Object Directive Manipulation Through RFID

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Abstract: In highly informative, perception-rich environments that we call Omniscient Spaces, robots interact with physical objects which in turn afford robots the information showing how the objects should be manipulated. Object manipulation is commonly believed one of the most basic tasks in robot applications. However, no approaches including visual servoing seem satisfactory in unstructured environments such as our everyday life. Thus, in Omniscient Spaces, the features of the environments embed themselves in every entity, allowing robots to easily identify and manipulate unknown objects. To achieve this end, we propose a new paradigm of the interaction through Radio Frequency Identification (RFID). The aim of this paper is to learn about RFID and investigate how it works in object manipulation. Specifically, as an innovative trial for autonomous, real-time manipulation, a likely mobile robot equipped with an RFID system is developed. Details on the experiments are described together with some preliminary results.

Keywords: Object directive manipulation, Omniscient spaces, RFID, Knowledge integration

1 Introduction

There is much recent interest in the development of service robots to support human beings in our daily environments such as homes or offices. Over the past decades, we have carried out extensive research to advance service robots towards autonomous ones. During that span, it seemed that our goal was far beyond the state of the art technology. For instance, object manipulation was commonly believed one of the most basic tasks in robotics, however we often assumed that every object was known *a priori*. Why not build more dependable environments, where physical entities practically afford robots their identity and features showing how they should be manipulated? To make our environments cater to the needs of inhabitants, every single entity as well as robots needs to have some level of intelligence. The features of the environments are distributed over surrounding areas and interact with robots through a variety of ways provided. In our latest developments of object manipulation technology [3], we tagged every necessary information available to the object. Therefore, the object affords robots an important piece of information required to manipulate it autonomously.

Manipulation consists of identification and grasping of an object followed by a series of task-directed motions. Almost without exception every object has its own manipulation positions quite noticeable to humans. For instance, mugs have a handle for picking up and electrical devices have several switches and/or buttons for operation. However, this should be more challenging to robots. Vision-guided manipulation has been an oft-tried approach in sensor-based robotic manipulation [1], [6], [10]. Even though developments in the field of computer vision have provided many opportunities for exploring physical locations and identification of objects, vision was not entirely satisfactory and had some shortcomings. Particularly, human everyday environments are highly unstructured and complex, thus vision is considered less attractive. It frequently suffers from the line-of-sight, lighting, accuracy/time, and deficiency in non-geometric data. Sometimes, a pair of cameras is a minimum essential.

To overcome such shortcomings, we employ the RFID technology in robotic manipulation. RFID uses a radio frequency communication to automati-

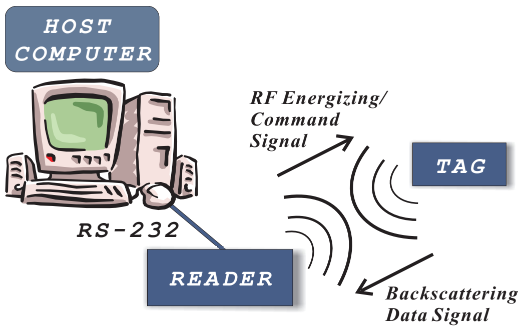

Figure 1: Non-contact radio frequency recognition.

cally 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 [2], [4], [11]. 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. 1. 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 [9].

In this paper, we propose a novel manipulation strategy which refers to the object embedded information through RFID showing how the object should be manipulated. A feasibility study on the proposed strategy is performed by experiment.

2 Object Directive Manipulation

Objects inherently have all the information required for their manipulation that we already know from our good experience. Until now, we did not use those useful information and unnecessarily called for complicated manipulation algorithms. We should ask objects about their identity and features in order to deal with them properly. To achieve this end, we use RFID to tag information to objects beforehand and read it out. The information of objects can be given

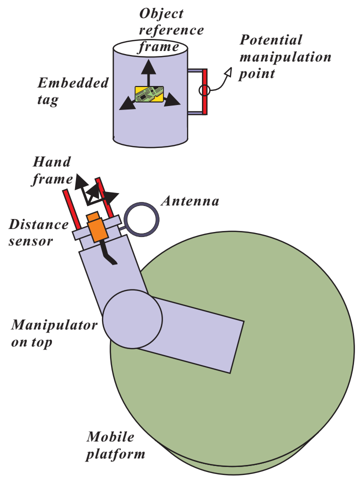

Figure 2: Identification of an object and its manipulation point.

when they are manufactured. This is quite similar to bar codes printed on products. Thus, once objects are manufactured, they could afford robots their built-in features and information required for manipulation through RFID. Having environment models to capture information through images and subsequently extract visual and/or geometric information can be costly. However, if RFID is widely adopted, robots could recognize and manipulate objects easily without having to have a massive amount of knowledge about their environments and high-level intelligence in a centralized controller. In such environments that we call *Omniscient Spaces*, every single object has information about itself instead and capabilities to do communication and information processing.

2.1 Manipulation-related information

RFID could eliminate costly identification processes and computational burdens for the determination of optimal manipulation points. Specifically, to manipulate an object, robots in their current positions need to move the gripper to the grasp position of the object. For this, the possible grasp position should be known to the robot. As shown in Fig. 2, an unknown object can be identified through RFID. Practically, potential manipulation positions, which should be encoded in the tag together with the general object information, can be defined with respect to the local reference frame fixed to the object. Therefore, if robots could find their relative locations with respect to the object reference frame, it would be straightforward to align their gripper with the manipulation position.

Also, it is quite clear that vision can not provide non-geometric information such as material properties of the object. Thus, for instance, robots do not know how heavy the object would be. If robots have such information ahead of manipulation, they could control grasping forces adequately. The improper use of grasping force could lead to breakage or slipping of objects. Likewise, objects under manipulation may have particular constraints in terms of the position and orientation arising from their geometry. For instance, the mouth of mugs should face vertically upward as something might be contained inside. These sorts of information should be needed in order to complete required manipulation as intended. We encode such object-related information into the tag and have the robot read the information out through RFID.

2.2 Locating object coordinate frames

Werb [15] pointed out that the requirements and basic design of local indoor positioning system are fundamentally different from those of global positioning system. Locating objects and people indoors use a variety of interface and interpretation techniques [12], [13], [14]. First of all, in the proposed approach, the location of the object should be known with respect to the manipulating robot. One of the shortcomings with RFID is that it could not localize tagged objects precisely. We are only informed whether tagged objects are in a certain read range of the reader's antenna. The read range is a maximum distance to read data out from the tag. After identifying tagged objects, the robot needs to know about the precise positions with respect to the object. For this, practically, we mount a distance sensor on the robot together with the reader in order to measure the distance between the robot and the object. Eventually, how to localize the reference coordinate frame attached to the object is the most important key to the proposed approach [5]. Thus, we have devised a scheme to help the robot easily find the object reference frame. We put a mark on the tag showing the reference frame in which the coordinates of grasping and/or activating positions are defined. Specifically, we make a small hole in the center point of the tag. Then, the laser sensor possibly detects an abrupt change in distance around the hole, enabling the robot to find the reference point of the object (Fig. 3).

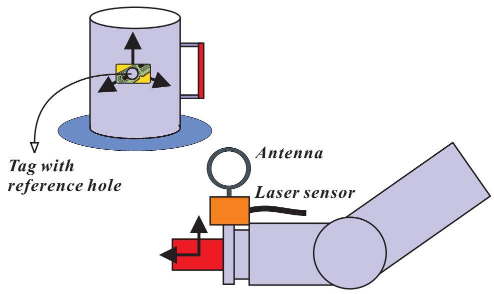

Figure 3: Locating the center hole of the tag.

3 Experiment

We investigate the feasibility of RFID-based manipulation by experiment. This section goes into details about the setup. Let the configurations of the room be known to the robot as the household items do not change their position often. The spatial coordinates of the household items otherwise can be also encoded in their tag. The robot is commanded to manipulate an object. When the object is within the read range of the robot's reader, the robot reads out the object data from the embedded tag. Then, in turn, the robot understands the features of the object showing how it should be manipulated. For instance, the grasping positions are encoded. The robot scans the object to align its tool center point (TCP) with the object reference frame and measures the current relative positions of the object from the TCP. This will transform the nominal target position vector into the TCP frame. Finally, the robot aligns the TCP with the desired point of manipulation of the object. We briefly outline our experimental system in the following.

3.1 Reader and tag

An RFID reader (Intersoft [7] WM-RO-MR-2) and two passive read-only tags (Intersoft IT30RO) are shown in Fig. 4. Table 1 shows the specifications of the reader used in the experiments. This system includes a reader/decoder board and antenna installed in a rugged, sealed compact enclosure. The board demodulates and decodes the data that is then sent as a packet using a two-wire RS-232 interface. The transmit signal output and the common ground reference signal from the reader should be connected to the receive signal input and the common ground of the computer, respectively. To support the transmission, a program that provides an interface to the serial ports of the host PC is written. Practically, a green LED

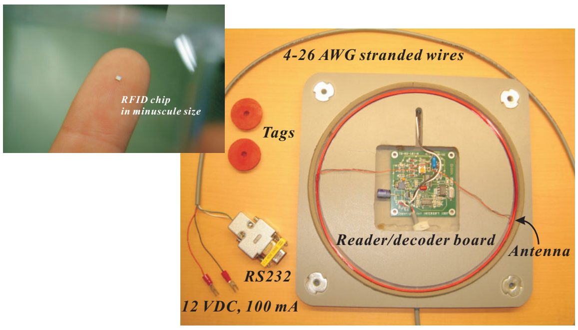

Figure 4: An RFID reader and tag.

blinks on the surface of the reader when a valid tag is within range and has been read by the hardware. Power should be supplied to the reader with a linear low-noise regulated positive DC +12VDC, 100mA power supply.

Table 2 shows the specifications of the tags used in the experiments. The tags include a transponder and antenna circuit. They provide a permanent serial number for identifying objects in which they are embedded. The tags are inactive until they enter the correct radio frequency field. They do not require a battery and receive power from the radio frequency beam so that the reader interrogates them. Thus, they have a very long lifetime without maintenance requirements and can be made sufficiently small and inexpensively as shown in Fig. 4. Normally the larger the tag antenna and reader antenna, the longer the read range. Currently the longest possible range we can obtain with WM-RO-MR-2 and IT30RO is 20 cm. This result may vary depending on the environment.

Table 1: Reader specifications in the experiments.

Function	Medium range
Interface	RS232 9600 baud 8 data bits no parity 1 stop bit
Read range	up to 50 cm
Power requirements	12 VDC, 100 mA
Dimensions $[cm]$	21.5 × 21.5 × 1.9
Operating temp $[^oC]$	0 to 40
Material	Gray PVC
Connection	Cable (4-26 AWG)

Table 2: Tag specifications in the experiments.

Function	Passive read-only
Operating frequency	125 $KHz\pm$ 6
Modulation	Amplitude Shift Keying
Encoding	Manchester
Read speed	1,954 bps
Memory size	64 bit read-only
Serialization	40 bit serial number
Dimensions $[mm]$	30 × 6, *disk*
Operating temp $[^oC]$	-40 to +85
Storage temp $[^oC]$	-55 to +100
Material	Thermoset orthopolyester
Color	Red
Protection	IP68

3.2 Data transmission and display

The data packet is sent continuously if a tag is detected and remains in the reading range. The serial number of tag is decoded by the reader and is transmitted via the serial port of the host PC. Some RFID systems operate with a large memory up to 1M bits, but most systems commonly use 128 bits or less memory. Such a limited size of memory would not be sufficient to input all necessary information. Technically, we could have a database in an information server on the network to which the serial number of the tag can refer. The database provides detailed information such as the spatial positions and sizes of objects, possible grasping points, activating switches or buttons, material properties, manipulation constraints, etc. The server minimizes the size of data to be encoded into the tag. Fig. 5 shows the screen display of the host PC with a pop-up window of object data as well as the virtual environment. When the reader reads out the data of tags, the 3D graphics model of objects is immediately displayed in position and relevant information is retrieved simultaneously. The display is considered a necessity for monitoring.

3.3 Laser sensor

An invisible semiconductor laser displacement sensor [8], which provides a detection range of 200 mm to 400 mm, is used in the experiments. This sensor scans the area where the tag is read. Practically, the mobile robot moves its manipulator over the area, then the sensor head (LB-300) mounted on the top of the gripper and amplifier unit (LB-1200) measure the distance of the tagged object and furthermore finds out

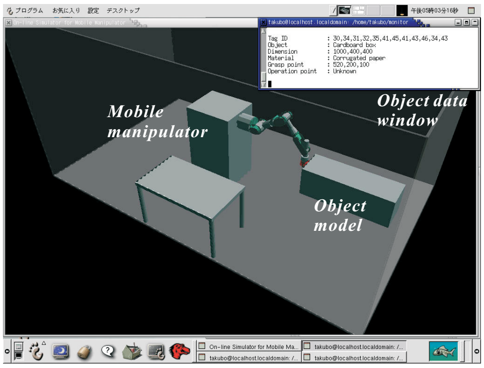

Figure 5: Screen display of the host PC.

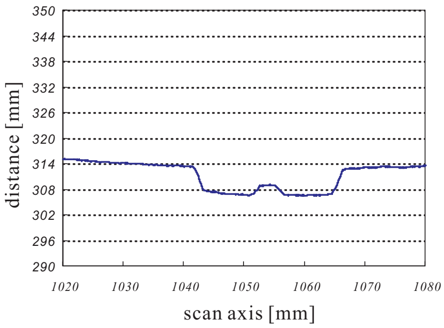

Figure 6: Distance measuring around the tag.

the center hole of the tag designated as the local reference point. Fig. 6 shows the distance reading over a vertical object with flat surface. The scanning speed was set to 5 *mm/sec* by the manipulator. The shape of the tag (*30 mm W* × *6 mm H, disk*) on the object surface was obtained. Several abrupt changes can be confirmed in the measured distance by about 6 *mm* and 2 *mm* that are equivalent to the height of the tag and the depth of the center hole, respectively. This will lead the gripper into the reference position from which the gripper moves toward possible grasp points or activating switches to do the commanded task.

3.4 Demonstration

Fig. 7 illustrates the snapshots of a robot that operates a household appliance through RFID. A manipulator (Mitsubishi Heavy Industries, Ltd. PA-10) equipped with a radio frequency reader and laser sensor is attached to the front side of the mobile platform (a Fuji Electric Co. custom-made). The mobile robot approaches an unknown object and reads the data of the tag to identify the object. The serial number of the tag is a pointer to retrieve information about the object from the database on the network. The data shows the built-in features of the object. Thus, for instance, the coordinates of the switch with respect to the local reference frame could be provided. The laser sensor then scans the area ahead and finds out any predefined marks on the tag, whereby positioning the robot the center of the tag to start the task commanded by the human. Subsequently the distance of the robot from the object is measured. Eventually the coordinates of the switch and the distance data get the robot moving toward the switch autonomously. The robot could switch on the TV without any guidance of the vision system. The robot system becomes an autonomous agent for integrating perception in unstructured environments and acting on behalf of the human.

4 Conclusions and Future Work

RFID is expected to play a significant role in different robotic applications in *Omniscient Spaces*. This paper was aimed at learning about how the RFID system worked efficiently in robotic manipulation without having to employ conventional vision-based modeling and manipulation systems. To the best of our knowledge, RFID was firstly employed beyond remote sensing applications in this work to have robots manipulate unknown objects easily. Specifically, a possible configuration of typical RFID systems for real-time robotic applications was introduced. Furthermore, details on the experiments were described with preliminary results. In the near future, we will extend to more complicated tasks with arbitrary orientations of objects. To help robots find out the object coordinate frames, we put distinguishable marks showing the local axes easily on the surface of tags. Currently, a new position and orientation sensing technique that employs the inverse square law of radio frequency strength is being tested.

Bilateral communication is required to keep an updated information on the objects. Once manipulation is completed as intended, the state of the object including the spatial positions might change. In any case, the robot could leave a message on the object indicating that the mission has been done. Any details about the updated object information can be provided over networks and they are possibly referred to by other robotic assistants in the same environment. The bilateral communication will extend functionality

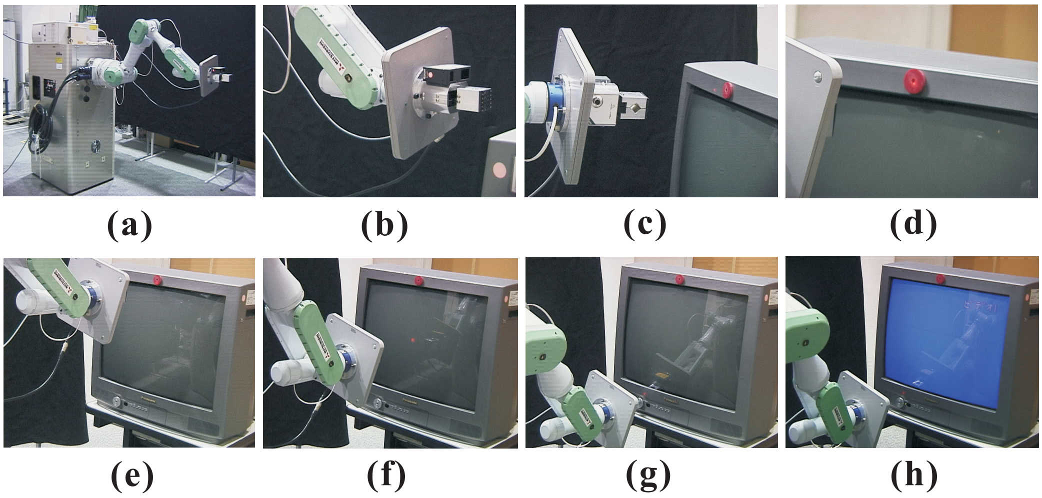

Figure 7: A mobile robot switches on TV: (a)-(b) approaches object and reads data out, (c)-(d) scans object surface, (e) aligns TCP with the reference hole and measures the distance, (f)-(g) moves toward switch, (h) switches on TV.

in RFID-based robotic applications, especially when multiple robotic assistants exist.

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