An Experimental Testbed for Knowledge Distributed Robot Systems

Hiroshi Hongu[1], Nak Young Chong[2, 4], Manabu Miyazaki[3], Koji Takemura[2]
Kenichi Ohara[3], Kohtaro Ohba[4], Shigeoki Hirai[4], and Kazuo Tanie[4]

[1]Advanced Engineering Systems, University of Tsukuba, Ibaraki, Japan 305-8577
[2]School of Information Science, JAIST, Ishikawa, Japan 923-1292
[3]Graduate School of Engineering, Shibaura Institute of Technology, Tokyo, Japan 108-8548
[4]Intelligent Systems Institute, AIST, Ibaraki, Japan 305-8568

ABSTRACT

A knowledge distributed robot system is proposed to generate sophisticated robotic behavior for real world applications with minimal programming effort. Whenever new products are brought into our daily life, robots should integrate them into existing recognizable environments. To solve robot programming difficulties, a distributed knowledge network connecting heterogeneous knowledge resources is proposed to collectively build up robots' knowledge required to accomplish a task. Specifically, the knowledge integrator merges specific knowledge with existing knowledge into a task requiring knowledge. For this, manufacturers put their product data tailored to bring out robot behaviors online and robots may access the data without authorization. To verify the validity of the proposed system, a testbed is built and table clearing task is performed.

Keywords: knowledge distributed network, RFID, online knowledge base, robot programming, table clearing

INTRODUCTION

Recently, robots are expected to do all of the household chores that we are doing in our daily life. Almost everyday, new products are manufactured and brought into our environments. This requires new recognition process to keep the robot updated on what is new and application program development to handle those new products. Therefore, end-users should have good knowledge of their robot programming. However, programming robots has proven to be quite an experience and seems almost impossible for ordinary end users. Therefore, to cope with robot programming difficulties in dynamically changing environments, we need to develop open and adaptive networking environments as shown in Fig. 1 that seamlessly merge the new products with existing objects and generate product-specific application programs with no additional effort [4].

In pervasive computing environments [9], every entity can be monitored and controlled to some extent. Accordingly, the robot is aware of the object information that can be updated in real-time. Likewise, an architecture for knowledge-based object registration was proposed in computer vision [1]. However the service provided, because of an information management perspective, has been mostly limited to location awareness and resource discovery. Thus, a new interface framework is needed to help the robot build its program automatically in changing environments, whereby it can provide a wide range of services with more sophisticatedly tailored behavior.

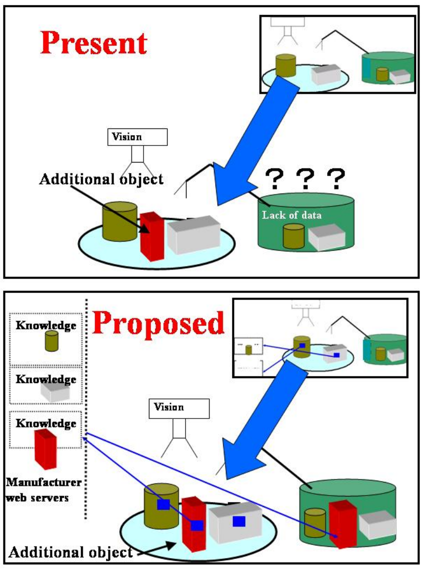

Fig. 1 Online knowledge base

Recently, radio frequency identification (RFID) systems gain increasing attention [5]. If we embed an RFID tag in every object and localize the object, this can be a powerful solution for robot recognition. Following this approach, we proposed a new paradigm of the interaction through RFID allowing robots to easily identify and activate tag-embedded home appliances [2]. We generalize this concept to include common household chores. Our proposed distributed knowledge network that connects distributed product databases and the robot can be a support infrastructure for automatic integration of heterogeneous knowledge sources to build an application program. In this work, a decentralized knowledge acquisition and task specific integration model is proposed, where the proposed knowledge integrator merges specific knowledge with existing knowledge into a task requiring knowledge. An experimental testbed is built to verify the proposed model.

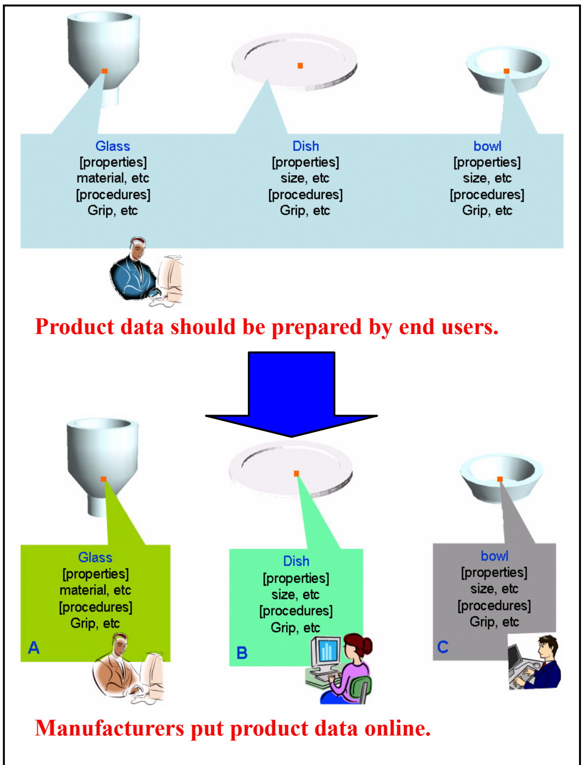

Fig. 2 Distributed knowledge generation and processing

TASK PLANNING

Table clearing can be considered one of the common household chores. The robot needs to pick up dishes and bowls on the table and place them in the pre-specified position. To make the robot perform this task autonomously, we propose a knowledge flow control model on the distributed knowledge network. It should be stressed that the robot has no preprogrammed knowledge about the object and the task. Distributed environmental knowledge will help the robot develop the competence for the task. Thanks to recent advances in information and communication technology, efficient storage and retrieval of data became possible. Thus, as shown in Fig. 2, each manufacturer attaches RFID tags to their product and put product data online. Our scenario facilitates remote access to the specific web server where more details about the object are given.

1) The task is commanded to the knowledge integrator.
2) The knowledge integrator collects information using RFID devices. The information includes the serial number of the objects, the location where the objects are to be stacked in the cart or other return positions, and the specific web site address.
3) Based on the information, the knowledge integrator creates the knowledge list of each object. The task is considered completed if the list is empty.
4) The knowledge integrator accesses the corresponding web address and acquires the necessary information required to pick up the object such as the grasping position and orientation and the image template associated with the tag ID.
5) The vision system detects the location of the objects through template matching. The new knowledge list is generated.
6) The robot picks up the nearest object to avoid possible collisions.
7) The knowledge integrator collects RFID data again and checks out the object ID taken away at the previous step. This will help the robot identify the ID of the grasped object.
8) The robot stacks up the objects on the cart. Some objects can be perceived as having the same shape. However, the tag data allows the robot to separate the objects properly.
9) The system returns to step 2) and repeats steps 2) through 8) until the knowledge list becomes empty.

TESTBED DESCRIPTION

A prototype system is implemented based on the scenario mentioned in the previous section. For this, we have built a demonstration test bed as shown in Fig. 3.

RFID system

The RFID system (Nippon Avionics VicPro development kit) is controlled via RS232C serial communication from the knowledge integrator. An operating frequency of 13.56MHz electromagnetic wave is used in the system. The reader is attached on the table as shown in Fig. 4 and collects the object data stored in the tag.

The tag data acts as a pointer to storage locations for detailed knowledge about the object.

Fig. 3 Experimental testbed

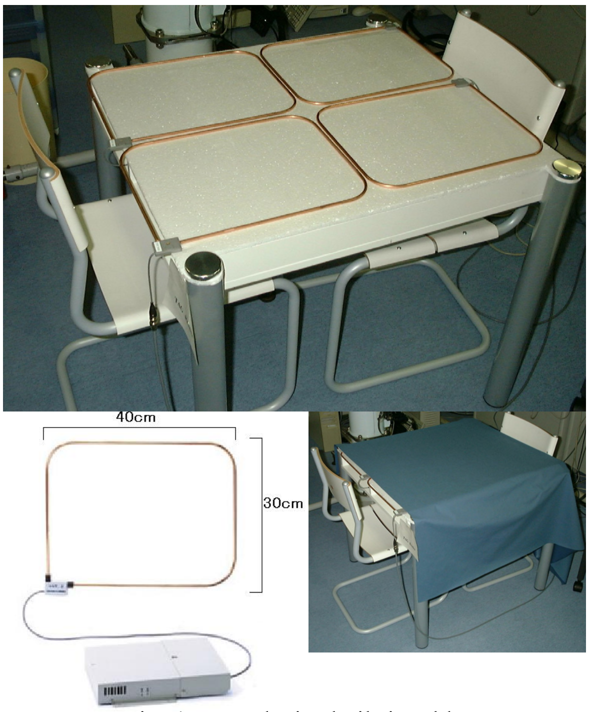

Fig. 4 RFID device built-in table

Robot manipulation

Mitsubishi PA-10 robot is controlled by the company's motion control CPU board in the robot controller PC running Windows XP. The motion control CPU board and the servo driver are communicated at a control frequency of 2msec through the high-speed serial communication ARCNET. The Takano Bearing Model RH707 is attached as an end-effector and connected to the same controller PC through parallel digital I/O.

Object location sensing

There have been many proposals for indoor location awareness. Those systems may differ from one another by the target application [6]. Since the RFID system is not designed for location sensing [3], [8], the vision system is used together with RFID. A ceiling mounted CCD camera is used to get the correct position of the objects on the table. The Hitachi IP5000, a fast image processing system on a half-size PCI board, is inserted into the controller PC running Linux to connect an NTSC camera and video output monitor. The board is equipped with 40 video memories of 512 x 512 pixels and provides plenty of fast image processing functions in hardware.

Online knowledge base

The World Wide Web (WWW) is a distributed hypermedia system available through the Internet. The object knowledge source written in Extensible Markup Language (XML) is uploaded to the WWW server. This enables the knowledge integrator, implemented in EusLisp, to acquire knowledge from diverse sources geographically distributed.

CONCLUDING REMARKS

As one of the common household chores, table clearing was considered toward practical use of the robot in the house [7]. The testbed was built at AIST in Tsukuba, Japan to verify the proposed knowledge flow control and integration process as illustrated in Fig. 5. We developed a new framework of distributed knowledge networks to deploy easy-to-use robot systems into our daily life with minimal programming effort. Fig. 6 shows the snapshots of successive robot motions in the experiments. Without any human intervention, the robot cleared the table autonomously. While most existing autonomous robots typically require a massive amount of initial knowledge about the environment, the robot in this experiment with no initial knowledge learned how to accomplish the commanded task interacting with its environments. It is notable that different real world applications can be achieved easily through proposed knowledge networks, if robots may access the

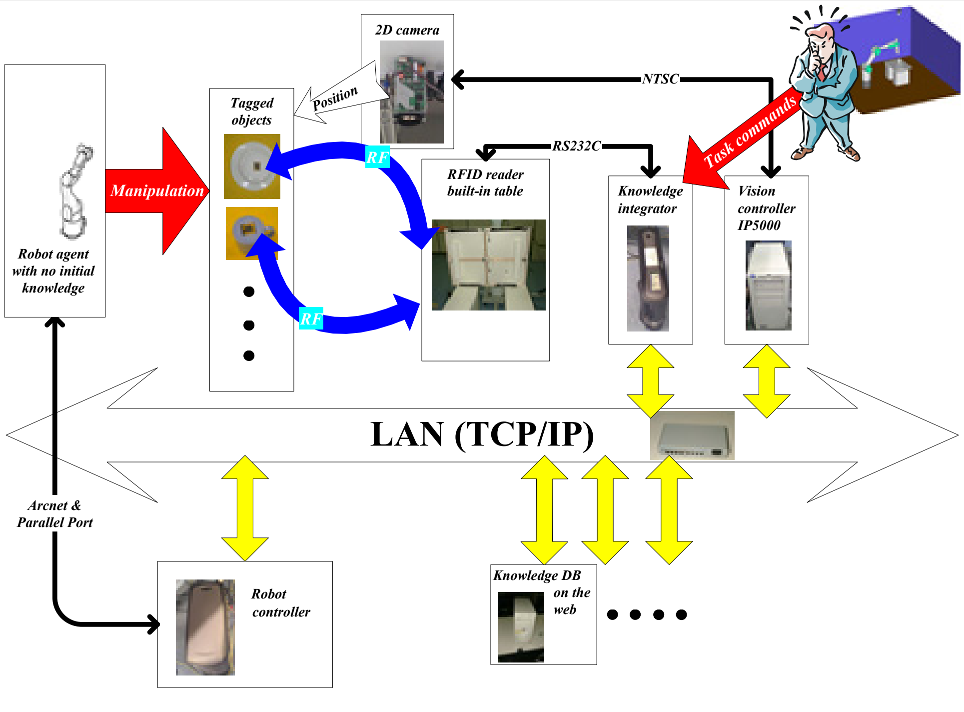

Fig. 5 Knowledge flow control and integration model

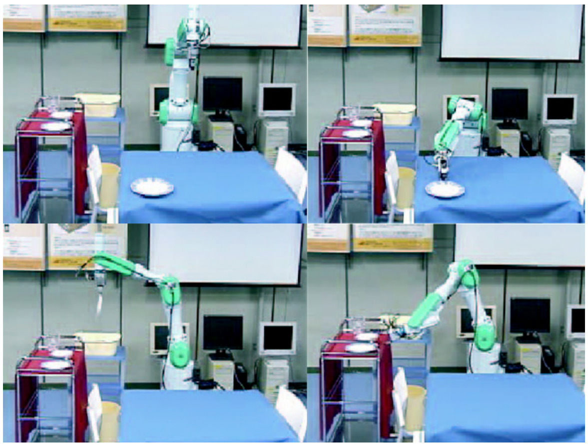

Fig. 6 Snapshots of successive motions of the robot.

object online data tailored to bring out their behaviors. Practically, data entry formats should be designed to standardize the online data input, which allows robots to selectively acquire only the necessary data.

REFERENCES

[1] M. Boukraa and S. Ando, An Invariance-Based Object Registration Architecture Using Electronic Tags and XML. Proc. 1st Int. Conf. on Information Technology and Applications, paper 87-5, 2002.

[2] N.Y. Chong and K. Tanie, Dependable Manipulation Based on RFID. Proc. Int. Symp. on Robotics and Automation, pp. 330-335, 2002.

[3] N.Y. Chong, H. Hongu, and K. Tanie, Object Localization in Omniscient Spaces. Proc. Int. Conf. on Advanced Robotics, pp. 118- 123, 2003.

[4] N.Y. Chong, H. Hongu, M. Miyazaki, K. Takemura, K. Ohara, K. Ohba, S. Hirai, and K. Tanie, Robots on Self-Organizing Knowledge Networks. Proc. IEEE Int. Conf. on Robotics and Automation, 2004.

[5] K. Finkenzeller, RFID Handbook: Radio-Frequency Identification Fundamentals and Applications, John Wiley & Sons Ltd., 1999.

[6] J. Hightower and G. Borriello, Location Systems for Ubiquitous Computing. IEEE Computer Magazine, pp. 57-66, 2001.

[7] H. Hongu, A Study on Knowledge Distributed Robot Systems Using IC Tags. Master Thesis, Advanced Engineering Systems, University of Tsukuba, 2004 (in Japanese).

[8] M. Kim, T. Takeuchi, N.Y. Chong, 3-D Localization Using a 3-axis Orthogonal Antenna. Proc. JSME Conf. on Robotics and Mechatronics, 2004.

[9] MIT Project Oxygen, http://oxygen.lcs.mit.edu/.