Knowledge Distributed Robot Control Framework

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Abstract: In this work, we propose a new framework of robot control for a variety of applications to our unstructured everyday environments. Programming robots can be a very time-consuming process and seems almost impossible for ordinary end users. To cope with this, this work is to provide a software framework for building robot application programs automatically, where we have robots learn how to accomplish a commanded task from the object. An integrated sensing and computing tag is embedded into every single object in the environment. In the robot controller, only the basic software libraries for low-level robot motion control are provided from the robot manufacturer. The main contributions of this work is to develop a server platform that we call Omniscient Server that generates the application programs and send them to the robot controller through the network. The object-related information from the object server merges into robot control software to generate a detailed application program based on the task commands from the human. We have built a test bed and demonstrated that a robot can perform a common household task within the proposed framework.

Keywords: Knowledge networking, Omniscient spaces, RFID, Robot programming, Object directive manipulation

1 Introduction

Controlling a robot is not as easy as we think, particularly if the robot is deployed in complex, unstructured environments. Currently, a massive amount of knowledge about the environment and high-level intelligence has to be centralized in the robot controller and also programmed in detail to have robots perform commanded tasks even in well-known environments. Programming robots has proven to be quite an experience and almost impossible for ordinary end users. We approach the problem of programming robots from the point of view of task-oriented integration of distributed knowledge. For this, we build perception-rich environments from which the robot extracts and collects useful information easily. An integrated sensing and computing tag is embedded into every single object in the environment. This is quite similar to bar codes printed on products. However, besides the serial number of the object, the tag includes task-related information such as the geometric and physical data, built-in features, and operation constraints and user manual of the object in order to handle the object properly. Such information will be provided by the object to robots whenever requested. Specifically, we expect each of the manufacturers to input all the information about their product when it is manufactured. On the other hand, the robot maker or end user provides no environment models and application programs in the robot controller.

An architecture for knowledge-based object registration was also proposed in computer vision [2], [3]. The features of the environments can embed themselves in every entity, allowing robots to easily identify and manipulate unknown objects. We proposed a new paradigm of the interaction through Radio Frequency Identification (RFID) to control and activate tag-embedded home appliances [7]. This paper pro-

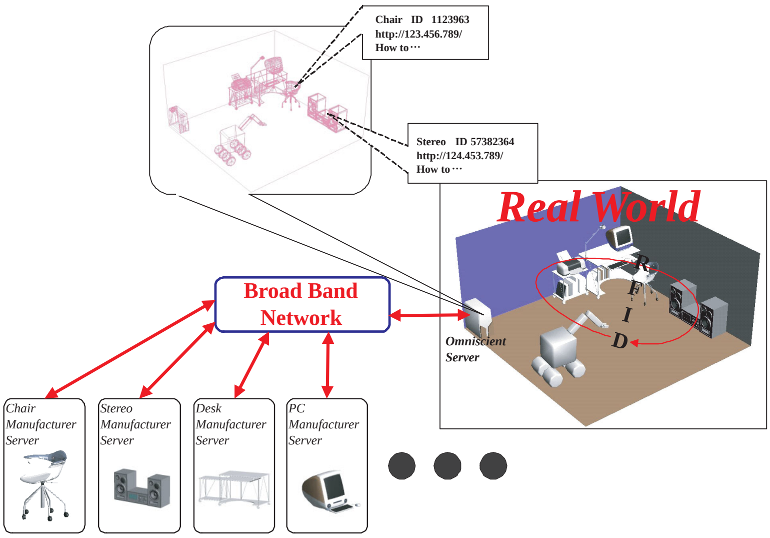

Figure 1: A framework for knowledge networking.

poses a framework for knowledge networking and integration that enables easy deployment of robot systems into our everyday environments without detailed knowledge of robot programming. We have built a test bed and demonstrated that a robot can perform a common household task within the proposed framework.

2 Knowledge Networks

Normally a robot's behavior is generated by end user programming integrating diverse information about any particular environment that the robot might face. We have been trying to centralize and manage all the knowledge about robots' environments in their controller. Thus, programming robots can be a very time-consuming process and seems almost impossible for ordinary end users. Better management of environment knowledge will lead to an easy-to-program robot system. This section addresses how to allocate individual information resources and integrate them through knowledge networking as shown in Fig. 1. Knowledge networking focuses on the integration of knowledge from different sources. Achieving such networking requires re-structuring functionalities in creating and using knowledge.

2.1 Knowledge creation

So far, end users have been trying to create and/or collect all the knowledge about robots' environments with which a task program is built. No one doubts that each of the manufacturers can create knowledge that is the best available. Once knowledge is created, it can be kept up-to-date and optimized based on feedback sent by the end users.

2.2 Knowledge storage

An end user centered knowledge base has been used to store all knowledge. Each of the manufacturers can maintain their own knowledge server that provides up-to-date knowledge of product features and the latest user manual.

2.3 Knowledge integration

Knowledge integration mainly concerns interaction between new and prior knowledge in a knowledge base [13]. Diversely distributed information in an environment is incorporated into a knowledge integration server to generate detailed robot task programs.

3 Omniscient Spaces Through RFID

In highly informative, perception-rich environments that we call Omniscient Spaces, robots interact with physical objects which in turn afford robots useful information. “Omniscient” literally means “knowing everything.” Thus, in Omniscient Spaces, every objects are known to robots. However, we do not provide robots with any information about their environments directly. In robot programming, environment modeling always becomes a troublesome issue requiring very time-consuming efforts to build a knowledge base. In Omniscient Spaces, a source of information is the object or environment itself. Any information can be collected through mutual interaction between the robot and the object and seamlessly converted into a robot data. This work is to provide a software framework for building robot application programs automatically, where we have robot learn how to accomplish a commanded task from the object. To achieve this, we need to make sure the object in our environments is ready to provide useful information. An integrated sensing and computing tag is embedded into every single object in Omniscient Spaces.

We employ the RFID technology in collecting information in this work. RFID uses a radio frequency communication to automatically identify, locate, and track objects, people, or animals. Basically, radio frequency eliminates the need for an optical line-of-sight and can be used to provide bi-directional information flows [6], [9], [14]. Because of its simplicity for use, especially the passive RFID system has been used for many years in various RF remote sensing applications. Passive RFID systems generally consist of three components, namely a reader, passive tag, and host computer as shown in Fig. 2. Using radio frequency waves, the reader transmits a signal to activate a passive tag. The tag, in turn, transmits encoded data back to the reader, which acknowledges and logs the signal via the host computer. The tag has read-write capabilities, enabling its data to be modified remotely, as necessary. The encoded information is decoded by the reader's on-board micro-controller. Using the characteristic of frequency bands, typical passive RFID systems can be designed accordingly [12]. Fig. 3 shows the RFID read/writer system used in this work. Detailed specifications are given in Table 1 [4].

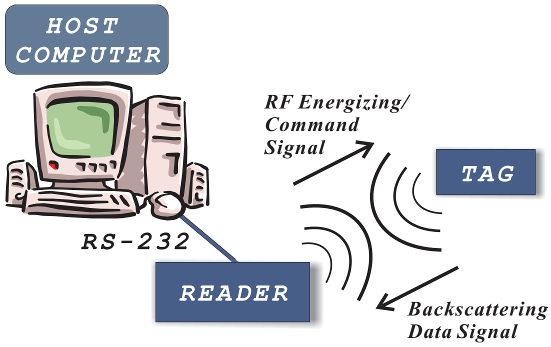

Figure 2: Radio frequency identification.

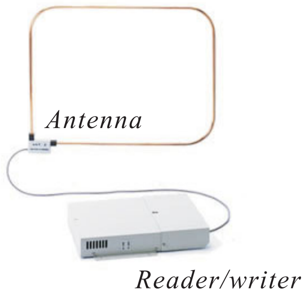

Figure 3: An RF reader/writer system.

4 Test bed

We have built a test bed as shown in Fig. 4. Each of the components are currently connected to a Fast Ethernet network, which is to be replaced by a radio transmission where appropriate. A set of dishes and bowls is on the dinning table. Detailed object information is stored in each of the object knowledge servers on the network that is provided and maintained by the object manufacturer. Thus, for instance, dish makers tag product features and user manual to the dishes. If a target object is identified, the Omniscient Server downloads necessary information off object server and builds detailed motion planning data considering the robot configurations and position with respect to the object. The motion planning data is forwarded to the robot controller to make a robot agent perform a commanded task. A ceiling mounted camera is used to get positions of objects on the table. Specifically, the least square algorithm is incorporated in the Direct Linear Transformation method [1] in camera calibration (Fig. 5).

5 Experiments

Figs. 6 shows the knowledge integration process in the experiments. Our current target task is to have the home robot take dishes to the dishwasher after meal. Once such command is given, the Omniscient

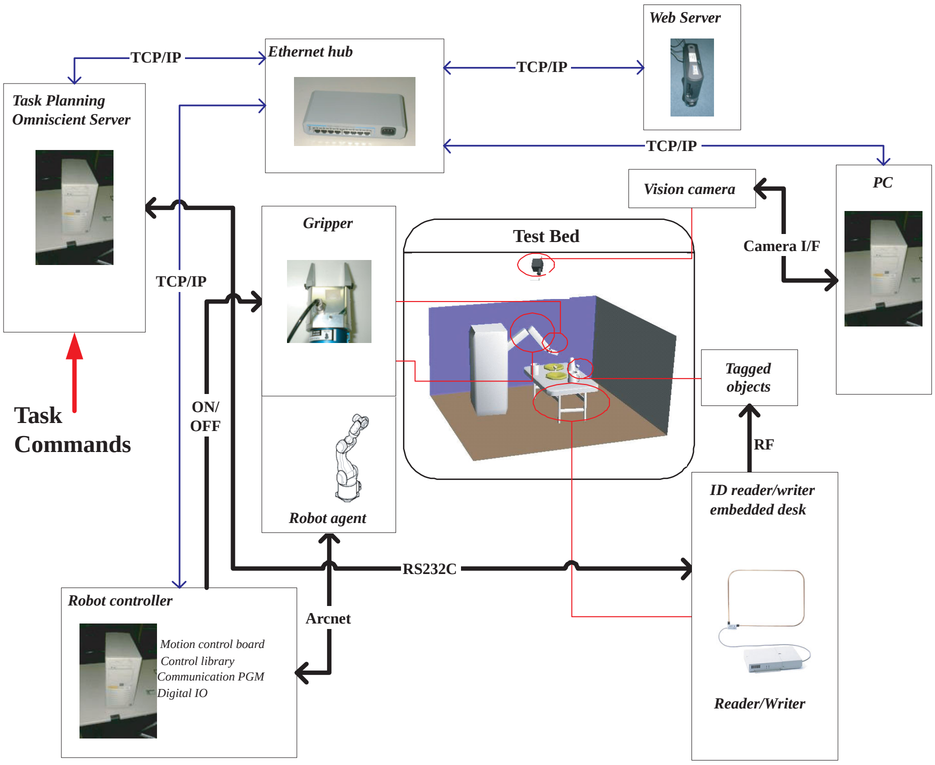

Figure 4: An experimental testbed.

Table 1: Reader specifications in the experiments.

Function	Reader/writer
Communication protocol	ISO 15693-2 26 kbps
Operating frequency	13.56 MHz
Host interface	RS232C or RS422A 9.6 kbps
Read range	up to 40 cm
Power requirements	AC 100V, 0.1A
Power consumption	10W
Dimensions $[mm]$	200 $\times$ 172 $\times$ 40
Operating temp $[^oC]$	-10 to 50
Operating humidity $[\%RH]$	5 to 95

Server generates the list of dishes first communicating with a set of built-in RFID readers under the table. After identifying tagged dishes on the table, the robot needs to know about the accurate positions and orientations of the dishes with respect to the robot coordinate frame. One of the shortcomings of RFID readers is that they are not able to localize tagged objects accurately. They only inform us whether tagged objects are in a certain read range of their transmitter antenna. For local indoor positioning systems, Werb [16] pointed out that the requirements and basic design are fundamentally different from those of global positioning system. A variety of techniques have been used to locate objects and people indoors [5], [15]. Especially, in inductively coupled RFID systems, if the measuring point of radio signal is moved away from the signal source, the strength will decrease. We proposed that a robot equipped with RFID reader can identify a tag from its read range and measure multiple signal strength samples with different positions. Then, from the known path of electromagnetic field strength, the distance of each sample data can be estimated. Given a set of distance samples with different robot positions, the robot triangulates the positions and orientations of tagged objects [8], [10]. To be sure, such an RFID reader is not yet available and currently under development by the authors.

Temporarily, in the experiments, a ceiling-mounted vision system detects the position of objects [11] using the image templates on the web address registered on

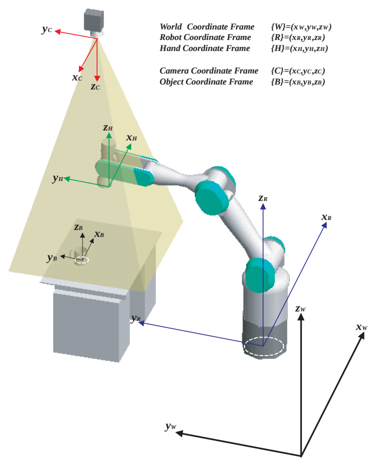

Figure 5: Definition of coordinate frames for camera calibration.

the memory of the tag. Then, the Omniscient Server generates the motion planning data using knowledge for handling dishes on each of the product web servers and position data from the vision system. Detailed information provided in the experiments is the height of the grasping point, the deviation from the center of dishes, the orientation of the robot gripper. Such an instructive knowledge merges into the robot control software in the Omniscient Server to run a built-in program in the robot controller. Once the target position and orientation is given from each of the knowledge server, the robot system approaches the dishes with an optimal grasping configuration. Fig. 7 shows individual scenes.

6 Conclusions

Programming robots has proven to be difficult, particularly if the robots are deployed in complex, unstructured environments such as our everyday environments. We approached the problem of programming robots from the point of view of task-oriented integration of distributed knowledge. To achieve this goal, we have proposed Omniscient Spaces based on knowledge networking. End users will be relieved of the burdens of complex robot programming challenges through the proposed approach, which emphasizes the necessity of keeping the knowledge about the object and environment distributed and communicated whenever requested. This work explored innovative ways to allow for the realistic deployment of current robot systems

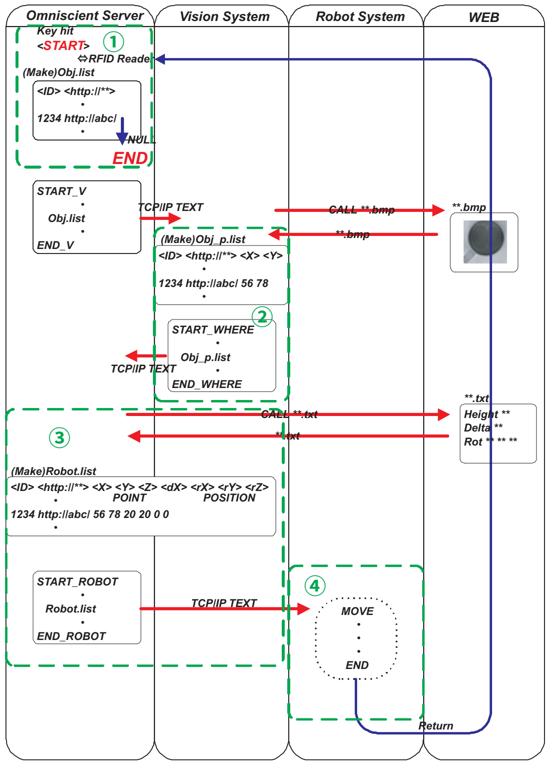

Figure 6: Flowchart of knowledge integration in preliminary experiments.

without detailed knowledge of robot programming, especially into man-made unstructured environments.

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References

[1] Y. I. Abdel-Aziz and H. M. Karara, "Direct Linear Transformation from Comparator Coordinates into Object Space Coordinates in Close-Range Photogrammetry," *Proc. ASP Symp. on Close-Range Photogrammetry*, pp. 1-18, Falls Church, VA, 1971.

[2] M. Boukraa and S. Ando, "An Invariance-Based Object Registration Architecture Using Electronic Tags and XML," *Proc. 1st Int. Conf. on Information Technology & Applications*, paper 87-5, Bathurst, Australia, November 25-28, 2002.

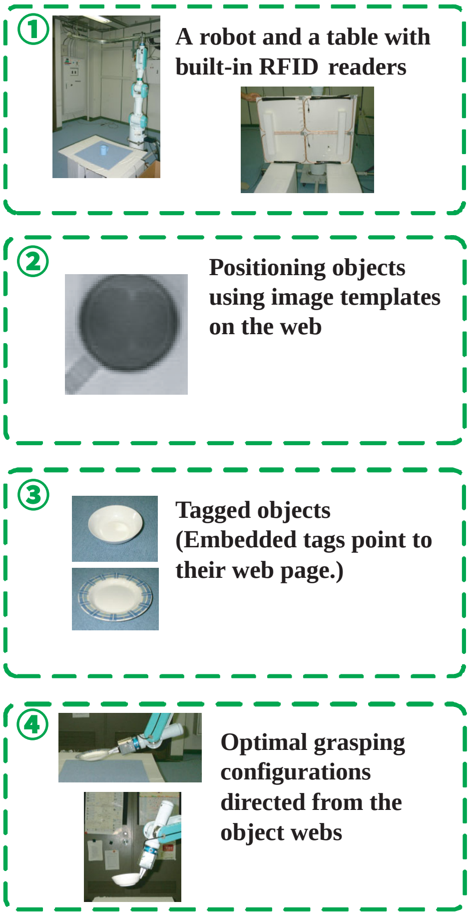

Figure 7: A close look at experimental scenes.

[3] M. Boukraa and S. Ando, "Tag-Based Vision: Assisting 3D Scene Analysis with Radio-Frequency Tags," *Proc. IEEE Int. Conf. on Image Processing*, pp. I269-I272, Rochester, NY, September 22-25, 2002.

[4] *http://www.avio.co.jp/products/system/rfid/index.htm*

[5] P. Bahl and V. N. Padmanabhan, "RADAR: An In-Building RF-based User Location and Tracking System," *Proc. IEEE INFOCOM*, Vol. 2, pp. 775-784, Tel-Aviv, Israel, March 2000.

[6] A. Bensky, *Short-range Wireless Communication*, LLH Technology Publishing, 2000.

[7] N. Y. Chong and K. Tanie, "Dependable Manipulation Based on RFID," *Proc. Int. Symp. on Robotics and Automation*, pp. 330-335, Toluca, Mexico, September 1-4, 2002.

[8] N. Y. Chong, H. Hongu, and K. Tanie, "Object Localization in Omniscient Spaces," *Proc. Int. Conf. on Advanced Robotics*, pp. 118-123, Coimbra, Portugal, June 30-July 3, 2003.

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

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

[11] R. Horaud, F. Dornaika, and B. Espiau, "Visually Guided Object Grasping," *IEEE Transactions on Robotics and Automation*, pp. 525-532, Vol. 14, No. 4, 1998.

[12] Y. Lee and P. Sorrells, *microID 13.56 MHz RFID System Design Guide*, Microchip Technology Inc., 2001.

[13] K. S. Murray, *Learning as Knowledge Integration*, Ph. D. dissertation, Dept. of Computer Sciences, The University of Texas at Austin, May 1995.

[14] D. M. Pozar, *Microwave and RF Design of Wireless Systems*, John Wiley & Sons, Inc., 2001.

[15] I. Siio, "User Position Detection Using RFID Tags," *Information Processing Society of Japan Human Interface Special Interest Group Note 00-HI-88*, pp. 45-50, 2000, *(in Japanese)*.

[16] J. Werb and C. Lanzl, "Designing a Positioning System for Finding Things and People Indoors," *IEEE Spectrum*, Vol. 35, No. 9, pp. 71-78, 1998.