FLIPPIN' : Exploring a Paper-based Book UI Design in a Public Space

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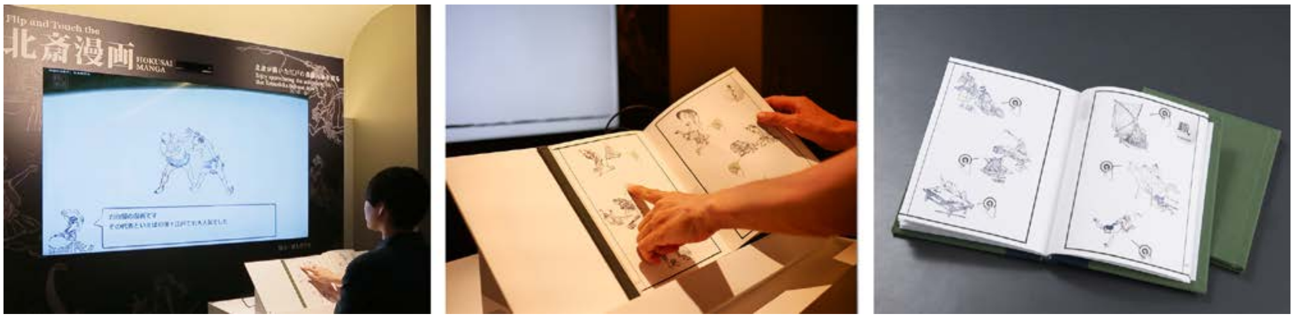

Figure 1a. "Flip and Touch the Hokusai Manga" evaluation exhibition using FLIPPIN' UI system (left); Figure 1b. Touch point operation (center); Figure 1c. FLIPPIN' UI device designed to realize a reading experience comparable to a traditional book (right).

ABSTRACT

Digital information systems are increasingly being used in public spaces such as museums. Such systems should be easily accessible, arouse interest and offer useful information, and be easy to use. We present FLIPPIN' user interface (UI) system, which mimics the look, feel, and usability of traditional books. We explored how the paper-based book UI is designed to improve the usability problems in a public space while creating the prototypes with the aim of introducing Japanese cultural assets and conducting a field evaluation to compare the proposed system to a touch panel UI. The results of evaluation indicated the positive effects of the system, especially in terms of the usability and user's active appreciation derived from a physical book interaction. In addition, we present design guidelines derived from our findings. The suggested design guidelines are expected to facilitate the future development of effective interactive digital information systems in public spaces.

Keywords

Paper computing; book user interface; tangible; digital information system; public space; interaction design

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

CHI 2017, May 06-11, 2017, Denver, CO, USA
© 2017 ACM. ISBN 978-1-4503-4655-9/17/05…$15.00
DOI: http://dx.doi.org/10.1145/3025453.3025981

INTRODUCTION

People increasingly obtain information via digital devices rather than traditional paper-based books. However, digital devices have usability problems, particularly with respect to reading. These problems are caused by a lack of physical book interaction with the device. With e-books (e.g., Amazon's Kindle and Apple's iBook), users interact by swiping and touching the digital display to perform various functions such as moving to the next page, bookmarking or highlighting an important section, and determining their position in the book. With paper-based books, users perform physical operations such as turning pages, folding a page and making notes. In addition, they can determine their reading position by simply looking at the book or touching piled page-papers of the book [1, 2, 3].

The superiority of such physical interactions has been clarified by studies that explore the optimal interaction design of e-books. For example, in a study that compared reading paper and on-line documents, O'Hara et al. found that reading speed and comprehension are superior with a physical book [4]. Liesaputra et al. analyzed the features associated with reading a paper-based book and created a 3D virtual book application with features similar to those of a paper-based book. They found that the usability of a paper-based book was superior to that of an e-book used to read digital documents such as PDF files [5]. Based on these findings, we assume that digital devices that emulate paper-based books may resolve e-book usability problems.

The results of studies that compare the usability of paper-based and digital books have enabled development of a new reading experience by combining the feel and usability of a traditional book with the advantages of digital technologies in terms of information retrieval and flexible representation [6]. Several studies have assumed the use of digital books for reading in a personal space such as a home or classroom and expected to support users' immersive reading for enjoying the depth of content as well as their learning activities [7, 8].

Digital devices that present reading material are also used in public spaces. Such devices are used to present guidebooks, annotation boards, and pamphlets in a public facility, e.g., a museum, and urban areas. The use of such digital information systems has rapidly increased in recent times. In the near future, digital information systems are expected to have a wide range of applications, e.g., interactive guidance systems that use stationary touch panel devices and information systems that use personal mobile devices. However, the following three issues must be considered for information systems in a public space.

Issue 1. How easily can UI devices be accessed or used by all visitors.

In a public space, operating a touch-panel user interface (UI) within a limited period tends to impose an inconvenient level of effort for visitors. As a result, people sometimes leave the facility without engaging the provided information systems.

Issue 2. How the system stimulates user interest via content.

In a public space, information systems are expected to provide both essential and supplemental information. Therefore, such systems should efficiently encourage visitors to find information that is relevant to their interests. However, it is difficult for visitors with various tastes to actively obtain such information within a limited period.

Issue 3. How digital systems are designed to solve the reading usability problem.

When reading an e-book, for example, when using a touch-panel UI, it is difficult to grasp the entire content quickly and know where you are in the book. In a public space, this usability problem is notable because the number of pages in a virtual book or the amount of hyper-text content can increase due to the presentation capabilities of digital devices, and many visitors will not spend the time required to find the desired information.

We expect that the usability of traditional paper books will help solve the e-book usability problem in public spaces. With respect to studies targeting applications in public spaces, their paper-based UI devices play crucial roles in digital information system in a public space, e.g., art exhibition using books [9] or posters [10] in a museum. However, few studies have targeted public space applications.

Thus, to address these issues, we examine the design of a paper-based book UI for information systems in public spaces. We created prototype systems, evaluated them in a field, and attempted to create design guidelines for future information systems in public spaces.

PREVIOUS WORKS

We focus on the usability of paper-based books in digital device. The challenge is to enable unobtrusive paper-based input sensing while preserving the lightweight, feel of paper and operational stability, thereby enabling effective interaction between users and the content using a paper-based UI device.

Regarding sensing techniques for turning pages, several studies have investigated the possibility of embedding soft sensors and electronics in paper. Watanabe et al analyzed reader's paging actions and developed an interface system by attaching a light-dependent resistor (LDR) and a bend sensor to each sheet [3]. This system realized feedback by sensing a subtle bending when turning pages of a book. Back et al. adopted the method of reading radio frequency identification (RFID) tags on each page of the exhibition installation "Listen Reader" [9]. This novel technique enabled the device to work without a battery. However, this method of attaching an electronic component to each page is unsuitable for a book comprising many pages even though these components are inexpensive. Several studies have adopted Augmented Reality (AR) techniques, e.g., reading an AR marker printed on a page [8, 11, 12]. Although such methods constrain a user's reading-environment conditions, such as device position and lighting, it has the advantage of being easy to implement on books because it is only necessary to print a marker on each page. Regarding the ease of implementation, there are methods for printing electronic circuits onto pages using conductive ink [7, 13, 14]. Though simply sensing and actuation mechanism only are built at this time, these methods allow to implement on books by printing or drawing the wiring patterns.

In addition, several studies have examined information presentation methods using a paper-based book UI. An information presentation method where the user operates a book UI and images or text are projected onto its pages or the reading environment has been used [15, 16, 17]. This method enables users to see superimposed book information and projected content. However, this method imposes some limitations on the environmental lighting and viewer position. In addition, liquid-crystal display (LCD) systems have been used [18]. Such systems expand presentation environment possibilities; however, the user is forced to view information in a book and a display device simultaneously. Figueiredo et al. created systems that comprise a display device and an adjacent book UI device, and they clarified the roles of each device by outputting synchronized content to both devices [19].

DESIGN

Field configuration and limitations

We selected the Knowledge Capital Association's "ACTIVE Lab." in the Grand Front Osaka shopping mall near Osaka station [20] (Figure 2) for our evaluation. The exhibition facility comprises 12 areas and introduces new technologies and activities sponsored by corporations, universities and other institutions in a way that is fun and easy to understand for everyone. More than 700,000 people visit the lab each year, with an average of approximately 1,900 visitors per day. We conducted the evaluation in an area where artwork and cultural assets are introduced using near-future media.

The advantages of this location are as follows. (1) This is a public space. A variety of visitors attend because admission is free and the facility is located near hotels and Osaka station. (2) This facility allows research to be conducted; thus, it is easy to collect data from interviews, observations, and user-behavior logs using camera-based sensors.

However, the following constraints exist. (1) The system should be designed such that users can operate it without instruction. (2) The hours of operation are from 10 AM to 9 PM, seven days a week, and the evaluation period is expected to last from April 15, 2016 to March, 2017. Therefore, the durability and robustness of the exhibition apparatus should be appropriate because many visitors attend this location. (3) There is limited floor space (2.5 m × 2.5 m) and lighting conditions should not interfere with nearby exhibitions. We exhibit Japanese cultural assets to raises awareness of Japanese culture. Note that we target adults in terms of stakeholder requirements.

Figure 2. Toppan Printing Booth in "ACTIVE Lab." (The Grand Front Osaka).

Content configuration and limitations

We chose to exhibit *the Hokusai Manga*, which is a collection of sketches of various subjects by Japanese artist Katsushika Hokusai (1760–1849) (Figure 3). *The Hokusai Manga*, which comprises nearly 4,000 sketches in 15 volumes, was one of the best-selling publications at the time. *The Hokusai Manga* is considered to be the Edo period encyclopedia. Hokusai's influence stretched to western contemporaries. A more direct influence was "Japonism" in 19th century Europe. We selected *the Hokusai Manga* because it is available in high-quality digital form and the content can be edited flexibly.

The exhibition's purpose is to introduce visitors to *the Hokusai Manga*, which includes a variety of drawings and various woodblock printing techniques in small sketches.

Figure3. "The Hokusai Manga" by Katsushika Hokusai, from the Uragami collection.

FLIPPIN' design

We considered four design specifications. The first is to design a system with which the user interacts with the content on an LCD using a book UI device to represent Hokusai's precise drawing under bright lighting conditions, enable the sharing of information among multiple users, and attract the interest of visitors near the exhibition.

The second is to assign the roles of the book UI device and the display device. The book UI device is a controller that operates the software. In addition, the book UI guides the reading experience based on user interest. The display device visualizes various operations, such as switching sketches, scaling, and providing additional information about sketches. We assign these roles to each device to avoid user confusion while appreciating the content.

The third is to set the basic manipulations of the book UI, i.e., "flipping pages" and "touching the touch-sign on paper" to mimic how a real book is read compared to the swipe and touch operations of a touch-panel UI.

The fourth is to reproduce the usability of a paper-based book while preserving the system's operational stability and robustness. In consideration of previous studies [7, 8, 9, 13], we adopted the following implementation methods: (1) a page-sensing function embedded in the book device that does not require radio frequency (RF) or camera-based recognition technologies to enhance the robustness of the UI; (2) a wiring and sensing-pad pattern on paper using a thin conductive film or conductive ink to retain the look and feel of a real book.

Additionally, our paper-based book UI system was named FLIPPIN'.

PROTOTYPE

System configuration

The exhibition-installation system was named *Flip and Touch the Hokusai Manga*. It comprises an 80-inch LCD (SHARP PN-H801: resolution, 3,840 × 2,160 pixels), a camera sensor (Microsoft Kinect v2), a PC (HP Z840) with the content application (developed with Unity 3D 5.3 in wireless communications) installed on its hard drive, and FLIPPIN' UI device (Figure 4). This device is operated by flipping pages or touching specified points on a page, and the input signals are sent to the content application. Then, the application displays enlarged images of sketches or guidance information. Simultaneously, to collect the log data, the users' behavior is recorded frame-by-frame using Kinect.

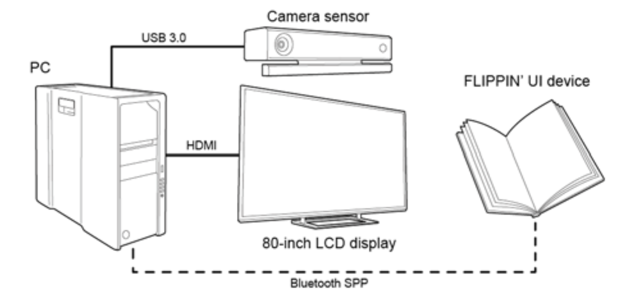

Figure 4. "Flip and Touch the Hokusai Manga" System Configuration.

FLIPPIN' UI device configuration

We implemented and bound FLIPPIN' UI device in the following way. Electronic components such as an Arduino microcontroller, a capacitance touch-sensor controller (MPR121 × 4), an accelerometer module, a Bluetooth module (RN-42), and a Li–Po battery were integrated into the inside of the face cover (Figure 5). Sensor pads and wiring patterns were printed on each page using conductive ink (Agic). For page detection, the sensor controllers detect the variation of capacitance as sensor pads come closer to each other, and the PC application determines whether the page opens or closes according to the resulting values.

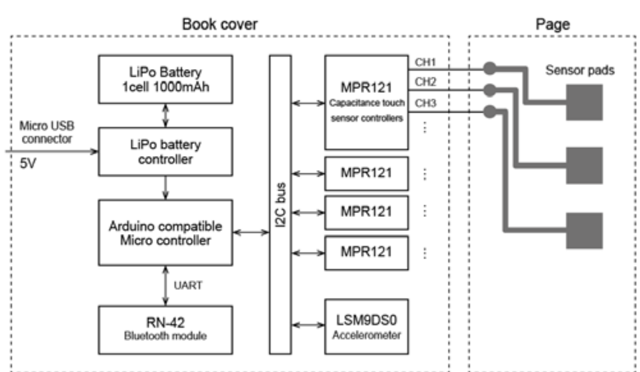

Figure5. "FLIPPIN'" System Configuration.

Each page has a dual-layer structure comprising a conductive-ink-dedicated paper for electronic wiring and a Japanese paper for printing content such that the electronic wiring pattern does not affect the content on the pages (Figure 6). The reason for using Japanese paper is to provide a soft, slightly rough feel similar to a real page of *the Hokusai Manga*. In this way, FLIPPIN' UI device was bound with 22 pages (Figure 1c).

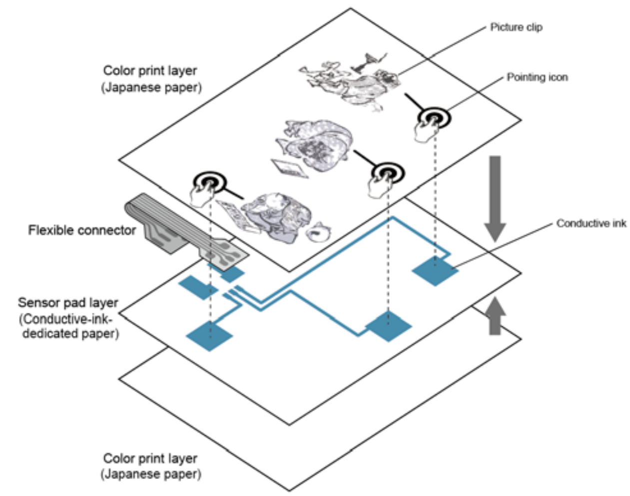

Figure 6. Wiring on a paper by conductive ink.

The content configuration

The content of *Flip and Touch the Hokusai Manga* comprises the following three sections. Section 1 offers commentary on how to operate the book, who Katsushika Hokusai was, and the nature of *the Hokusai Manga*. Section 2 presents the Manga (sketch) collection, which comprises 66 selected sketches classified into categories such as jobs, daily life, eating, and animals. Each category comprises 6 sketches in facing pages. The user turns a page of the Manga collection. Then, 8 or 10 sketches including 6 sketches printed on FLIPPIN' UI device are displayed on the large display in front of him/her. The user touches a pointing icon on the page. Then, the sketch is enlarged, animated with sound effects and additional information is presented on the display. Section 3 presents a quiz game in which silhouettes of images in the sketches are presented, and the user must match these to the corresponding sketch in Section 2.

Prototype 1

We created three prototypes with different design patterns to explore the design of a presentation installation using a book UI system.

In Prototype 1, the content on the display progresses with the content of the sections based on a preset time. Prototype 1 was designed so that users could experience all sections. In addition, we expected to gradually stimulate user interest according to the order of all sections.

The system flow of Prototype 1 is as follows (Figure 7). First, the user moves in front of the exhibition and a commentary movie about *the Hokusai Manga* is played automatically on the display. Second, FLIPPIN' UI device is picked up and an instructional video is played. Third, the Manga collection starts to play, and the user freely appreciates *the Hokusai Manga* for 2 minutes. Fourth, two silhouette-matching questions are asked in a quiz game.

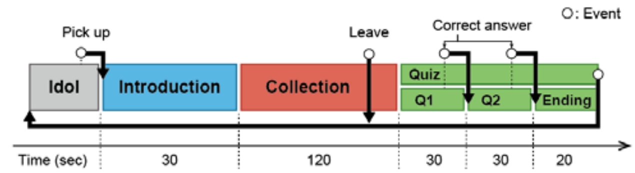

Figure 7. System flow of Prototype 1.

Prototype 2

Prototype 2 was designed so that users could access each section freely by turning pages to experience the content at their pace according to their interests, which was expected to encourage appreciation of the content.

The system flow of Prototype 2 is as follows (Figure 8). FLIPPIN' UI device in which the content is edited, including the commentary, Manga collection, and quiz sections, is picked up, and the title is shown on the display device. In the introduction section, the user reads the commentary on FLIPPIN' UI device. If the user touches a pointing icon in the commentary, additional information (such as Hokusai's chronology table and sketches) is displayed on the display device. In the collection section, in response to the user's turning of pages or touching of an icon, the categories of sketches is changed, and the selected sketch is enlarged and moved with additional information on the display. Furthermore, if the user turns the quiz section page and touches an icon, then a question appears on the display.

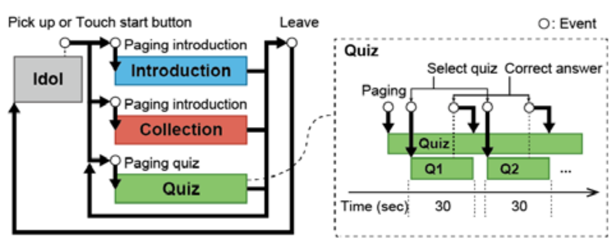

Figure 8. System flow of Prototypes 2 and 3.

Prototype 3

Prototype 3 was designed to compare the usability of physical paging using FLIPPIN' UI device and swipe paging using a touch-panel UI device (GeChic on-Lap, 15 inch) (Figure 9). We expected physical paging to be superior to swipe paging. The virtual book application installed on a PC (HP ZBook 15) for the touch-panel UI.

This virtual book was edited the same as that of the content of the book in Prototype 2. The system flow of Prototype 3 is shown in Figure 8. In Prototype 3, flipping and touching operation in Prototype 1 and 2 replaces swiping and touching operation on a touch-panel display.

Figure 9. Touch-panel UI device and Prototype 3 content.

EVALUATION

Method

Focused evaluation of FLIPPIN' was conducted on July 28 and 29, 2016; August 13 and 14, 2016; and September 3 and 4, 2016, at the Grand Front Osaka, ACTIVE Lab. The purpose of this evaluation was to evaluate general users' experiences of using FLIPPIN' (including the touch-panel UI system of Prototype 3) and to acquire design insights. We used the previously described three prototypes for this evaluation.

The subjects of this evaluation included all visitors who came to our booth at the ACTIVE Lab. They were not informed that they were participating in an evaluation during their experience of using FLIPPIN'; however, the people who were interviewed were made aware of their participation.

Two types of log data were acquired: the operational log of the users operating FLIPPIN' and the behavioral data obtained from the users around and within the booth. The first dataset includes the number of users, duration of their experience, number of paging, number of pointing, duration spent on each page, and duration spent on each section. The second dataset includes participation ratios. If a person entered a certain area and Kinect detected his/her body, the system counts the person as a user. Based on the number of recognized persons and the number of users as per the operative log data, the system calculates the ratio of participation.

We observed the users who had experienced FLIPPIN'. The method of observation was semi-constructive and included factors such as sex, external characteristics, age, behavior, facial expression, comments, the scale of watching between the main display and the book interface, and the scale of interest between the system and the contents. The same two persons observed the participants during the evaluation.

We obtained consent and conducted interviews with users who experienced FLIPPIN' for more than 1 minute. The interview method was semi-constructive and included several factors, such as age, occupation, nationality, knowledge of the content, proficiency with IT devices (e.g., tablets and smartphones), a detailed explanation about their behaviors, facial expressions and comments during the experience, negative and positive opinions about the UI and user experience, the ratio between focusing on the main display and the book interface, and changes in interest in the content before and after FLIPPIN' experience. Note that the same interviewer conducted all interviews.

The results of evaluation

In total, there were 161 users for Prototype 1, 242 for Prototype 2, and 183 for Prototype 3. We conducted observations for 41 groups and 84 users, 34 groups and 73 users, and 62 groups and 104 users for Prototype 1, 2, and 3, respectively and then interviewed 8 groups and 15 users, 10 groups and 21 users, and 4 groups and 8 users for Prototype 1, 2, and 3. In this case, a "group" means a unit of the users who simultaneously experienced FLIPPIN'.

Figure 10 compares the durations of experience for the three prototypes on the basis of their operative log data. The average experience-durations on Prototype 2 and 3 were 104.8 s and 89.7 s, respectively. Since Prototype 1 has a restriction upon the maximum duration of the experience, the comparison is only effective between Prototypes 2 and 3 in this case.

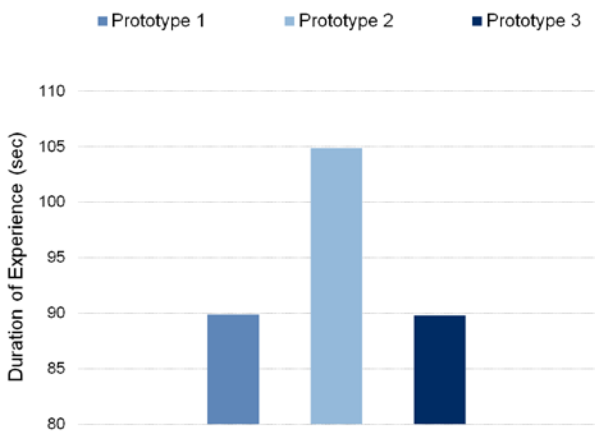

Figure 10. Comparison between experience duration for the three prototypes. [1]

Figure 11 compares the number of paging among the three prototypes. The average numbers of paging on Prototype 2 and 3 were 16 and 12.7, respectively. In addition, the average numbers of pointing on Prototype 2 and 3 were 18.6 and 10.8, respectively.

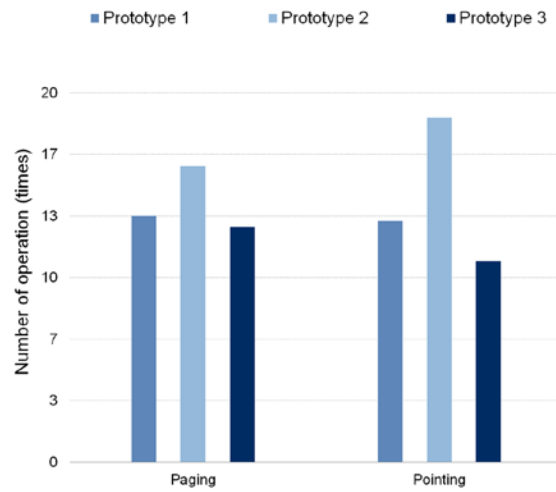

Figure 11. Comparison of the number of paging and pointing operations among the three prototypes. [2]

Table 1 compares the durations spent on examining each section of the three prototypes. For Prototype 1, the largest duration was spent on the introduction section on condition that this section automatically proceeds within 30 seconds, whereas for Prototype 2, the largest duration was spent on the collection section.

	Introduction (sec)	Collection (sec)	Quiz (sec)
Proto1	**26.5534732**	72.62271676	10.54081277
Proto2	9.82202276	**79.24832416**	**10.61679307**
Proto3	9.214661261	66.91787819	5.197089071

Table 1. Comparison of duration spent examining each section with the three prototypes.

We obtained four main concepts from our observations of the users.

Observation 1: "Smooth participation"
With each prototype, the users instantly touched the UI device, started operating the device, and understood how to operate it through actual operation.

Observation 2: "Multiuser cooperation"
With Prototypes 1 and 2, more users cooperated compared to Prototype 3. For example, a user was trying to look at

[1] Proto1-2: p=9E-09, Proto1-3: p=1.2E-05, Proto2-3: p= 0.0528 (F Test)

[2] Proto1-2: p= 2.12571E-05, Proto1-3: p= 1.0103E-14, Proto2-3: p= 0.00045 (F Test). Pointing, Proto1-2: p= 3.33067E-15, Proto1-3: p= 4.11815E-08, Proto2-3: p= 0.059994602 (F Test)

other pages while another user was reading a page on the book UI. This is related to the first design specification mentioned in FLIPPIN' design.

Observation 3: "Transition of interest from interface to content"
Prototype 1 and 2 users showed decreasing interest in the interface itself and mutual conversation within a few minutes of using the system. The main topic of conversation changed to interactions with contents, such as image scaling, animation, and sound effects. In particular, Prototype 2 user spent more talking about content than the users of the other two prototypes. This may be related to the third design specification in FLIPPIN' design. On the other hand, Prototype 3 users showed less interest in the content after they became accustomed to the interface.

Observation 4: "Easy comprehension of the content"
Most users attempted to comprehend the content at the beginning of their experience while they learned how to operate the system through actual operations. Prototype 1 and 2 users spent less time comprehending the content compared to Prototype 3 users, and many Prototype 3 users quit during their experience.

Implications

Repair and Robustness
The first version of FLIPPIN' UI device needed to be replaced every few days because the flexible connecter part became disconnected. The copper foil tape on the connecter part became disconnected after users had repeatedly opened and closed a page. This problem was solved by exchanging the copper foil tape with conductive cloth tape. Moreover, due to influence from the local radio environment, the wireless Bluetooth communication was sometimes disable. In addition, we selected a wired USB cable to enhance operational stability after one week.

Improvement of experience duration
The interface increased the experience duration of users in the public space. Figure 10 shows that Prototype 3 had lower experience duration than Prototype 2. This was because touch panels and tablets are already widely used, and the users were uninterested in the proposed interface. Thus, long durations could not be maintained unless the users were interested in the content.

Improvement of interest in content
The interface increased user interest in the content. Through interviews, it was found that 11 users out of the 10 groups and 21 people observed with Prototype 2 commented that interest in the content had improved. List.1 shows typical examples of user comments. Note that only one user out of the four groups and eight people observed with Prototype 3 gave similar comments.

"Yes, I think that it was easier to get interested in the contents in comparison to reading a normal book. Indeed, I pushed them, and then some characters were animated. This is why I feel it was easier to understand or somehow more attractive." (20's/female/student)

"I got a feeling that I'd like to see other paintings as well as the contents, and I feel that I want to experience it again." (40's/female/housewife)

"Touching the contents made me feel more interested than just looking at them." (40's/male/manufacturing industry)

List.1: Examples of improvement in interest toward the contents displayed through the novel interface.

Figure 11 shows that Prototype 2 had the largest numbers of paging and pointing. This result supports the idea that the novel interface increases users' interest in the content.

User-experience design to encourage social interaction
All the prototypes prompted social interaction in cases where multiple users played the game. For example, the following phenomena were observed:

A user pointed out a character in the Manga collection section, and another user left comments about it.

A user was in charge of paging, and another user was in charge of pointing.

Based on these findings, if a specific function and user experience could be designed for multiple users, their satisfaction could be further increased.

Scenario design based on the interests of the users
Prototype 1 adopted a single-thread scenario that showed the introduction section to the users via the main display, presented the Manga collection section for 2 min, and then automatically moved to the quiz section. As a result of interviews and observations, the users who were interested in the book interface tended to miss the introduction section because they had to see two different areas, namely, the main display and the book interface. Additionally, the users who were interested in the content had to stop their experience because the collection stopped after 2 min. Some users attempted to replay the content two or three times after the quiz section.

Based on these results, Prototype 2 adopted a multithread scenario that showed the introduction section to the users via the book interface, thereby allowing users to freely experience the introduction, collection, and quiz sections. As a result of this update, the average experience-duration on Prototype 3 increased by about 15 s than the experience-duration on Prototype 1. However, the users of Prototype 1 and 3 watched the introduction section for about 26 s and 9 s, respectively, on an average.

Thus, we concluded that the best scenario is a hybrid one that shows the introduction section first and then allows users to freely experience the collection and quiz sections. In this case, the system should have a function to skip the introduction section for users who would repeatedly experience the system. In addition, the book interface shows an alert for the users to look at the main display during the introduction section; this will avoid the problem of users missing this section.

DISCUSSION

In this section, based on our evaluation results, we discuss how an information system using FLIPPIN' could solve the three issues described previously.

Issue 1. How easily can UI devices be accessed or used by all visitors.

With respect to this issue, we presume that FLIPPIN', which employed in Prototype 2, changed the quality of usability. From user observation 1, "Smooth participation," users showed a tendency to immediately begin exploring operation methods while actually handling the system with all prototypes. However, in consideration of the experience duration (Figure 10), the number of operations (Figure 11), and the implication that duration experience was improved by the interface, it can be assumed that Prototype 2 encouraged users to continue interacting with the system.

Issue 2. How the system stimulates user interest via content.

From the implications that the interface contributes to improvements, Prototype 1 and 2 could improve user interest in the content. All the prototypes influenced to encourage the users to have conversations among them and to stimulate their interest. It is considered that both the UI device and a large display make it easier to share the content. Furthermore, in consideration of observation 2, "Multiuser cooperation," it was easier to share the UI device with Prototypes 1 and 2 compared to Prototype 3.

On the other hand, from a hypothetical perspective, FLIPPIN' could help build an interaction mental model. We assume that phenomena associated with observation 3, "Transition of interest from interface to content," were caused by immediately building an interaction mental model because turning pages is directly related to progressing through the content. In contrast, when reading an e-book using a touch-panel display, he/she could not automatically operate the system and focus on the content.

Issue 3. How digital systems are designed to solve the reading usability problem.

The exhibition design using FLIPPIN' has suggested clues to solve the reading usability problem of digital information systems in public spaces. This is supported by observations 2 and 4, i.e., "Multiuser cooperation" and "Easy comprehension of the content." The phenomenon was derived by a physical book interaction, and it demonstrated the superiority of FLIPPIN'.

From the above mentioned section, we presume that FLIPPIN' improved three issues. In particular, the novelty and the usability derived from a physical book interaction provided a positive effect on our information system. However, this does not mean that our system sufficiently solves the reading usability problem because it has some limitations, such as the number of pages and unchangeable content, compared to existing digital devices.

CONCLUSION

Here, based on the evaluation results and the stated implications, we formulate design guidelines for information systems using a paper-based book UI in public spaces. In particular, the guidelines will help designers and engineers guide to design an interactive information system that has the limitations and needs as the same as that of ACTIVE Lab where we conducted the evaluation.

The design guidelines are divided into two categories.

Paper-based book UI device design:

1. Mimicking real books.

Users tended to recognize a paper-based book UI device as a novel device. In public spaces, novelty is an important factor that encourages users to use information systems. For practical application, it is even more important to mimic the look, feel, and usability of a real book in order to provide users novelty. To realize a novel device, FLIPPIN indicated the effective implementation method of combining usability of a real book and digital technologies with robustness.

2. Paper-based book UIs should allow simultaneous users.

This is related to the implication, "User-experience design to encourage social interaction" and observation 2, "Multiuser cooperation" in evaluation section. The interaction affordance of book encourages to immediately build user's interaction mental model and to share the operation method and the content.

3. Paper-based book UIs should be edited to be able to read from anywhere based on user's interest.

This is related to the implication, "Scenario design based on the interests of the users", and our observation that Prototype 2 is superior to Prototype 1. Prototype 2 is edited so that users could access each section freely based on their interest. We observed that some users began with the quiz section, and then continued to enjoy the collection section.

Content design:

1. Content progression should not be limited by preset times.

Content progression with preset time leads to user frustration. As mentioned in the implication, "Scenario design based on the interests of the users", with Prototype 1, users who were attracted to *the Hokusai Manga* were forced to stop viewing after a predetermined duration, and some users restarted and continued their appreciation.

2. It is desirable that explanatory information is presented as the feedbacks from user's operation.

Users tended to not read the introduction section that the explanatory information is written nearly 150 words in terms of English, in Prototype 2. On the other hand, from the user interviews, the users indicated that more comments are required when enlarging a sketch. From the findings, it is inferred that even if explanatory information is provided for users in a public space, the active reading is encouraged by easy input operation and immediate feedbacks based on the user's interest.

3. The easiness of creating system image should be leveraged for the instruction.

In all prototypes, most users immediately understood the system's operations when first handling the device. In such systems, an easily understood and effective system image should be created. We observed the tendency of disturbing the handling by a one-sided interaction such as 30-seconds instructional video of Prototype 1. Therefore, the instruction description of the operation should be kept to a minimum.

4. Device roles should be clearly identified.

In this study, users were sometimes unable to decide whether to look the book content or the display content. Thus, more specific device roles are required for such systems. For example, Figueiredo et al. attempted to guide the user's visual line by identifying the role of each device by synchronizing the contents of book and display device according to these positions [13].

The present study has demonstrated the practicality of the interactive information system with our paper-based book UI, FLIPPIN', through a field evaluation. In addition, design guidelines for interactive information systems in public spaces have been suggested. FLIPPIN' allows easy access to information by mimicking the look, feel, and usability of traditional books with robustness and arouses interest in content through social interactions. If the technical limitations of producing paper-based book UIs are solved in future, such interactive information systems could become convenient alternatives to actual paper guidebooks or pamphlets in public spaces.

ACKNOWLEDGEMENTS

We would like to thank all the participants, Mitsuru Uragami of the Uragami Sokyudo, Naruo Shigeta, Kazuaki Morisawa, Yuichi Uchiyama of Toppan Printing Co., Ltd. and The Grand Front Osaka, the Knowledge Capital, ACTIVE Lab.

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