Ontology based Human-Robot Interaction Knowledge for Intelligent Services

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Abstract Most existing robot knowledge is domain-specific and not suitable for personlized services because of the focus on performing specific service tasks and the lack of knowledge description for users respectively. To overcome such limitations, we propose an ontology-based human-robot interaction knowledge categorized into five ontology models to avoid service-dependency and to maintain extensibility: user, robot, perception, environment, and action. In addition, we develop a knowledge management system to manage the extension and inference of the knowledge.

Keywords Human-robot interaction · ontology-based robot knowledge · knowledge management system

1 Introduction

Service robots are designed to perform their tasks automatically in a specific environment. To perform service tasks effectively, sensory data of a robot and symbolic semantic information of real environment must be integrated into the robot knowledge with semantic associations between the concepts for the data and information. Moreover, robots that produce personalized intelligent services must interact with users, thus symbolic knowledge description for users must be defined in robot knowledge [1].

In this paper, we introduce human-robot interaction knowledge based on ontological models for personalized robot services. We define concepts of user, robot, robot action, and service environment for domain knowledge and concepts of spatial and temporal things for general knowledge. These concepts are hierarchically constructed and linked with semantic property relations internally and externally to represent the real world. In addition, we develop a knowledge management system to manage the extension and inference of the knowledge.

2 Related Works

There have been many attempts at managing knowledge for service robots. Lim GH et al. [2] introduced an Ontology-based Unified Robot Knowledge (OUR-K) framework. OUR-K describes five main kinds of knowledge: contexts, objects, spaces, actions, and features.

Tenorth and Beetz [3] developed KNOWROB, which is an OWL based knowledge processing framework based on Prolog [4]. KNOWROB defines the notion of spatial-temporal things and robot-self models. It introduces the concept of computable relationship and describes spatial relations between objects.

3 Intelligent Service Robot Ontology

We propose Intelligent Service Robot Ontology (ISRO), which defines not only robot, user, and environment information for personal service robots but also the semantic relations between them. Our robot knowledge is easily extendible because the upper concepts are defined in a generic form, thus it can handle various kinds of service environments. To maintain the extensibility of knowledge, as shown in Fig.1, we mainly categorize the robot knowledge into five subdivided ontology models with bi-directional semantic relations: User, Robot, Perception, Environment, and Action.

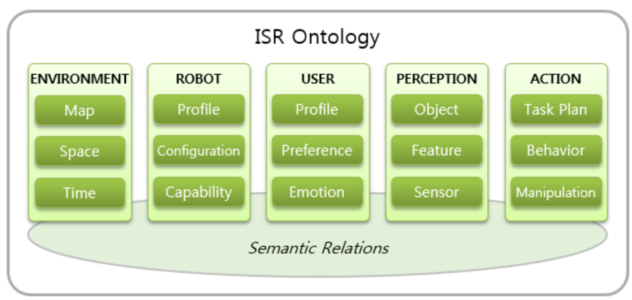

Fig. 1. Five main models of ISRO

3.1 User Ontology

Information of the user who is the target of intelligent robot services are represented in the User ontology model. User ontology defines concepts related to user's personal profile (e.g. name, gender etc.) and user's contextual information (e.g. work place, schedule, and emotional state).

3.2 Robot Ontology

Robot ontology defines knowledge on the robot as a service agent. The knowledge includes specifications of a service robot such as its type, capabilities, and components. To perform service tasks, a service robot needs capabilities for the tasks. For example, if a service contains a task for moving to another location, the type of service robot (or the service robot itself) should have a navigation capability (using *hasCapability* property) and

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hardware or software components (using *dependsOnComponent* property) for execution of the task.

3.3 Perception Ontology

Perception ontology defines the concept of various kinds of objects and their attributes which a robot can visually perceive in the service environment. Objects in Perception ontology range from connection parts of objects, such as hinge and joint, to human-scale objects, such as document, table, etc. Object attributes like size, color, shape, and state represent the features of an object. We also define various properties (such as *on*, *under*, *inFrontOf*, *connectedTo*, *locatedIn* etc.) to represent semantic relations of objects in a service environment.

3.4 Environment Ontology

Knowledge on the service environment where the robot performs service tasks is represented in the Environment ontology model. We define the concepts for places (Room, Hallway, Building, etc.), temporal things (CalendarDay, TimeInterval, *temporalRelation*, etc.), and map information. Especially, maps are composed of three types (metric, topological, and semantic). Objects, places, and their spatial relations are represented on the maps in form of ontology instances.

3.5 Action Ontology

Action ontology defines actions of a service robot to perform service tasks. Actions range from primitive physical actions (grabbing, moving, rotating, etc.) to mental actions (logical inferring and perceiving). In this model, not only a series of actions, but sub/super-action relations and even sequence of actions can be represented as a task plan.

4 Knowledge Management System

Robot knowledge needs to be continuously managed to assure consistency and integrity of the knowledge. We developed a knowledge management system and, as it can be seen in Fig.2, the system mainly consists of a knowledge service interface, which produces requested knowledge to other agent systems, and a knowledge inference module, which performs rule-based reasoning.

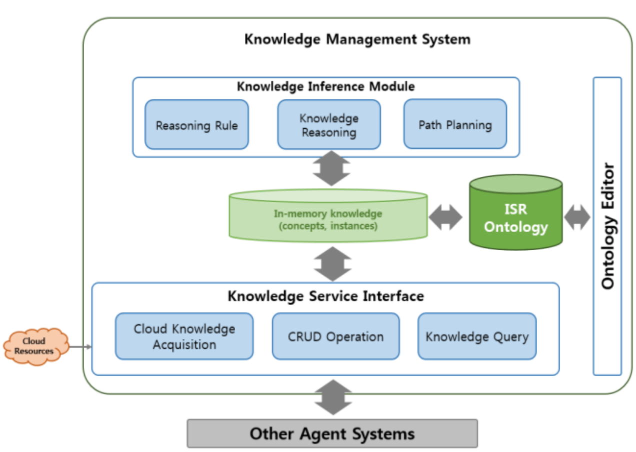

Fig.2. Overview of Knowledge Management System Architecture

4.1 Knowledge Service Interface

In the knowledge management system, our robot knowledge is managed not only by manually revising or updating with the ontology editor but also by interacting with other agents based on knowledge queries. Thus, we implement a knowledge service interface that produces four fundamental functions of data management (Create, Retrieve, Update, and Delete, or commonly referred to as CRUD). As the interface received a knowledge request, a SPARQL [5] statement for the request is automatically generated, and the query to the ontology is performed in Jena framework.

4.2 Knowledge Inference

In our system, the knowledge inference module provides relation based ontological inference, spatial reasoning, and temporal reasoning. Ontological inference ranges from class hierarchical relations and types of instances to OWL restrictions on property. Spatial relations (e.g. *on*, *nextTo*, *insideOf*, etc.) are inferred by comparing coordinate values of objects or places given predefined rules. In a similar manner, by using the time difference of specific events, temporal reasoning results in time interval relations such as before, after, during, and so on.

5 Conclusions

In this paper, we introduced the easily extendible human-robot interaction knowledge for personal service robots. The robot knowledge defines knowledge descriptions based on ontology models for user, robot, service environment, perceptual objects, and robot actions. Furthermore, we developed the knowledge management system, which is composed of the knowledge service interface and knowledge inference module to update the knowledge and to generate inferred knowledge.

As future work, in terms of human-robot interaction, we will define and construct an interaction model for the diversity of robot conversation.

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References

1. K. Severinson-Eklundh, A. Green, and H. Hüttenrauch, “Social and collaborative aspects of interaction with a service robot,” Robot. Auton. Syst., vol. 42, no. 3, pp. 223–234, Mar. 2003.
2. Lim GH, Suh IH, Suh H, “Ontology-based unified robot knowledge for service robots in indoor environments”, IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans 41: 492–509, 2011.
3. M. Tenorth, M. Beetz, “KNOWROB - knowledge processing for autonomous personal robots,” in IEEE/RSJ International Conference on Intelligent Robots and Systems., 2009.
4. W Clocksin, CS mellish. “Programming in Prolog”, Springer-Verlag, Berlin, 1981.
5. PRUD’HOMMEAUX, E. AND SEABORNE, A. 2008. SPARQL query language for RDF. W3C recommendation. http://www.w3.org/TR/rdf-sparql-query/.