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Transforming library operation with robotics

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Abstract:

Some years ago, in the context of a project titled "the UJI librarian robot", the UJI Robotic Intelligence Lab developed a robotic mobile manipulator that was able to autonomously locate a book in an ordinary library, and grasp it from a bookshelf, by using eye-in-hand stereo vision and force sensing. The robot was composed of a robot arm mounted on top of a mobile vehicle, and was only provided with the book code, a library map and some knowledge about its logical structure. The system took advantage of the spatio-temporal constraints and regularities of the library environment by applying disparate techniques such as stereo vision, visual tracking, probabilistic matching, optical character recognition, motion estimation, multisensor-based grasping, visual servoing and hybrid control, in such a way that it exhibited a robust and dependable performance. The system was tested, and experimental results showed how it was able to robustly locate and grasp a book in a reasonable time without human intervention. A second version of the system was developed later enhancing the robot capabilities by replacing the parallel-jaw gripper with a three-finger hand, so that book extraction was just one among many possible manipulation skills.

Keywords: Robotics, library assistance.

Introduction

Along the time, technology has provided systems to automate routine tasks in factories, offices, libraries and homes. In particular, libraries have awaken great interest since they are semi-structured environments where machines coexist with humans and several repetitive operations could be automatically performed. In this regard, robotics research has focused on three library activities: book localization, book inventory, and book loan and return. Note that the first one is aimed to aid the user to find a book, while the last two are aimed to facilitate store management to the librarians.

In terms of library assistance, a few examples can be found in the literature. So, students at Aberystwyth University developed Hugh [1], an artificially intelligent robot designed to take verbal requests, work out from its digital catalogue where the hard copy is, and lead students to the relevant bookshelf. Additionally, some libraries have incorporated robot systems with the purpose of introducing technology to children. For instance, this is the case of Roanoke County library 1 that uses a Pepper robot as a teaching tool for the community; the Longmont Library that integrates BiBli2 to communicate with and introduce robotics to kids with autism; or the Guelph Public Library counts with Beepbot3 to help kids learn life skills such as socialization, reading, spelling, math and coding.

From a librarian point of view, one of the most critical issues is the maintenance of the order of the books since it is time-consuming and never ending as materials are continuously moved. In fact, a book outside its site could create a considerable delay between being requested and retrieved. To keep complexity of inventory management, several libraries as that of the University of Chicago have re-structured their space. That is, libraries have been redesigned such that no traditional bookshelves are present. Instead, a massive underground storage is managed by bot librarians to put each returned book in its corresponding place. Note that this robot structure is also used to retrieve and provide the user with the requested books in a few minutes.

Alternatively, Radio Frequency Identification (RFID) systems can be used to quickly scan shelves using handheld RFID readers capable of automatically registering when a book is misplaced. In this sense, AuRoSS (Autonomous Robotic Shelf Scanning) was developed [2]. This autonomous robot navigates through the Singapore's National Library during nights to scan the RFID tags embedded in each book and provide librarians with a report of the missing and misplaced books, who act accordingly. Along this line, several solutions have been also proposed such as Robbie [3]; AdvanRobot [4]; or TORY [5], a commercial solution for RFID inventory robot.

[1] https://www.wsls.com/news/virginia/roanoke/pepper-the-humanoid-robot-comes-to-roanoke-county-public-library

[2] https://www.thedenverchannel.com/thenow/meet-bibli-a-robot-thats-teaching-autistic-kids-valuable-communication-skills

[3] https://globalnews.ca/news/5084963/guelph-library-robot/

Going a step further, autonomous robot systems may be used for delivering books. However, this is still an unexplored research field. Some attempts are robots like Isaac at the National Library of Australia4, that coexist with human staff in the underground storage to quickly provide the requested materials to the user. In this paper, we present the UJI librarian robot, an autonomous system assisting users in book delivery from some book information introduced in the digital catalogue and firstly introduced in [6]. So, after the usual book web search, the book code is sent to the robot system and, from that information, the robot is able to navigate to the corresponding bookshelf, search the book, extract it from the bookshelf and deliver to the user in the library desk.

System Description

As mentioned above, the user request through the digital library catalogue triggers the robot work flow. Broadly speaking, the complete system performance could be summarized as follows: a modified digital library catalogue is in charge of extracting the book code, i.e. the signature associated to each book for its classification in the library. This code is necessary to approximately locate the book within the library. From that information, the navigation module plan the better route to get the correct bookshelf from a library map. Once there, the robot searches the required document. When found, the book is extracted and delivered to the user.

With the purpose of properly carrying out these tasks, several software modules have been developed:

- Book code extraction: the library web page has been modified so that a book demand is transparent to the user. So, from a book request by title, author or keyword, the system uses the library catalogue to translate that information into the book signature.
- Robot navigation: in libraries, books are normally grouped by its knowledge area, in such a way that, given a book code, its location can be estimated in terms of building, floor, and bookcase. Note that some parameters must be adapted to properly determine the book location when a new library is considered, although the rest of modules will remain the same.
- Vision module: with the aim to read and compare book codes, a vision module is required. For that, the white book labels are firstly segmented and located in the image. These *tags* are sent to the OCR module to read the identification codes.
- Book localization: when the robot reaches the goal bookcase, it starts the book search. Firstly, the robot checks the bookcase by analyzing the first-row books. If correct, the search process continues determining the correct module based on the books on the last bookshelf. Following a similar process, the bookshelf row is established and finally, a linear search allows the system to find the book or to warn its missclassification.

[4] https://www.abc.net.au/news/2018-08-17/robot-couriers-set-efficiency-in-motion-at-national-library/10118356

- Book grasping: the next step is to grasp the goal book. At this point, two different grippers were considered (see Figure 1). At the early stage, a parallel jaw gripper was used. In this case, the left *nail*, that was longer that the right one, is inserted first into the separation between books. Then, the second fingertip is introduced and, after closing both fingertips to hold the book, the manipulator extracts the book from the bookshelf. In our second version, a Barrett hand was used. In this case, the book is extracted by imitating human gestures as shown in Figure 1.
- Book delivery: the book is finally delivered to the user.
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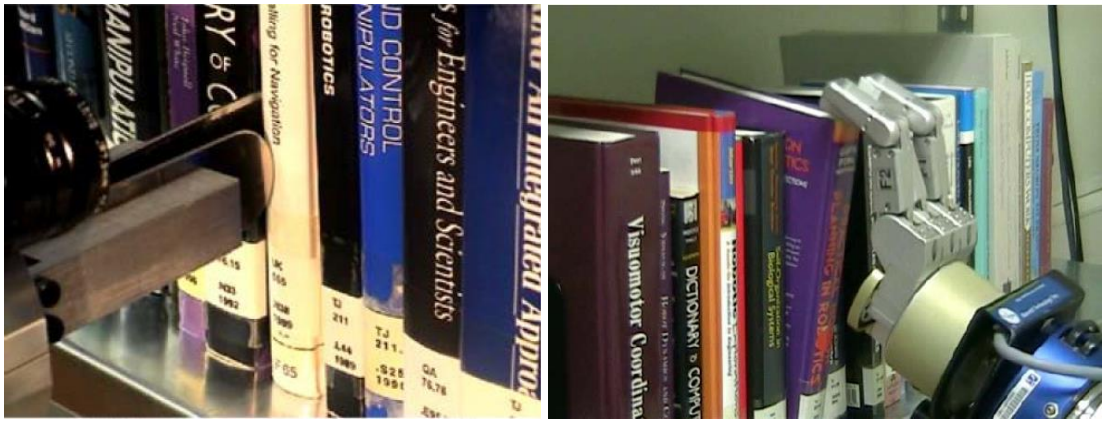

Figure 1. Book grasping based on the considered robotic gripper: parallel jaw (left) and Barrett hand (right)

Hardware

Keeping these tasks in mind, the robotic platform was designed accordingly (see Figure 2) such that:

- A mobile platform to autonomous move around the library. In particular, the ActivMedia PowerBot has been used since it can load up to 100 Kg, which is enough to carry the robot arm and the uninterruptible power supply (UPS) system. This system is equipped with sonar sensors and bumpers for obstacle detection and safe navigation.
- A manipulator to extract and grasp a book. In this case, a PA-10 manipulator and its controller are mounted on the PowerBot mobile robot.
- A stereo camera to locate the books in the library.
- A robotic gripper to grasp the required book. In particular, two different systems were tested: a parallel jaw gripper and a Barrett hand. Note that this change only affected to the book extraction module, since the process must be adapted to the gripper in use.

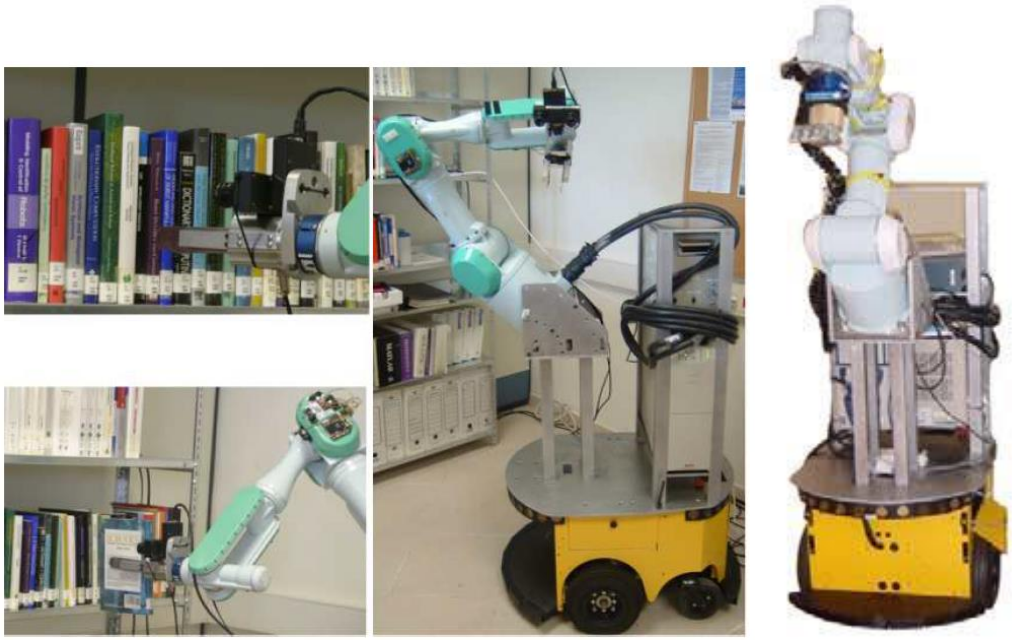

Figure 2. The UJI Librarian robot: first prototype (left) and second prototype (right)

Conclusions

A review of the literature highlights the interest taken in library automation, especially in the field of the inventory and book location. The proposed solutions go from rebuilding the library, to require human action to complete the task. In this context, we propose the *UJI librarian robot*, an autonomous system aimed to assist users in book delivery from some book information. So, the user just interacts with the digital catalogue by introducing some information about the book of interest. This search feeds the robot with the book code and, from that data, the robot estimates the bookshelf, locates the book within it, extracts the book and delivers it to the user. Note that all the implemented modules could be also used for inventorying and locating all the materials in a library without the need of installing any additional infrastructure.

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