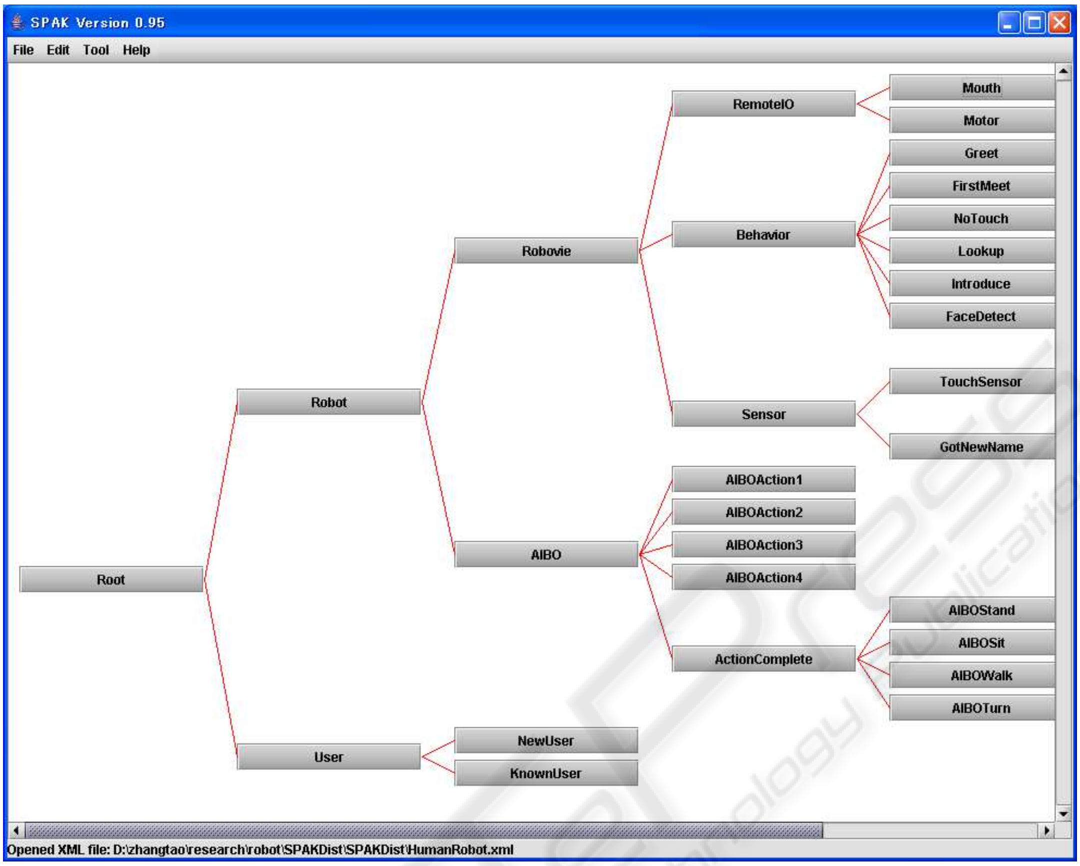

Figure 3: Frame hierarchy of symbiotic human-robot system.

"Greet", etc.). The Robovie's behaviors can be used for human-robot interface. For AIBO, there are many frames on its actions. Some of them are AIBO's atomic actions ("AIBOStand", "AIBOSit", etc.). Others of them are about AIBO's behaviors comprised of several atomic actions. Concerning the users, there includes frames about new users ("NewUser") and known users ("KnownUser"). Since many frames for symbiotic human-robot system have been defined, if relative conditions defined in the frame are satisfied, this frame will be actuated and commands given in this frame will be performed. Fig.4 is the slot-editing table showing slots belonging to a frame of AIBO. In this frame, we can know that if three arguments are given by relative frames, the command defined in the slot "onInstantiate" will be performed. With this system, coordinative control of symbiotic human-robot system is performed by teleoperation operation through SPAK.

The process of cooperative operation can be described as below.

- With the human-robot interface installed in Robovie, Robovie can recognize human and send information about human to SPAK, such as user's name;
- With the results of human-robot interaction, SPAK instructs Robovie and AIBO to start activity;
- As defined beforehand on the activity of symbiotic human-robot system, Robovie informs human about AIBO actions firstly;
- AIBO moves.
- As SPAK gets the response from AIBO that indicates the end of AIBO movement, SPAK will instruct next action for both Robovie and AIBO.

Fig.5 shows the experimental environment. The experimental scenario is given in the next page. As doing this experiment, all instructions are generated by SPAK and sent to each robot. After each action, each robot should inform its status to SPAK. According to the status, SPAK will send the next command to each robot according to the designed plan. With the control of SPAK, the whole system performs the task conditionally and automatically.

Property of AIBOAction1

File Edit

Name	Type	Value	Condition	Argument	Required	Shared
Name	String	AIBOAction1	ANY		✔	✔
mSpecificRo...	Instance		ANY	AIBO	✔	✔
mMouth	Instance		ANY	MouthIO	✔	✔
mAIBOAction	Instance		ANY	zhangtao	✔	✔
onInstantiate	String	aibo("PLAY:A...	ANY		☐	✔

Figure 4: Slot-editing table showing slots belonging to a frame of AIBO.

Figure 5: Experimental environment by use of symbiotic human-robot system.

Robovie: (Robovie looks at the person's face and try to recognize it.)
Robovie: *Hi, how are you! I have never seen you before. What is your name?*
(Robovie shakes it hand a little bit.)
Human: (A person types his name XXX into the computer of Robovie.)
Robovie: *Hi,* XXX*. How are you going today? AIBO will play with you.*
(Robovie shakes its both hands with person while it is speaking with the person.)
Robovie: *AIBO is standing up now.*
AINO: (AIBO stands up and sends back the response to SPAK after its movement.)
Robovie: *AIBO is walking up now.*
AINO: (AIBO walks a little bit and sends back the response to SPAK after its movement.)
Robovie: *AIBO is turning to the left with 90 degree now.*
AINO: (AIBO turns to the left with 90 degree and sends back the response to SPAK after its movement.)
...

5 CONCLUSIONS

A new platform-based teleoperation control approach of a symbiotic human-robot system is proposed. In this method, features of various robots, human-robot interface and cooperative operation can be defined by frame-based knowledge representation and implemented in SPAK by XML format. By use of this method, an actual symbiotic human-robot system was constructed and its experimental results demonstrate the effectiveness of this method. In the further research, we will apply this system for performing more complex tasks, especially using it for welfare enterprise, such as assisting the elder living at home. Since this symbiotic human-robot system is open to any kinds of robots as well as human-robot interfaces, it can be extended widely for many kinds of applications.

REFERENCES

D. Koller, A. P. (1998). Probabilistic frame-based systems. In *Proc. of the 15th National Conference on AI*, pages 580–587.

Minsky, M. (1974). A framework for representing knowledge. *MIT-AI Laboraroty Memo 306*.

Tairyou, G. (1998). Development of frame-based knowledge engineering environment. Master's thesis, Tokyo Denki University.

Schilling, K. J. and Roth, H. (1999). Control interfaces for teleoperated mobile robots. *Proceedings of 7th IEEE International Conference on Emerging Technologies and Factory Automation*, 18-21.

Ueno, H. (2002). A knowledge-based information modeling for autonomous humanoid service robot. *IEICE Transactions on Information and systems*, E85-D(4):657–665.

V. Ampornaramveth, P. Kiatisevi, H. U. (2003). Toward a software platform for knowledge management in human-robot environment. *Technical Report of IEICE*, 103(83):15–20.