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ROBOTIC GRIPPERS FOR HANDLING BOOKS IN LIBRARIES

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Abstract: *Recent developments in robotics outside traditional industrial applications increasingly focus on robots operating in an unstructured environment and human vs. robot interactions. Among the most recent application fields for robots used in unstructured environments are personal and service robotics, space and underwater robotics, medical and rehabilitation robotics, construction robotics, agriculture robotics. However robots that are designed to perform specific library tasks are relatively rare. In this case a mobile robot arm is used to manipulate the books on a shelf. In this context, this paper describes the most relevant performances of prototypes designed for robotic manipulation of book material.*

Keywords: *librarian robot, manipulation, service robots*

1. INTRODUCTION

Current trends in robotics research are focused especially on autonomous and semiautonomous robots. Some authors assign these robots to the class of service robots [1]. According to the International Federation of Robotics a service robot is designed for the well-being of humans and equipment, excluding manufacturing operations [2].

Service robots feature arm structures similar to industrial robots [3].

In terms of applications service robots are divided into professional service robots and personal service robots. In addition to service areas such as cleaning, surveillance, inspection and maintenance these robots are employed for hazardous, impossible or unacceptable manual tasks. Personal robots are service robots which include domestic robots that may perform daily chores, assistive robots for people with disabilities or elderly people, and robots used for entertainment [4].

Currently, very active researches are conducted in the field of service robots as results from the programmes of the most international conferences on Robotics (***I****nternational* ***C****onference on* ***R****obotics and* ***A****utomation* – ICRA, ***I****nternational* ***C****onference on* ***I****ntelligent* ***R****obots and* ***S****ystems* – IROS, etc.). However, robots that are designed to perform specific library tasks are relatively rare. In this case a robotic arm is used to manipulate books on a shelf [5].

2. BOOK MANIPULATION

The issue of object manipulation is solved by using standard, well-known geometries of articulated arms that can satisfy a wide area of conditions.

Considering the above, the problem of book manipulation can be approached like a standard manipulation problem.

The basic steps related to a complete automatic manipulation of a book can be described as follows:

- book identification (by title, author or subject) and automatic relation to its location;
- positioning of the manipulation system in front of the book to be picked up;
- pick-up from the shelf;
- motion towards a transfer unit (connection between the conservation area and the user area);
- release of the book and position reset.

The serviceable surface for pick-up is the back, considering also the adjacent books [6].

3. ROBOT-ENVIRONMENT INTERACTION

A robot can interact with the environment by ensuring adequate contact followed by the motion required by the task. Although robot manipulators have been successfully applied to various tasks, their versatility is limited. E.g. when a manipulator is assigned to pick up objects of different sizes and attributes, its end-effector needs to be adapted to the object's parameters.

4. GRIPPING OPERATION ANALYSIS

The design of a robot gripper is based on following parameters:

- maximum depth of the shelf;
- maximum book size;
- maximum book mass;
- minimum book thickness.

Book pick-up:

- the hand approaches the book, and one finger (often the forefinger) is used to tilt the book around its base;
- the other fingers grip the book;
- the book is drawn out.

Book repositioning:

- the gripped book approaches the shelf, in such a way the lower corner edges are the first to be positioned (between adjacent books);
- the book is pushed into the shelf;
- the body of the book is readjusted in vertical position.

The robotic unit is designed to simulate the human approach: when a book is correctly positioned into its shelf the only accessible surface is the back of the book. [6].

5. ROBOTIC GRIPPER FOR BOOK HANDLING IN LIBRARIES - STATE OF ART

With regard to robotic library systems, relevant research has been conducted. In this context, a remotely operated solution was presented by Tomizawa and coworkers [7], the University of Tsukuba, Japan. Their work was based on a robotics project from the Johns Hopkins University [8], ***C**omprehensive **A**ccess to **P**rint **M**aterial* (CAPM), who had built a robot limited to extract books from a shelf.

The robot uses a 7 DOF (***D**egrees **O**f **F**reedom*) manipulator of 1100 mm length in order to extract from and return books to a shelf [9]. The manipulator has a working range between 400 mm and 1100 mm above the floor (Fig. 1).

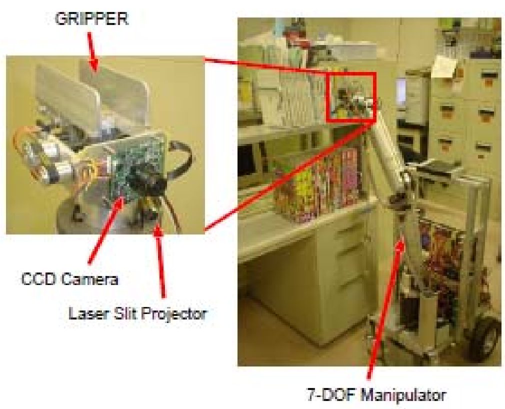

Fig. 1. 7 DOF manipulator and hand for book pick-up. (T. Tomizawa et al., 2003)

The hand consists of a gripper made of two flat fingers that can move right-and-left symmetrically; these fingers can hold books with a weight up to 400g, with a thickness under 50 mm [10].

UJI (i.e. the acronym of the ***U**niversity **J**aume-I*, ***C**astellón*, Spain,) Librarian Robot [11] is a service robot with a prototype mobile manipulator designed to assist in everyday tasks. The first application is its employment as an assistant in a public library to search books in the bookshelves, pick them up and take them to specified locations [12, 13].

The experimental setup, presented in Fig. 2, requires a mobile platform (Nomadic), a robot arm (Mitsubishi PA-10, 7 DOF parallel-jaw gripper), and a camera in hand (MEGA-D Megapixel Digital Stereo Head) configuration. Moreover, a special design of the fingers in the parallel-jaw gripper was necessary.

The first tests with this system show good performance. For instance, the time necessary to localize a label from an initial image is always less than 1s. Moreover, the next image processing, including OCR (***O****ptical* ***C****haracter* ***R****ecognition*), to identify the label, is always within 5-10 s. A ratio of 5 s per each centimeter of book is needed before the book is grasped (e.g. a book of 4 cm thickness takes 20s). All tests have been conducted using a 266 MHz Pentium II Processor.

Recent experiments show that the system is robust enough to manipulate non-conventional books, as shown in Fig. 2 (right) [5].

Fig.2. The system in action.
(M. Prats et al., 2004)

The new experiments developed with this system, but with another mobile platform (ActivMedia PowerBot) show an important improvement [14] in terms of book locating, identifying and extracting. With regard to gripping, a ratio of 1.5 s per 1 cm of book will be needed (e.g. a book with a width of 4 cm requires 6 sec). All experiments used a 1.2 GHz Pentium IV Processor [15].

In another experiment a manipulator uses a three-fingered Barrett hand and a JR3 force/torque and acceleration sensor mounted at the wrist.

The researchers tested force/pressure control strategies in a real application: a robot that pulls out a book from a bookshelf.

By placing tactile sensors on the robot fingertips, the robot can estimate whether the initial contact is good. The current system is able to autonomously ensure a good initial contact on the top of the book even from a very rough initial estimation.

Fig. 3. The robot grasping the book.
Left: initial contact. Middle: Maximizing contact surface. Right: doing the task.
(A. Morales et al., 2007)

Three types of behaviors have been implemented as shown in Fig. 3. The first one controls the force that the manipulator applies on the book through the contact on the fingertip. The second one tries to maximize the contact area in order to assure that the reference force can be reached. Finally, the third behavior is to extract the book.

In the future new gripping actions will be implemented so that the UJI service robot would be able to handle objects of different shapes [17].

With ubiquitous robotics, distributed computing, and sensor networks evolving rapidly, robotics engineers are using the ambient intelligence concept as a basis for developing advanced robot technology. At the ***I****ntelligent* ***S****ystems* ***R****esearch* **I**nstitute (ISRI) of the Japan's National Institute of ***A****dvanced* ***I****ndustrial* ***S****cience and* ***T****echnology* (AIST), the researchers have been studying knowledge-sharing robot control associating distributed objects in physical space with a knowledge database in virtual space using RFID tags as physical hyperlinks [18].

Fig. 4 The librarian robot system, the intelligent floor, and the intelligent bookshelf. (B. K. Kim et al., 2008)

The librarian robot consists of a manipulator which can recognize and manipulate books, and a mobile platform, which can localize and navigate itself using floor-embedded RFID tags [19].

The complete librarian robot system is shown in Fig.4. The intelligent floor for robot localization and the intelligent bookshelf for checking the book status are connected to a middleware-based network.

Fig. 5. Book handling.
(B. K. Kim et al., 2008)

Fig. 5 shows the robot gripper handling a book. Here, the robot gripper developed in AIST was used, as shown in Fig.6. The robot system retrieves book parameters from the database using the attached RFID tag.

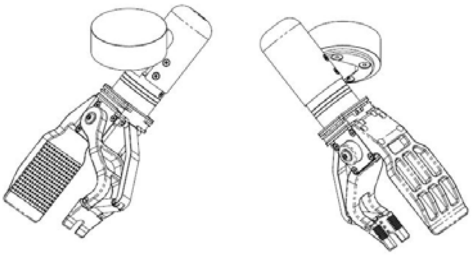

Fig. 6. Robotic hand designed to handle a book.
(B. K. Kim et al., 2008)

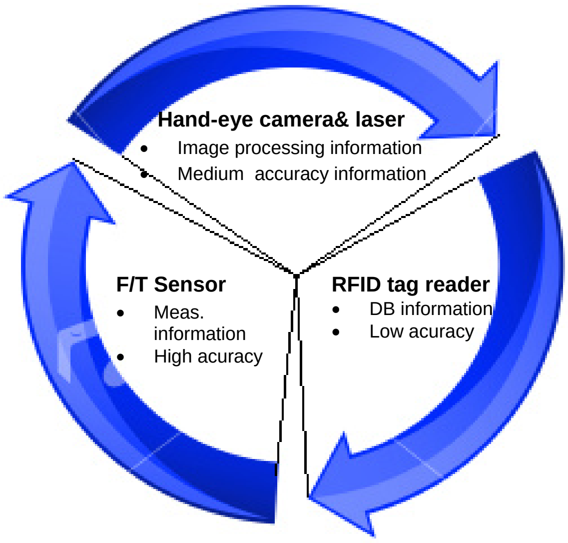

Fig. 7. The relationship among the sensors.

Hence, using the hand-eye vision and the laser installed on the gripper, the robot gets the image of the arranged books and then identifies the target book through image processing. Also, the robot detects the force variation signal from the gripper.

Fig. 7 shows the relationship between these sensors [20].

6. CONCLUSION

Developing a robot capable of handling all types of objects used in human living environment is extremely difficult.

This paper attempts a comparative analysis of two similar approaches and the solutions adopted regarding library robot systems designed to improve library user assistance.

With respect to this, AIST devised some methods, as part of environmental structuring for effective adaptation of robots to human living environment.

Here, following aspects should be emphasized:

- In both cases, the analyzed library robot systems were designed to perform similar book-handling tasks.
- Both robot systems were designed to include human-specific capabilities. However, the AIST-system is largely based on the wider concept of “intelligent ambient” whereas the UJI-system concentrates mainly on the combination of sensory/force aspects.

- The AIST-system can thus be viewed as part of a wider framework including advanced concepts such as ubiquitous robotics, distributed computing and sensor networks. This allows for increased robot versatility and adaptability to different library environments.
- The UJI-system focuses mainly on the robot's individual handling performance. It attempts to improve a number of specific tasks that relate to book handling capabilities through enhancing its force/vision coupling characteristics.

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