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A Paper Book Type Input Device for Page Navigation in Digital Documents

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SUMMARY This paper aims to support quick and easy page access in digital documents. We tried to use a paper book as a device to navigate pages for digital documents. Our proposed system allows the users to perform the same interaction as a paper book such as inserting fingers among pages or folding an edge of the page as a dog-ear. Three experiments were conducted to confirm the effectiveness of the proposed system. As a result, we confirmed our proposed system was superior to conventional navigation methods especially in moving back and forth among pages.

key words: *digital document, paper book, input device, page navigation*

1. Introduction

This paper proposes a novel interaction technique and an input device to operate page access in digital documents.

When we read novels or short stories, our reading process is usually serial; that is, we read them sequentially from beginning to end by turning pages one-by-one [1]. However, in a work or academic situation, readers often move back and forth across different pages or different documents [2]. O'Hara and Sellen [3] observed the process of reading scientific articles and reported that readers frequently moved their focus and compared information from different pages of the documents. During the reading, they skimmed articles to grasp the flow of text, moved to previous pages to confirm definitions of terms, and turned forward pages to refer to figures or references. Marshall and Bly [4] observed the behavior of reading magazines in readers' daily life and found that various types of lightweight navigation, such as holding a page in preparation for turning the page and partially turning a page to look at other pages, are frequently performed.

The superiority of paper books in page navigation has been described in various studies [2], [3], [5]. We have also conducted several experiments to investigate the effect of paper books in page navigation. In reading documents with endnotes, when referring to endnotes and returning to the previous parts, the interruption time for turning pages was significantly shorter when reading from paper than when reading from computer displays [6]. With a paper book, participants of the experiments frequently performed reading and turning pages simultaneously; that is, these two different actions overlapped each other temporally. On the other hand, with a computer display, readers had to look away from current reading position to operate a scroll bar or a page-turning button and it made difficult to perform two different actions of reading and page turning simultaneously. Turning pages with paper does not rely only on visual aid. People can turn pages using two hands with tactile feedback as well as audio and visual feedbacks and this enables quick and flexible page turning.

In reading to answer questions from a text manual, participants were able to find answers more quickly when using paper books than when using a tablet PC and a desktop PC [7]. When accessing a certain section from a table of contents, they were able to return to the table of contents in no time because they inserted their finger in this page. People seem to be highly accustomed to access pages in paper books. Therefore, when moving to other pages, they inserted their finger almost unconsciously and this worked as a temporal bookmark to return to the previous page.

When we operate documents in a large display space, clicking windows to switch active documents and dragging windows to arrange documents are important operations and we usually use a mouse as a general-purpose pointing device. However, in tablet PCs, each tablet presents a single document and we do not have to operate windows. In this situation, remaining operation for documents is page access and the easiness to operate accessing pages will become important. To support this, we have explored page access methods for digital documents by learning from the strength and flexibility of page navigation with paper books [8].

2. Related Work

A large number of attempts have been proposed to make page access of digital documents comfortable. XLibris [9], which is a pioneering digital reading device, equipped physical buttons to turn pages to give tactile feedback to readers. Chen et al. [10] developed a dual-display electronic reader which allows readers to turn pages using the gesture to open and close the two display panels.

Attempts to use special bendable devices to turn pages have also been performed [11], [12]. They turn pages and control the speed of page turning according to the degree and direction of the curvature of the bent devices. Additionally, some researches make use of bendable flat sheets to provide an operational feeling like paper sheets [13]–[16]. They can provide folding or twisting gestures by us-

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ing the whole flat panels of the sheets. Furthermore, some attempts provide additional small feather-like bendable objects on tablet PCs and enable turning pages by flipping them [17], [18].

A visualization technique that mimics page-turning of physical books is also implemented as software [19]. It visualizes halfway status of page-turning and gives the look and feel of physical books. Similar visualization techniques are implemented in various e-book applications in tablet PCs by using swipe interaction to turn pages. Lee's smart e-book system provides richer visualization and interaction to handle digital books [20]. It provides visualization to grasp the remaining book length intuitively and allows flipping through multiple pages using multi-finger touch or pressure of fingers.

As we described before, one of the strengths of paper books is that readers can easily move back and forth among different pages and they can compare information of different pages. Some attempts have been proposed to support this situation in e-book applications. They allow giving temporal bookmarks using a finger touching gesture [21], clipping a part of a page and putting it aside of other pages [22], shrinking unfocused parts of documents [23], and viewing two different parts of documents for reading and referencing [24].

To sum up, most previous attempts admit the strength of paper book navigation and implement some features of paper books. However, they have just implemented some aspects of the affordance of physical paper books or resolved some problems of digital book navigation that are supported in paper books. Therefore, their manipulability does not seem to reach the level of paper books.

In this research, we use a paper book itself as a control device to make use of the affordance of physical books for page navigation in digital documents.

3. Proposed System

3.1 Basic Framework

We try to use a paper book itself, not the mimic of paper books, as a device to navigate digital documents. Namely, we use a paper book like a mouse to operate digital documents. In our framework, when we turn a page of the paper book, a page of the active document on the corresponding device is turned. When we turn several pages of the paper book, the same number of pages is turned in the digital document. This framework can allow the same interaction as a paper book such as inserting fingers among pages or folding an edge of the page as a dog-ear.

If the change of an opened page in the paper book is always reflected in a displayed page in a digital document, it may cause a problem that the displayed page is changed against the intention of a user. For example, a page might be unintentionally turned when the user holds the book or passes it to others. Therefore, we introduce two modes called *navigation mode* and *non-navigation mode*. In the

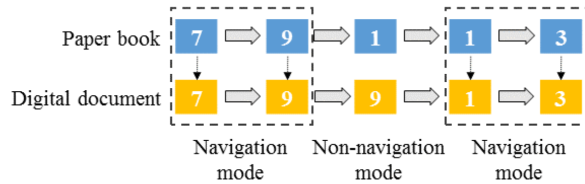

Fig. 1 Page transition in the absolute navigation method

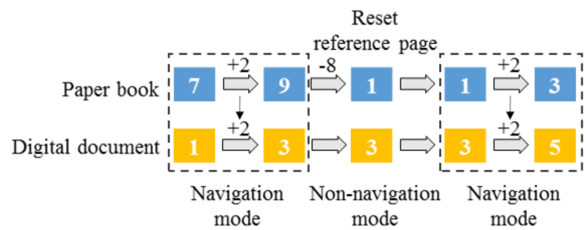

Fig. 2 Page transition in the relative navigation method

navigation mode, the users can turn the pages in the digital document according to the change of an opened page in the paper book. On the other hand, in the non-navigation mode, the change of an opened page in the paper book is not reflected to the displayed page in the digital document.

Next, we can consider two possible methods to control displayed pages in digital documents using a paper book. One is an *absolute navigation method*, which opens the same page in the digital document as the opened page in the paper book while in the navigation mode as shown in Fig. 1. The other is a *relative navigation method*, which turns pages in the digital document based on a variation of the paper book pages as shown in Fig. 2.

In the relative navigation method, the absolute value of the opened page number in the paper book is not important because only the increase or decrease of the opened page number in the paper book is reflected to the displayed page in the digital document. To control the page access in this method, the starting page of the navigation mode is important because this page is used as a reference when calculating the variation of the opened page number in the paper book. Therefore, we call this a *reference page*.

When we tap a certain position on a touch-sensitive screen, the absolute position of the panel is used to access information. We can say the absolute navigation method is similar to the framework of a touch-sensitive screen. On the other hand, when we use a mouse, the position of the mouse does not mean anything for the connected PC. The movement of the mouse is reflected to the position of a cursor on the PC screen. Therefore, we can say the relative navigation method is similar to the framework of a mouse.

The absolute navigation method enables an intuitive operation because the page number of the paper book is directly reflected to the displayed page in the digital document. However, accessible pages are limited depending on the page length of a paper book in this method. For example, users cannot access page 100 and after in a digital document using a paper book of under 100 pages.

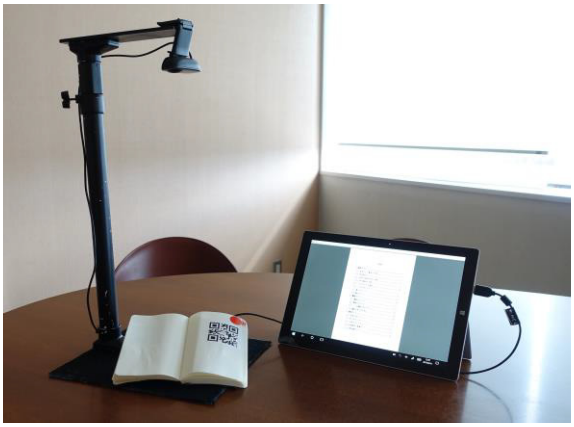

Fig. 3 Prototype of the proposed system

Additionally, when users switch from the non-navigation mode to the navigation mode, this method has a problem that may cause page-turning unintended by the user because the opened page in the paper book is immediately reflected to the displayed page in the digital document at the timing of the mode switching. To prevent this problem, the users must match the opened page number in the paper book with the displayed page number in the digital document before switching to the navigation mode.

On the other hand, in the relative navigation method, accessible pages are not limited because users can reset the reference page. Moreover, the users do not have to adjust the opened page in the paper book before switching to the navigation mode because page-turning does not occur at the timing of the mode switching in this method. Therefore, in this research, we adopt the relative navigation method.

3.2 Implementation

We have built a prototype system called *Navigation Book* based on the basic framework. Navigation Book consists of a paper book, a USB camera, a laptop computer, and a frame for fixing the USB camera as shown in Fig. 3.

The book size is 9.3x14.1 cm and the number of pages is 95. Each page of the paper book contains a QR code in which the page number of the paper book is encoded. QR code size is 4.4x4.4 cm. The page number of the paper book is also printed on each QR code. In this research, the system recognizes the current page number of the paper book using the QR codes. We use a free library called ZXing for recognizing the page number that is encoded in each QR code. When the system detects the change of opened page in the paper book, the system turns pages of the digital document by the same amount of change in the paper book.

In this research, two navigation modes are switched depending on a current location of the paper book. Red circles (2 cm in diameter) arranged on each page of the paper book are used to specify the current location of the paper book. When the red circles are not detected by the camera for a certain period of time, the system resets the reference page that is used for calculating the change amount of page. This behavior corresponds to the action of lifting a mouse up to reset the starting point of mouse movement.

Logicool HD WEBCAM C270 (max frame rate: 30 fps) is used as the USB camera. Navigation Book uses camera images for recognizing the location and opened pages in the paper book. The camera is placed at a height of 56 cm above the desk surface so that the bottom plate area of the frame roughly equals to the field range of the USB camera. Therefore, the system can detect the change of opened page in the paper book when users handle a book on the plate.

The software system is implemented on Surface Pro 3 (Windows 8.1). The Surface Pro 3 is also used as a display for digital documents. Adobe Acrobat Reader DC is used for displaying a digital document on the Surface Pro 3.

4. Evaluation

We conducted following three experiments to confirm the effectiveness of Navigation Book.

- Page access (Experiment 1): Participants must access specified pages on a digital document in a specified order.
- Back-and-forth moving (Experiment 2): Participants must access table of contents and specified section pages one after another.
- Answer finding (Experiment 3): Participants must find answers from a text digital document.

In all experiments, we measured the task completion time. Experiment 1 was conducted to measure the performance of simple page access. Back-and-forth moving is frequently observed in reading academic papers or patents. When reading academic papers, readers must refer to references, figures, or endnotes and go back to the previous text position. Answer finding is frequently observed in work-related reading. According to Adler et al.'s study [1], about 24% of reading in a work situation was reading to answer questions.

4.1 Method

Design and Participants. For the three experiments, the experimental design was a one-way within-subjects design. The independent variable was system condition with four levels: turning pages with a keyboard (Keyboard), turning pages with a mouse (Mouse), turning pages using touch gesture (Touch) and turning pages with Navigation Book (Book).

Participants were 12 people (10 men, 2 women). Their ages were 21-26 years (avg. 23.6). Each had three or more years' experience using PCs. Their corrected visual acuity was better than 14/20. They performed two trials in each condition. The system condition order was counterbalanced to cancel effects of the trial order overall.

Materials and Task. In Experiment 1, we used a PDF document of 50 pages. The task was to access specified pages on a digital document in specified order (e.g. 3→15→26→45).

In Experiment 2, we used a PDF document of 53 pages including a table of contents to section pages. The task was to access the table of contents and specified section pages one after another as shown in Fig. 4.

In Experiment 3, we used a text manual dealing with business manners such as instructions for telephone conversations or orders of precedence. This included a detailed table of contents consisting of 9 chapters and 63 sections. The total length of the documents was 84 pages. Tasks were to search answers from the text manual to fill in the blanks as shown below.

- In a sleeper train, (   ) is a seat of honor.
- The use of a mobile phone while driving a car is prohibited by (   ).

Participants could refer to each question during searching for answers.

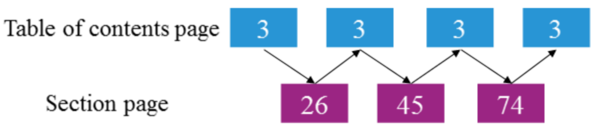

Fig. 4 Page order in Experiment 2

Fig. 5 Snapshot of Navigation Book condition

Environments. Surface Pro 3 (Windows 8.1) was used as a display in all conditions.

In the Keyboard condition, participants used a genuine keyboard for Surface Pro 3. They navigated pages with cursor keys of the keyboard.

In the Mouse condition, they used a three button mouse with a mouse wheel. They dragged a scroll bar or rotated a mouse wheel to turn pages.

In the Touch condition, they navigated pages with a swipe or a tap. When using swipe interaction, inertial scrolling was allowed; that is, when users swipe swiftly, page turning was carried out after the finger was released and the scrolling speed gradually decreased.

In the Book condition, the device of Navigation Book was placed in front of the participant. The display was placed beside the device of Navigation Book as shown in Fig. 5. In other conditions, the display was placed in front of the participant.

Procedure. Before the experiment, participants engaged in 10 min training to familiarize themselves with the operability of each system. At most 4 participants performed the task at the same time in each trial. Therefore, to measure

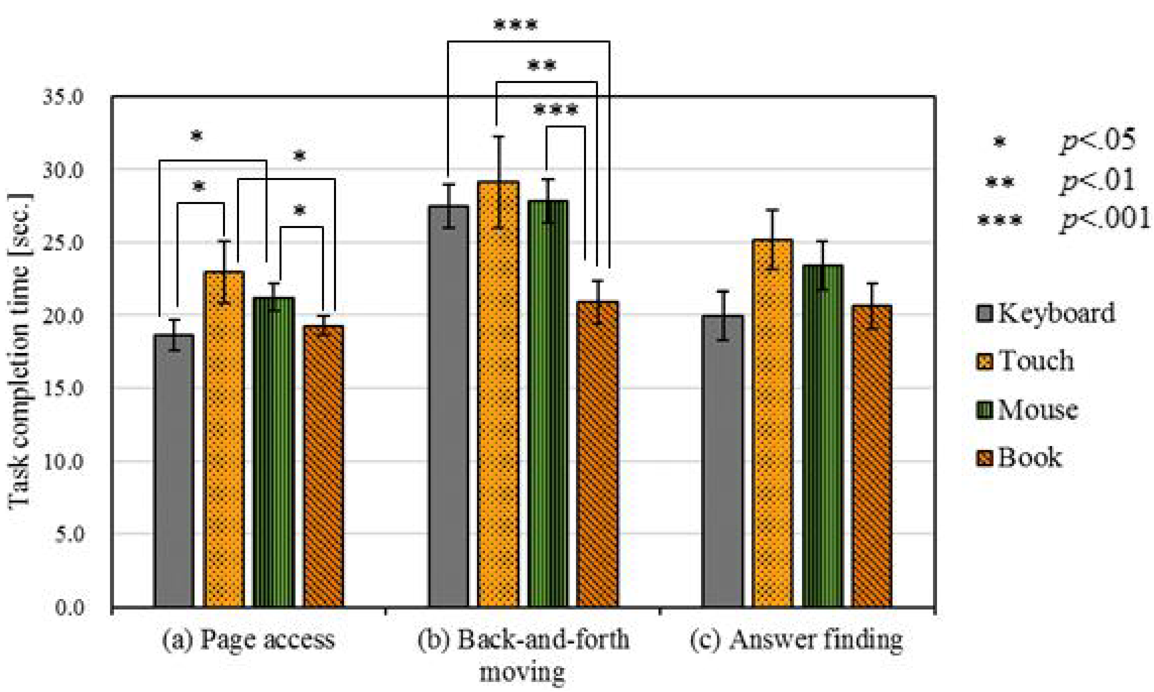

Fig. 6 Task completion time in each experiment

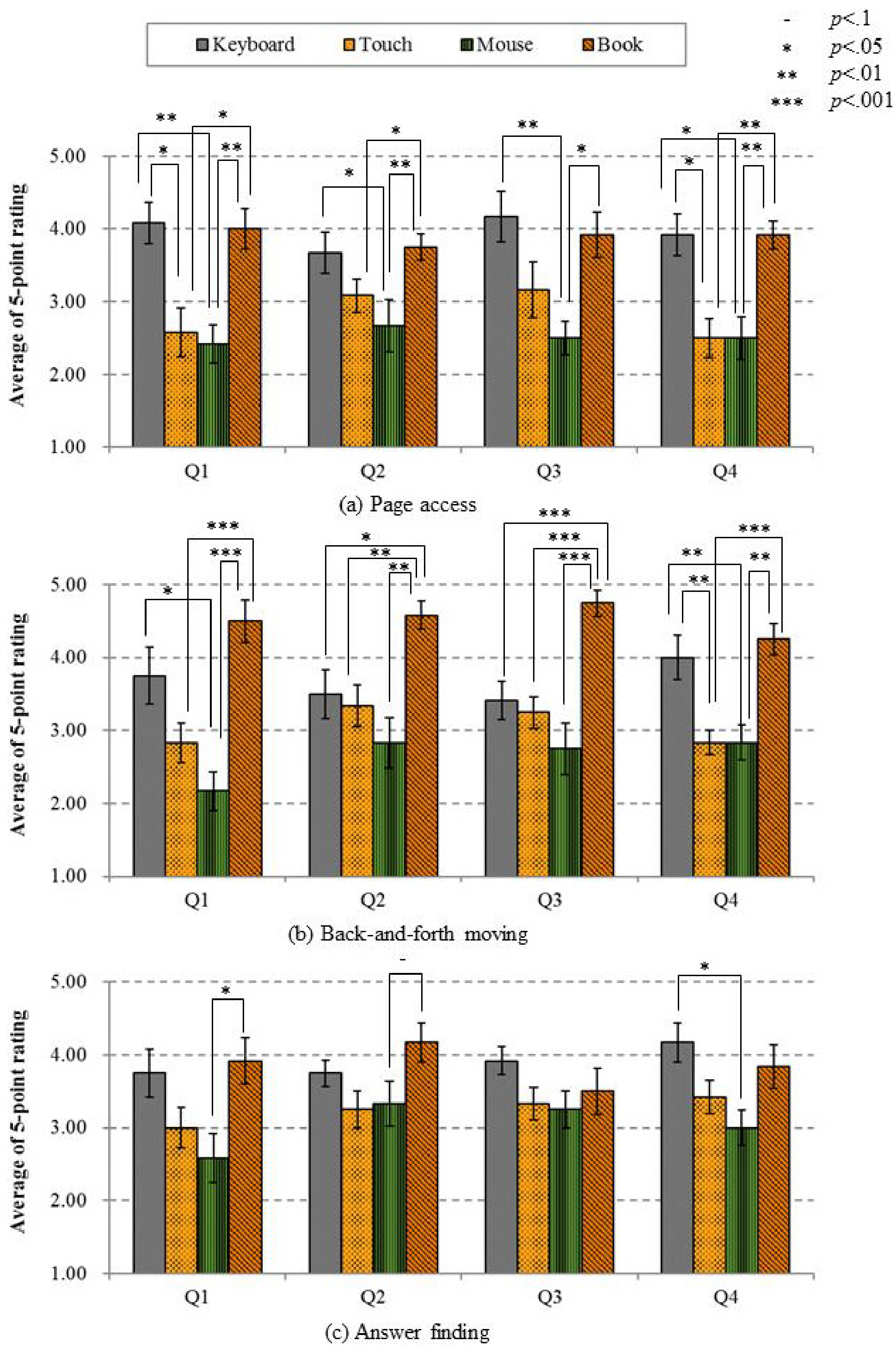

Fig. 7 Results of subject experiments (Q1. Was it comfortable? Q2. Was it convenient? Q3. Were you able to perform the task fast? Q4. Were you able to perform the task precisely?)

the task completion time, participants pushed a start or stop button of a stopwatch by themselves before they start the task and after they finish the task. We asked them to start the task as soon as possible after they push the start button. We also asked them to push the stop button as soon as possible after they finish the task. Moreover, before each trial, we reminded them to push the button to avoid forgetting to push the button before and after the trial.

After all the trials, participants evaluated 4 conditions (Keyboard, Mouse, Touch, and Book) for 4 question items (Q1. Was it comfortable? Q2. Was it convenient? Q3. Were you able to perform the task fast? Q4. Were you able to perform the task precisely?) using a 5-point rating (1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree).

After all tasks were completed, we conducted an interview to ask the impression for each condition.

4.2 Results and Discussion

Figure 6 presents the task completion times in three experiments. The error bar shows plus or minus one standard error from the average. Figure 7 presents the average of the ratings given for each question item. We conducted one-way repeated measures ANOVAs for three experiments. We used Tukey's method as a multiple comparison method.

Experiment 1: Page Access. Figure 6 (a) presents the task completion times in Experiment 1. The results show that the main effect of system conditions was significant ($F(3, 33) = 3.39$, $p < .05$). According to the multiple comparison, the task completion time in the Keyboard and the Book conditions was significantly shorter than in the Touch and the Mouse conditions ($p < .05$). No significant difference was found between the Keyboard condition and the Book condition.

Figure 7 (a) presents the average ratings for each question item in Experiment 1. The average ratings for Q4 in the Keyboard and Book conditions were higher than in the Touch and Mouse conditions. In the Touch and Mouse conditions, participants reported that they could not turn pages in the digital document sometimes even though they intended to do action to turn pages. On the other hand, in the Keyboard condition, participants also reported that they could navigate pages certainly and quickly by continuing to push a key.

In the Book condition, participants reported that Navigation Book was convenient when turning a large number of pages in the digital document. However, they also reported that it was a little troublesome to turn just one page with Navigation Book in comparison with the keyboard because it needs much movement of hands in comparison with the keyboard.

Experiment 2: Back-and-Forth Moving. Figure 6 (b) presents the task completion times in Experiment 2. The results show that the main effect of system conditions was significant ($F(3, 33) = 6.20$, $p < .01$). In this experiment, the task completion time in the Book condition was significantly shorter than in all other conditions ($p < .01$). There was no significant difference between conventional three methods. In the Book condition, participants could perform 24.0%–28.2% faster than in any other conditions.

In addition, the average ratings for all question items in the Book condition were higher than in the Touch and Mouse conditions as shown in Fig. 7 (b). For Q2 and Q3, the average ratings in the Book condition were higher than in the Keyboard condition. From these results, in the Back-and-forth moving experiment, we confirmed Navigation Book was preferred by the participants.

In the Back-and-forth moving experiment, participants inserted their finger in the page of table of contents when they move to a section page. Therefore, after they accessed to the section page, they could quickly return to the table of contents by just one action using their inserted finder as a temporary bookmark. Many participants actually reported the effect of Navigation Book in this point. We consider that this helped participants to navigate quickly in back-and-forth moving tasks.

Several participants expressed their amazing impression for the effect of Navigation Book in this back-and-forth moving experiment. One of them reported that he could perform the task with Navigation Book more than twice as fast as with any other devices. However, as we described above, with Navigation Book, participants could perform merely 24.0%-28.2% faster than with other devices. This indicates that participants felt the effect of Navigation Book better than it really was.

Experiment 3: Answer Finding. Figure 6 (c) presents the task completion times in Experiment 3. In the Answer finding experiment, any significant difference was not found between the four system conditions ($F(3, 33) = 1.73$, *ns*.).

In addition, for Q3 in the subjective evaluation, any significant difference was not found between the four system conditions ($F(3, 33) = 1.25$, *ns*.) as shown in Fig. 7 (c). On the other hand, for Q1, Q2, and Q4, significant differences were found between the conditions.

Several participants reported that they could read text while navigating with Navigation Book even though it was difficult to get information from text while navigating with other devices. This suggests that they could concentrate on reading even while turning pages with Navigation Book.

In the Book condition, when reading a page, participants were often inserting their finger between pages and holding up a page slightly as a preparation for next page turning. Such a proactive action seems to make page turning smooth and minimize the interruption time for page turning. We think this enabled the participants to concentrate on reading without paying much attention to turn pages and promoted getting information while turning pages with Navigation Book.

5. General Discussion and Future Work

In Experiment 1 and 3, the task completion time with Navigation Book was equivalent to the time with a keyboard, which was the fastest in conventional navigation methods. Moreover, in Experiment 2, participants could perform faster when using Navigation Book than when using any other conventional methods. These results show that Navigation Book is superior to conventional navigation methods.

Participants reported that Navigation Book allowed to turn pages using tactile feedback without looking at his or her hand. They also reported Navigation Book allowed the same interaction as usual paper books which we have been accustomed to. Therefore, when using Navigation Book, they could use techniques that are peculiar to the interaction with physical paper books such as inserting fingers to return the previously accessed page or to prepare next page turning.

However, some problems of Navigation Book were also reported by participants. For example, they reported that the system could not recognize the page number sometimes even though the book seems to be opened within the field of the USB camera. We confirmed the system often failed to detect the page number when a page of Navigation Book is tilting or a finger covers over a portion of the QR code. Therefore, we plan to develop a more robust original code or investigate other ways that the system can recognize the page number of a paper book without any code. We also plan to explore a new method to reset the reference page because several participants also reported that the system could not recognize the action to reset the reference page sometimes.

In the case of navigating a digital document with the larger number of pages, the superiority of Navigation Book may become smaller because users need to reset the reference page more frequently. Therefore, although improvement of the method to reset a reference page is also important, it is desirable that the users choose a paper book with the suitable number of pages depending on their navigation behavior so that they can minimize the frequency of resetting the reference pages. Although we provisionally used a paper book with 95 pages in this research, Navigation Book should provide paper books with the larger number of pages if the users frequently access pages in the digital document beyond the page length of the paper book.

Furthermore, several participants reported that they sometimes felt uncomfortable when the page number of the paper book did not correspond to the page number of the digital document. We think that it is not desirable that participants check the page number of the paper book while navigating. We also think such users' behavior will naturally disappear if the operability of Navigation Book is improved by making its size fit to users' hand and providing quick responses of the system.

When reading from a paper book, we usually need to use both hands to open a paper book. This will become a problem in situations that it is difficult to read with both hands such as reading with standing in a train. Typical reading of these situations is serial reading such as reading novels and it is not our main target activity. Our main target is reading with frequent page turning and frequent back-and-forth moving among pages, which is often observed in a work situation [2], [3].

To support such work-related reading effectively, we intend to expand our framework so that it can support annotation during reading. Additionally, we are now exploring the possibility of using Navigation Book as a tangible device of virtual reality or mixed reality and supporting annotation in this framework.

6. Conclusion

We proposed Navigation Book that can navigate pages for digital documents using a paper book. We conducted three experiments to compare the speed of page navigation between four conditions including the condition using Navigation Book. As a result, we confirmed the effectiveness of Navigation Book in page navigation for digital documents. In particular, when moving back and forth between different pages, participants could perform 24.0%–28.2% faster with Navigation Book than with any other methods.

However, some problems of Navigation Book were reported by participants in the experiments. For example, sometimes the system cannot recognize the page number correctly. Therefore, as a future work, we attempt to explore the method to improve the recognition performance for page number. Furthermore, we also attempt to downsize the device of Navigation Book or use a built-in camera of PC.

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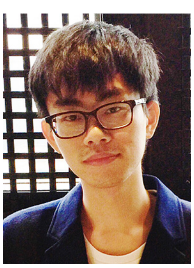

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