3G2-03

Cooperative Operation of Symbiotic Human-Robot System Through SPAK

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This paper addresses cooperative operation of symbiotic human-robot system. In order to implement cooperative operation, symbiotic human-robot system is modeled using frame-based knowledge representation. According to this knowledge model, the system is defined in the Software Platform of Agents and Knowledge Management (SPAK). With the support of SPAK, cooperative operation can be therefore carried out according to human request. This paper introduces an actual symbiotic human-robot system and demonstrates its cooperative operation by experiment.

1. Introduction

Since human society has entered the aged society, building a high-intelligent human-friendly symbiotic human-robot system is one of important research topics presently [1]. In this system, a human person is an ordinary member, who can communicate with intelligent robots by means of various patterns. According to human request, robots can provide many kinds of services by their cooperative operation. However, in order to build such a system and implement cooperative operation, this system should integrate many techniques, such as robotic technique, pattern recognition, tele-operation, etc. Particularly, it should involve the functions of human-robot interaction and robot behavior manager so that robots can acquire human request and manage their behaviors instead of human.

In this paper, a knowledge-based approach is proposed for cooperative operation of symbiotic human-robot system. With frame-based knowledge representation, a symbiotic human-robot system is modeled and defined in a software platform. With the support from this software platform, cooperative operation of system can be carried out according to human request.

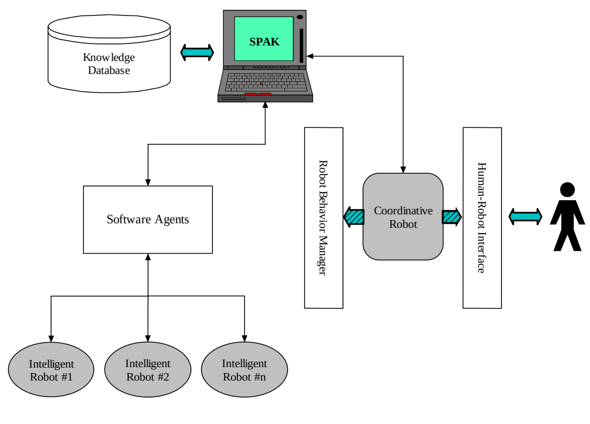

Fig.1 System architecture of symbiotic human-robot system

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2. Knowledge model of symbiotic human-robot system

In symbiotic human-robot system there are many different types of robots, as illustrated by Fig.1. All of them have their own intelligence. According to the difference of intelligence, robots are classified into coordinative robots and specific robots. The coordinative robots can interact with human through human-robot interface and coordinate the behaviors of other robots. The specific robots are adopted to perform the tasks according to the arrangement of coordinative robots.

In this paper, the modeling of symbiotic human-robot system is based on the frame-based knowledge representation approach [2]. With this method, features and behaviors of various robots and the plan of their cooperative operations can be defined by frames. The structure of a frame defined in this paper is consisted of several kinds of slots, such as name, type, A-kind-of (ISA relation), Descendants, Has-part, Semantic-links, Description, user slots, etc. As the element of a frame, each slot has the items of name, type, values, frame-related, default, option, etc.

In this knowledge model, the frames for describing the features of robots include their types, spatial positions, components, functions, etc. The frames for robot behaviors are defined to describe the atomic behaviors of each type of robot as well as relations among robots. The atomic behaviors of robots consist of basic action, speech, recognition, etc. Some behaviors of coordinative robots will be employed for human-robot interaction. And some behaviors of specific robots will be used to perform the task. The plan of cooperative operation of symbiotic human-robot system is defined by a series of frames. They are organized by the relations of robot behaviors, such as synchronization, succession, restriction, etc. One robot behavior may trigger the behavior of another robot if they have succession relation. In contrary, one robot behavior will interrupt the behavior of another robot if they have restriction relation. Several robots can behave at the same time if they have synchronization relation. This plan for cooperative operation can be made by coordinative robots according to human request. The knowledge model of symbiotic human-robot system is often described by a frame hierarchy organized by ISA relation. The ISA relation means that the lower frame belongs to the upper frame. The lower frame inherits all features given in the upper frame. But the lower frame has some concrete features that are not defined in the upper frame. The contents of frames are explained by their slots.

With the proposed knowledge model, a symbiotic human-robot system can be defined in a software platform and its cooperative operation can be implemented.

3. Implementation of Cooperative Operation

The implementation of cooperative operation of symbiotic human-robot system is by means of a software platform, called Software Platform for Agents and Knowledge Management (SPAK) [3]. This software platform 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 the integration of various existing modules over a TCP/IP network. SPAK consists of the many software components, such as GUI interface, Knowledge Database, Knowledge Manager, Inference Engines, JavaScript Interpreter, Basic Class for Software Agent, Network Gateway, etc.

In SPAK, a knowledge model of symbiotic human-robot system is described by XML format. 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). Corresponding to XML file, there is an interpreter to translate XML specification into relative commands.

For implementing the cooperative operation, some special slots are defined in SPAK, which are not given in knowledge model because they have Non-ISA relationships with other frames but they must be used for system operation. For instance, the slot "onLoad" is defined in the root frame so that SPAK can execute JavaScript code in the value field whenever this knowledge tree is attached to the running SPAK. The slot "condition" contains JavaScript expressions, which must evaluate to "true" for the frame to be instantiated. The slot "onInstantiate" contains the JavaScript code to be executed after an instance of this frame is instantiated. The slot "switch" is to enable or disable the activity frame.

The cooperative operation of symbiotic human-robot system has two steps. The first step is to get human request. It can be performed by means of human-robot interface. With this interface, many independent programs for performing various functions in coordinative robots, such as image capture, speech, keyword physical input, etc. can coordinative work to implement interaction between robots and human. The second step is to perform robot behaviors according to the plan of cooperative operation. In relative frames, a command or a command batch on actions of robots is given. They can be performed by use of the inference engines defined in SPAK. The inference engines are for executing forward and backward chaining.

As we know, features of robots in this system are quite different. In SPAK defines many kinds of Java classes representing the agents, such as server, user, robots, etc. These software agents representing objects (human or robots) may reside on the same or different computer while working together over TCP/IP network. It may control the robot hardware directly or by communicating with a local native robot control program. Through these agents, many functions defined in the knowledge model of symbiotic human-robot system can be implemented, such as information exchange, instruction generation, etc.

All robots are connected with server computers in which SPAK and distributed software agents system are respectively running, over a wireless TCP/IP network. All robots have their local control programs that can control their behaviors. When performing cooperative operation, the instruction from SPAK will convert to the command by software agents so that local robot controllers can execute. Thus, as we develop software agents we should understand the features of local controllers. But when we define any symbiotic human-robot systems as well as their behaviors in SPAK, it is no need to take into account the local robot control programs.

4. Experiment

An actual symbiotic human-robot system is constructed, which comprised of SPAK and four types of robots: Robovie, PINO, Scout and AIBO. Robovie is a kind of autonomous communication robots with many demo programs for speech, camera vision, motion, etc. Since Robovie has capability to realize human-robot communication, in this system Robovie plays the role of a coordinative robot for human-robot interaction. We developed some programs for human-robot interface in the Robovie by means of the techniques of image analysis, speech recognition, etc. PINO is another kind of humanoid robots. It can act stable biped walking like human. Scout is an integrated mobile robot system with ultrasonic and tactile sensing modules. AIBO is a kind of entertainment robots. It can provide high degree of autonomous behavior and functionality.

In the cooperative operation, Robovie gets the human request by face detection, speech as well as human physical input. With the arrangement of Robovie and the support of SPAK, PINO will shake its hands and walk to human. Scout can autonomously move along the designed trajectory. AIBO can play with human by its many kinds of actions. With the proposed method, these robots can perform many different tasks according to human requests. It demonstrates the effectiveness of this system. Since this symbiotic human-robot system is open to any kinds of robots as well as human-robot interfaces, it can be extended widely. This system would be therefore improved to be adapted to wide areas in the future.

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