MOTION DESIGN OF BEHAVIOR COMPONENTS IN REMOTE BOOK BROWSING ROBOT SYSTEM

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Abstract

In this research, we are developing a system for browsing books from remote places through the Internet by means of the teleoperation of a mobile robot. In the process of developing this system, we firstly designed and built a prototype of a mobile robot, specially equipped for the accomplishment of browsing determined books, which is mainly categorized by 3 basic goals: (1) picking up the book by using a manipulator, (2) opening the book and (3) turning pages by a developed browsing device. Likewise, this paper also describes the planning method for book browsing operation in the environment of a general library, and summarize some considerations about the system.

keywords : *Remote book browsing, Teleprecense, Human-Robot interaction, Mobile manipulator*

1 Introduction

In the modern times, remote human interaction and object teleoperation are becoming a huge necessity for increasing the means of information access and exchange of knowlegde for the benefit of human life. Our purpose in this paper is to explain some accomplished result in the realization of a system able to access objects located at remote places, by the integration of Internet technologies and robotic engineering developments such as mobile robots[1][2][3]. As a particular case, when we human, wish to interact physically with remote objects, or if it is the case with other humans then such engineering developments take an important role in order to success with those given tasks. In addition, the realization of such teleoperational applications by a mobile robot would enlarge greatly the extention of mobile robot's use in our everyday life scenes.

We have developed the mobile manipulator of the book browsing equipment, which includes a system for measuring the posture of the book[4][5]. An overview of the remote book browsing is illustrated in Figure 1 and their general tasks are listed as follows:

1. The user selects the target bibliographic reference category.
2. The robot moves toward the target shelf, meanwhile it is able to avoid obstacles.

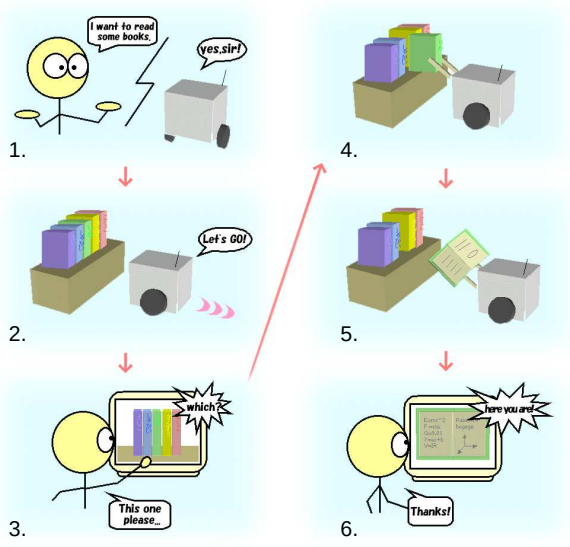

Figure 1: *Concept of remote book browsing system using a mobile robot: 1.selecting a book category, 2.robot navigation, 3.user book selection, 4.picking up, 5.book opening, 6.telebook reading.*

3. The user selects visually a book on the conputer monitor from the previously sent image (by the robot).
4. The manipulator pulls out the selected target book through user commands.
5. The robot opens the book and turns its pages.
6. Robot transmits images of the current page to the user making possible a tele book viewing.

This paper focuses on the description of each of the required tasks needed for remote book browsing, as well as, the explanation of basic motion design of behavior components in the environment of a general library.

2 System structure

In this system, our aim is to build a mobile robot able to carrying out the overall operation of a general book consulting, beginning from the shelf extraction of a book, turning over pages and browsing the books in an all-in-one system. The locomotion platform of the

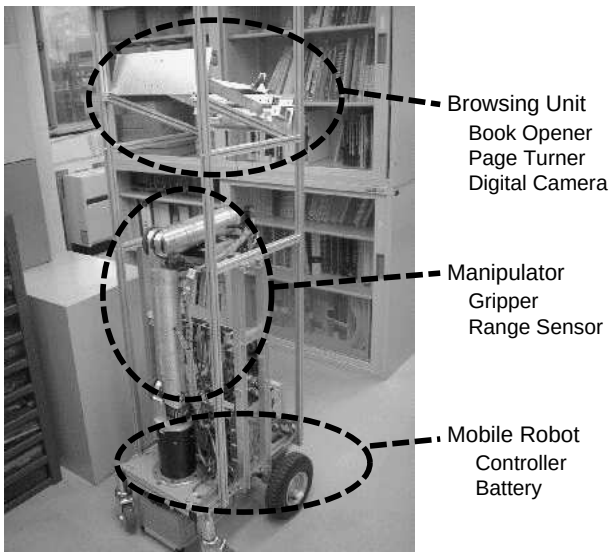

Figure 2: *Integrated book browsing robot.*

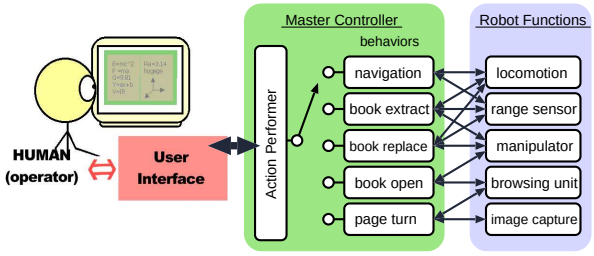

Figure 3: *Structure of the software*

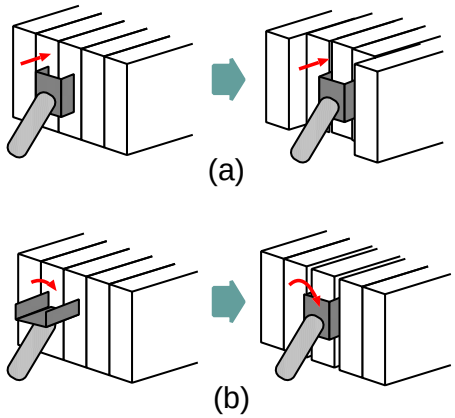

Figure 4: *Method for book grasping. (a) A vertical modality push the book into an undesirable situation. (b) Entering an inclined trajectory.*

autonomous mobile robot is equipped with a manipulator to grasp books and a mechanical browsing unit for opening and viewing its content. The control system and the set of commands which operate the actuators and the interface for establishing communication, were also built.

2.1 Hardware

The robotic hand was designed in order to extract and insert books and has been fitted at the extremity of the manipulator. Low cost components and simple mechanical structures were designed and adapted to the robot. Such is the case of the device for opening/closing books, and one device for turning over the pages (Figure 2).

2.2 Software

The developed robotic system software is basically compounded by 3 main layers such as (1) robot functions, (2) the master control and (3) the graphical user interface. See Figure 3.

The Robot Functions Layer operates in the lowest level of the 3 layers. In this layer is processed the monitoring of signal sensors as well as the motion control functions. These functions are performed according to the decisions of the Master Controller. The recognition process of book's posture and the control process of actuators are included in this layer considering each one as a concurrent function. The Master Controll Layer is general control performed in the note PC (carried on the mobile robot). In this layer, the action planner determines the next action-state according to the robot's situation, and also it is able to command the function modules. The User Interface is a layer whereby the user can see the information sent back by the robot and notifies to the robot about the human requests.

The teleoperation interface provide to the user a selector-based function for application of some motion behaviors. The robot software system consists of a set of programs for different actions of the robot. Each action-program is invoked by a corresponding behavior already selected by the user. With such software system thus, the robot is able to change flexibly its behavior according to the teleoperator requests.

3 Motion Design

This chapter explains the designed motions about three mainly behavior components.

3.1 Extraction of the book

We noticed that this task implies some accurate and special considerations. For such reason we approached several implementations in order to evaluate the more suitable performance. For instance, the robot's hand has to displace in front of the target book, which has been placed between other books. Subsequently, the hand is able to open itself adequately

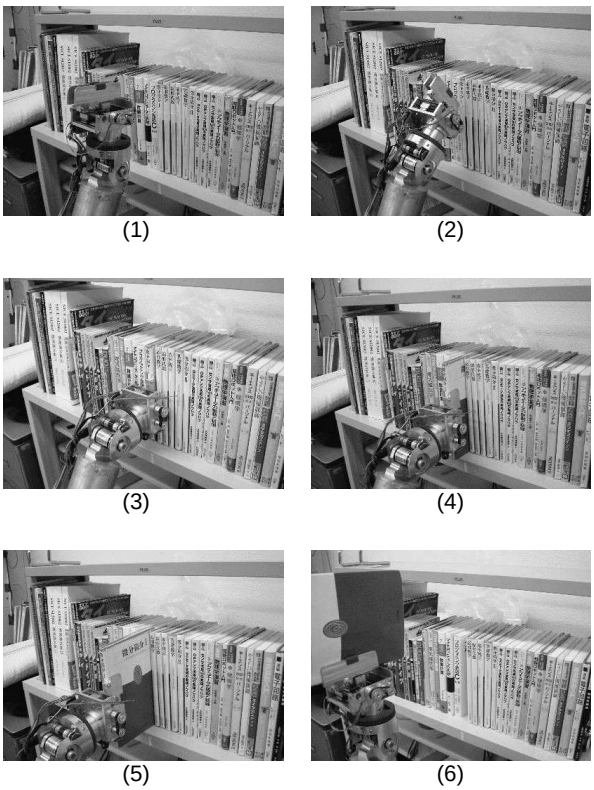

Figure 5: *Scenes of extracting.*

enough according to the book's thickness. In other words, the hand is able to make way into the interior of the shelf horizontaly between the boundaries of each book. However, this action frequently fails and hopefully 50% of the times successes, because the robot-hand pushes both side-books moving the target book within them in such way that it is not possible to control the desired position, like in Figure 4-(a). Some methods were implemented for overcoming such problem, but among them, the method of swinging down the gripper from the upper side (Figure 4-(b)) was the best and had the highest fault tolerance rate. The sequence for picking up a book is shown below, and the scenes of extracting it are shown in Figure 5.

1. The robot turns the manipulator to the direction of the bookshelf. If a user wishes to change the viewpoint, then the robotic hand's position will be moved vertically and horizontally (manipulator's movements).
2. The robot takes an image of the bookshelf, and looks for the posture of each book using its range sensor.
3. The hand is moved in front of the target book, and the hand posture is leaned into the same angle (Figure 5-(1)).

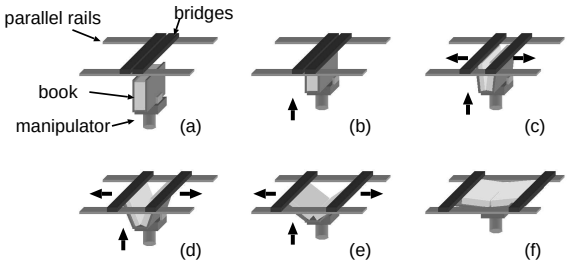

Figure 6: *Structure of book opening/closing device.*

4. Then, the gripper is widen proportionally to the width of the targeted book.
5. The wrist is rotated 90 degrees, and the gripper is swung down and inserted in both sides of a book (Figure 5-(2),(3)).
6. Finally, the hand pulls the gripper out (Figure 5-(4)-(6)).

The gripper must approach to the book within 2mm of accuracy in order to position by itself and grab smoothly the book. The developed manipulator can operate within 1mm error range and the accuracy of our vision sensor is 1mm[5], so this slove the problem of the 2mm accuracy required and enable the system to grab books from the shelf.

3.2 Opening/closing a book

The structure of the book opening/closing device is shown in Figure 6. This equipment consists of two set of parallel bridges and perpendicularly inside of two parallel rails. The edges of the bridges are softly nailed in a way that once separated, they can open a book which previously has been located beneath the nailed parts. Those bridges are able to slide from the center to the right and left, and symmetrically to move close and away from each other. The procedure of opening a book is described below:

1. Firstly, the edges of the book held by the mechanical hand are pushed until they reach the intersection of the two bridges in the center of the device (Figure 6-(a),(b)).
2. When the book reach the bridges, the limit is sensed by a touch sensor.
3. The next step is to open the gripper, here the hand pushes forward the book, and it holds inside the nailed parts of the bridges while those ones are opening gradually synchronized in accordance to a forwarded movement of the hand (Figure 6-(c)-(f)).

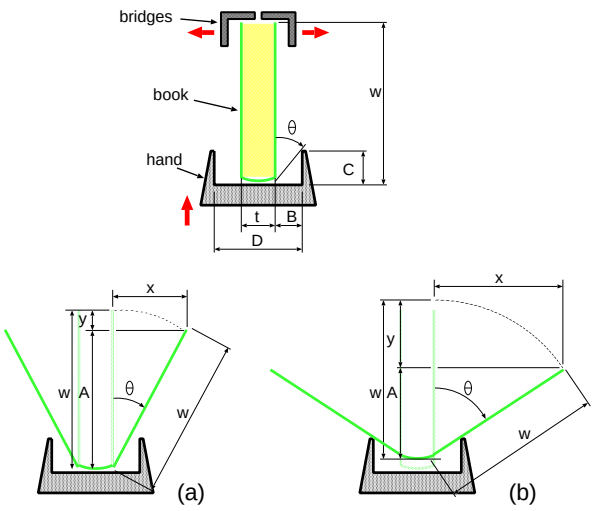

Figure 7: *Opening/closing book design model.*

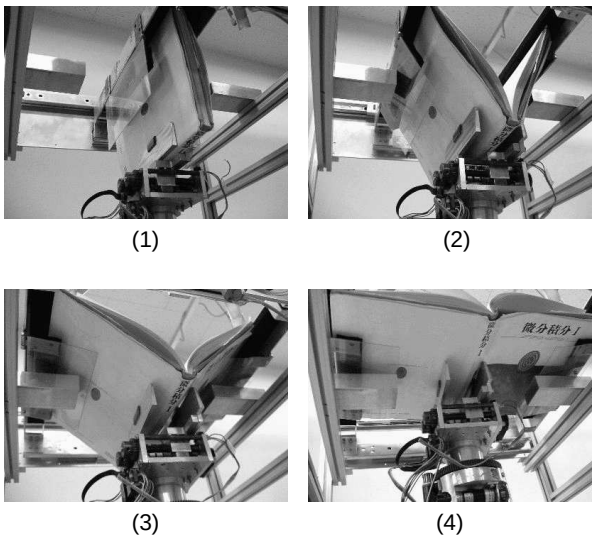

Figure 8: *Scenes of opening a book.*

The position between the equipment and the book when the opening/closing action is performed in Figure 7. The interval of two bridges x can be continuously opened from 0 to $2w$.

As shown in Figure 7-(a), while theta is small, the book touches the bottom of the hand. At this time, the manipulator's extent of movements is calculated by the following formula.

$$y = w - \sqrt{w^2 + x^2} \tag{1}$$

As depicted in Figure 7-(b), while theta is increasing, the back covers will separate from the bottom of the hand and will support the tip of the gripper. In addition, the manipulator's displaced distance is subtracted by lifted distance is represented by the following formula.

$$y' = y + \frac{AB}{x} - C \tag{2}$$

Here, C is the depth of the gripper and is 30mm in our system. A book can be opened by controlling the manipulator's displacement according to this expression. The scenes of opening a book are shown in Figure 8.

3.3 Turning over pages

By observing a human when turning over a book page by means of his hand, we just tried to imitate the motion of such fingerprint. As illustrated in the left side of Figure 9, when we are turning over the pages of a book, our hand thumb generally presses down on the surface of the page to turn over and raises it up slowly, and sliding with smooth friction our fingers towards the book center. We designed the page turning device imitating the above explained process. The device consists of four free links needed for pressing down vertically on the pages and a rotational stand set

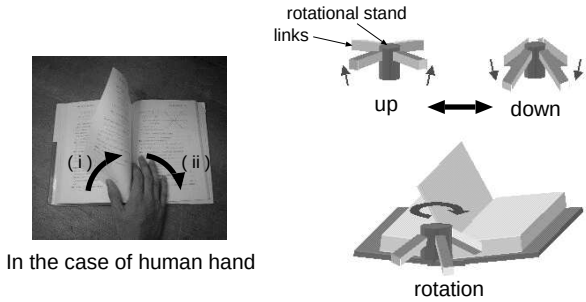

Figure 9: *Structure of page turning device.*

for sliding exerting pressure horizontally the links on the pages beneath, as shown at the right side of Figure 9. One extremity of each link is fixed to the rotational stand by a pin, and the other extremity is free of motion, hanging downward under gravity exertion. The free extremity of each link can be raised and lowered vertically due to an actuator. In addition, those link's extremities are coated by a frictional material to facilitate the sliding of pages. Figure 10-(b),(c) show time-charts of moving links.

1. During the process of turning over a page, all links are lowered and only two links among the four press down simultaneously over the left and right pages of the opened book.
2. Then, those links are slided by rubbing over the surface of the pages by rotating the stand, yielding to the rise of one page, and the left one for clockwise rotation or right-sided page during a counter-clockwise rotation.
3. Because of the stand gradually make to rotate the

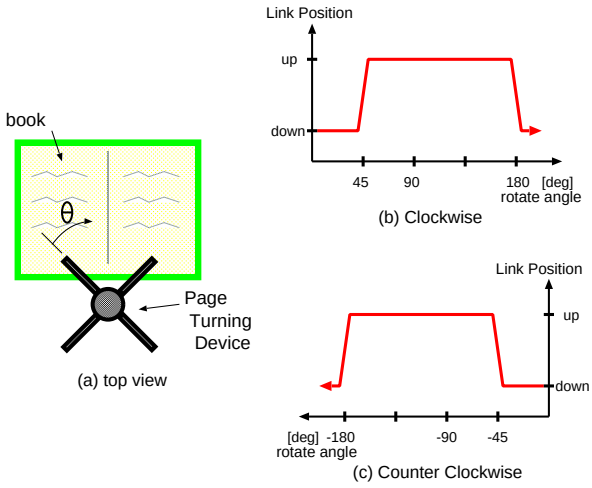

Figure 10: *Timing chart of page turning device. (a) model, (b) turning on the right, (c) turning on the left*

links, the raised page is sandwiched between one sliding link and a third link, which in return just starts for landing on the surface of the following page.

4. Hence, rotating about 180 degrees smoothly, the lowered links on an opened book, eventually result turning a page over another depending of the direction of rotation.

This action endlessly is repeated until the device reaches the page targeted by the teleoperator. The scenes of page turning are shown in Figure 11.

4 Conclusions

In this research, a remote book browsing system has been built in order to use a robot as an access media for a physical interaction with remote objects. The developed system has the capability of grabbing the book selected by an user, opening it and sending images of its opened pages to the remote user in other to provide assistance for telebook consulting.

In this paper, we focussed on the description of each of the required tasks needed for remote book browsing, as well as, the explanation of basic motion design of behavior components in the environment of a general library. As an overall performance of the system, the motion speed of the robot during the navigation mode was about 30 cm/sec and the time for grabbing and opening a selected book was about 30 sec. Likewise, turning over a page requires about 4 sec/sheet. The page turning-over equipment of the experimental system could turn over only one sheet of paper at once. These values will be improved in the future. Furthermore, in order to improve the operability and reliability of remote book browsing, our future works are to solve the following problems.

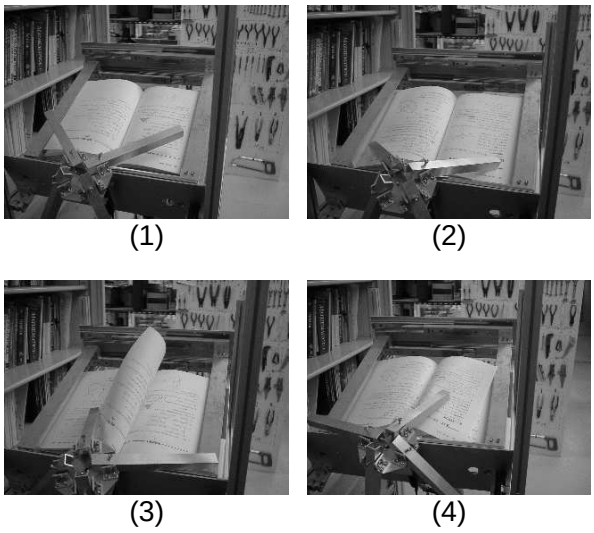

Figure 11: *Scenes of page turning.*

- Improvement of the book recognition.
- Improvement of the browsing task over the process speed.
- Implementation of the GUI more friendly viewable from the WWW.

Finally, we will test and evaluate our system in a real library environment.

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