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System interactive reader using eye-tracker technology in ebook reader

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ABSTRACT

Interest in using ebooks by the academic community is very high. Still, there is a problem when readers are reading through screens, tend to read fast, only scan the necessary parts, and don't focus on paying attention to the content they read, so this reduces the quality of reading because readers don't study the overall meaning of the sentence. Hence, this research aims to build an interactive reader system by integrating eye tracker technology with a webcam which is expected to solve the problem of decreasing the quality of reading through the screen by helping readers stay focused on their reading and providing an interactive system that makes it easier for readers to control the computer while reading. This research adopts the waterfall method and is divided into six stages. The system is designed using class diagrams, use case diagrams, and activity diagrams. Also, the system is built using the Python language with the Django framework. Then, the interactive reader system was tested using black box testing and usability testing methods. Based on the test results, it is shown that the interactive reader system that was built can help improve the quality and concentration when reading activities take place.

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1. INTRODUCTION

In the industrial era 4.0, the digitization trend is increasing, which evolves the technological approach in many aspects of people's lives. Likewise, the educational element applies digital technology as a learning medium, such as ebooks, videos, and other media. The high interest in using ebook media among the academic community can be seen in the results of a study by Casselden and Pears [1], which stated that 50% of students used ebooks to read about their course materials, and only 2.1% did not use ebooks.

Reading is a skill that is very necessary for daily activities. Reading both seriously and at leisure is a crucial component of literacy. The more someone reads, the more that person's skills in understanding and making conclusions from reading will increase [2], [3]. The digital world has entered all aspects of human life, including digital text, which has replaced conventional text. Digital reading media is becoming increasingly popular, although printed text reading is still a vital medium [4]. Behind the high interest in using ebooks, there is a problem when readers who are reading through screens tend to read fast, only scan the significant parts, and don't focus on paying attention to the content they read, so this reduces the quality of reading because readers do not examine the meaning as a whole. So, it takes a new strategy to improve reading quality in a digital environment such as ebooks, both online and offline, by students, which is necessary considering that ebooks are helpful for college students.

In light of the identified issues, incorporating innovative technology emerges as a viable approach to enhancing reading quality within the digital realm, particularly regarding human-computer interactivity. Presently, the predominant mode of computer interaction entails issuing commands through a combination of mouse and keyboard inputs. Nevertheless, the emerging eye tracker technology, albeit underutilized, is perceived to offer a high level of interactivity and holds the potential to supplant the conventional roles of the mouse and keyboard.

Eye tracker technology is a hands-free computing device where the computer only needs to track and measure human movements to execute commands. According to Nakano *et al.* [5], eye trackers can detect, then provide interpretation of subtle signals from the user. Furthermore, eye trackers can provide automatic assistance to human-computer interaction, in which the system perceives the user's cognitive state and responds to the user without explicit commands. Taore *et al.* [6] researched to diagnose color vision disorders using eye movements. In the last decade or so, researchers have continued to work on developing techniques and algorithms for eye tracking. Eye movement while reading is not continuous throughout the sentence. The researchers then used a small contact lens with a hole to determine the direction of the eye's gaze using an aluminum pointer connected to the lens [7].

Until now, researchers have been increasingly interested in studying more about this eye tracker technology. Some studies use eye-tracker and webcam hardware to research and develop eye-tracker technology. A previous study by Chen *et al.* [8] proposed an interactive eye-controlled reading system that uses the human eye instead of a traditional mouse to control digital text to support screen-based digital reading. However, this research uses eye tracker hardware to track the user's eye movements, so the system built is difficult to use for many people due to device limitations. So we need a similar interactive system that uses hardware that is more familiar to many people. In eye movement-based human-computer interaction, three types of eye movements can be used: fixation, saccade, or smooth pursuit [9]. Smooth pursuit is very commonly used in building various interactive applications. Although the use of eye gaze as a (human-computer) interaction in interactive applications has been studied extensively, simple calibration procedures remain a major challenge in this area of research [10]. In another study, researchers built a system that detects real-time head, eye, and mouth movements to control the mouse. They managed to build a system that can move the mouse based on head movement; where to activate the mouse, the user has to open their mouth vertically, click left/right the user has to close one of his eyes, and scroll either up or down the user can need to squint their eyes are such that the aspect ratio of his two eyes is less than the specified value [11], [12].

In addition to theoretical research, research implementing eye-tracking technology has been done before [13]–[15]. In their study, Zhang *et al.* [16] proposed an eye-tracking-based control system for natural human-computer interaction to provide a more natural and convenient communication mechanism. This system integrates mouse and keyboard functions, enabling users to achieve almost all computer inputs without traditional input devices. This research aims to develop an interactive system by integrating eye tracker technology using a webcam. The system is expected to solve the problem of decreasing reading quality through screens by helping readers stay focused and providing an interactive system that makes it easier for readers to control the computer when reading. This interactive reader system prioritizes interactive multimedia concepts that are explained by Valtakari *et al.* [17], which is the interaction between users and the material displayed, as well as the ease in the system for accessing each section. As for the four broad categories of eye movement measurement methodologies by Duchowski [18], this study implements the video-oculography (VOG) method. Stahl [19] described that in the VOG method, the eye image from the camera is processed by a computer to determine the horizontal and vertical positions of the pupil in the image, and this linear position is then converted to optical axis angular orientation.

2. METHOD

This research includes six stages of implementation, starting from data collection to testing the system that has been built. In detail, the research methodology carried out is shown in Figure 1. The first stage is the planning stage doing literature study and observation. They were followed by the analysis stage, which analyzes system requirements and tasks. This stage will describe how the system works and the data used in system design, which aims to identify system opportunities to support user activities.

Then to produce an exemplary system according to target needs, there is the design stage which is the implementation process to create a system design that corresponds to the results of the identification and analysis that have been done. In this stage, the system is designed and built based on the results of observations and data. The next step is the implementation stage, where the author develops the system based on the system design and the data from system requirements analysis results by writing program code. Then, the final stage is system testing. The test results are then analyzed to determine whether the system corresponds as designed.

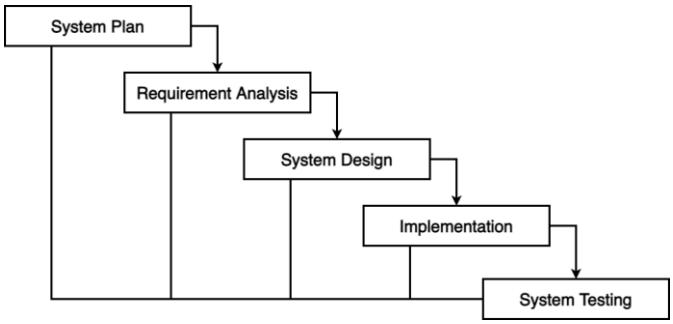

Figure 1. Research methodology

System architecture is a blueprint that delineates the organization and arrangement of interconnected components within a software system. In the context of this research, Figure 2 presents the system architecture diagram tailored explicitly for the interactive reader system. This diagram visually represents the hierarchical structure and relationships among the various components that constitute the system, providing a comprehensive overview of its design and functionality.

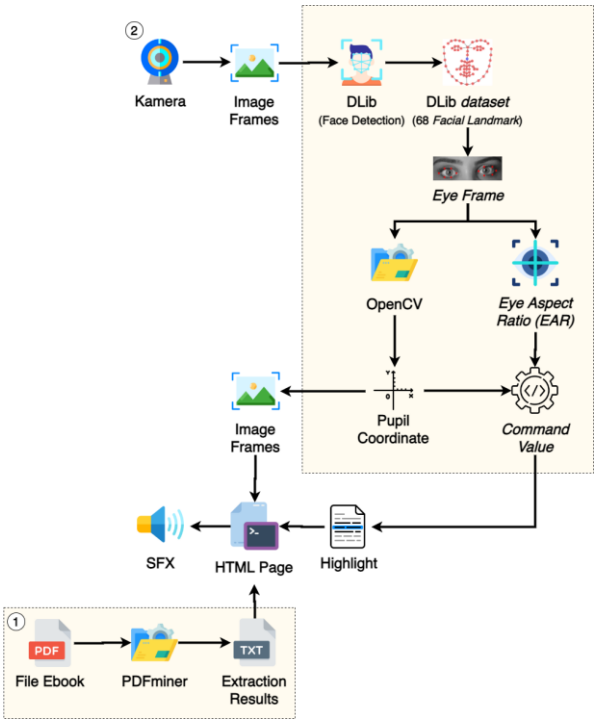

Figure 2. System architecture

Booch *et al.* [20] says unified modeling language (UML) is a standard system design language. The UML can be used to visualize, define, construct, and document the construction of a software-intensive system. There are several kinds of UML diagrams, including use case diagrams and activity diagrams. In this study, system testing is done by black box testing [21] and usability testing [22]. In black-box testing, possible test cases from the user's point of view will be tested. This black box test determines whether the system has returned the output according to the specifications. The black-box test design is carried out for each function in the system and is grouped based on the test scenario. The scenarios tested on the eye tracker function are described in Table 1.

Table 1. Black box eye tracker testing scenario

No	Scenario
1	A user reading ebook in a room with poor light intensity using the laptop's built-in webcam
2	A user who wears glasses reads an ebook in a room with poor light intensity using the laptop's built-in webcam
3	A user reading ebooks in a room with good light intensity using the laptop's built-in webcam
4	A user who wears glasses reads an ebook in a room with good light intensity using the laptop's built-in webcam
5	A user reading ebook in a room with poor light intensity using an external webcam
6	A user who wears glasses reads an ebook in a room with poor light intensity using an external webcam
7	A user reading ebooks in a room with good light intensity using an external webcam
8	A user who wears glasses reads an ebook in a room with good light intensity using an external webcam

Furthermore, usability testing tests the effectiveness of increasing user concentration when reading with the interactive reader system. One of the factors that affect reading comprehension is the level of concentration. If someone's attention is low, it will cause reading comprehension to be reduced. So, this usability test will also measure the level of reading comprehension and reading duration of all test participants to determine whether or not there are differences in reading comprehension levels and reading durations during reading activities using an interactive reader system. Figure 3 is a diagram of the test design adopted in this study.

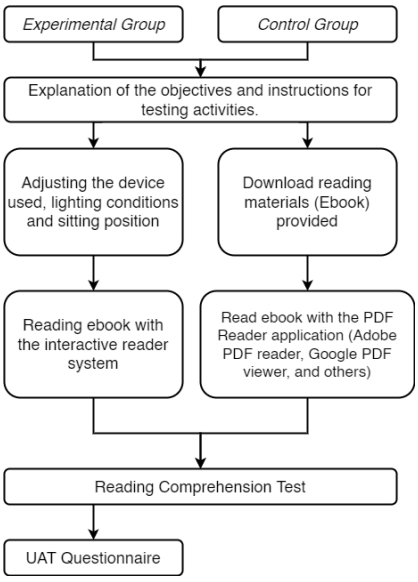

Figure 3. Usability testing design diagram

Based on the diagram above, the experimental procedure for usability testing involves the following four steps:

Step 1. The researcher explains in detail the purpose and rules of the test. Furthermore, participants in the experimental group will adjust the device used, light conditions, and sitting position. The other participants in the control group will download ebook files that have been provided.

Step 2. Next, participants did a 1-page reading activity. Fifteen participants in the experimental group read reading material through an interactive reader system, and 15 other participants read reading material through the PDF Reader application, which is available on their laptops. At this step, participants from both groups recorded the screen so that the researcher could determine how long each participant's reading duration was. Each participant completed the reading activity at their reading speed and was not allowed to review the reading material after completing the reading activity.

Step 3. Both groups of participants were given ten short questions to test their reading comprehension to determine whether the two groups showed any differences.

Step 4. Experimental group participants filled out a user acceptance test (UAT) questionnaire to measure the usability of the interactive reader system. The usefulness and ease of use aspects questionnaire from previous research by Chen *et al.* [8] were used with some sentences modified to conform to the

current study. While the questionnaire on the interaction aspect from previous research by El-khalifa [23] was used, some corrections were modified to work with the recent research.

To measure the aspects score on UAT, the Likert scale is used. The Likert scale is a rating scale that is added up when the researcher wants to measure respondents' attitudes, opinions, and perceptions by giving a score on how much respondents agree or disagree with the statements given. By using this Likert scale, an assessment score is provided from 1-6, with 1 being strongly disagreed and 6 strongly agree. The usability score measurement will be done by calculating the percentage of answers from the questionnaire that all test participants have filled out to get the eligibility rate by dividing the observed score by the expected score and multiplying by one hundred. Then the data obtained will be converted based on the eligibility criteria, as shown in Table 2.

Table 2. Eligibility category

Score in percent (%)	Eligibility category
<21	Very ineligible
21-40	Not eligible
41-60	Eligible enough
61-80	Eligible
81-100	Very eligible

3. RESULTS AND DISCUSSION

Figure 4 showcases an interactive reading page interface that offers additional features for user guidance. The interface incorporates a user-friendly guide, directing users to grant camera access and activate the detector by pressing the camera icon on the left before commencing the reading process. Furthermore, the interactive reading page presents a dynamic experience, as the system intelligently highlights the text line the user is reading, facilitating better focus and comprehension.

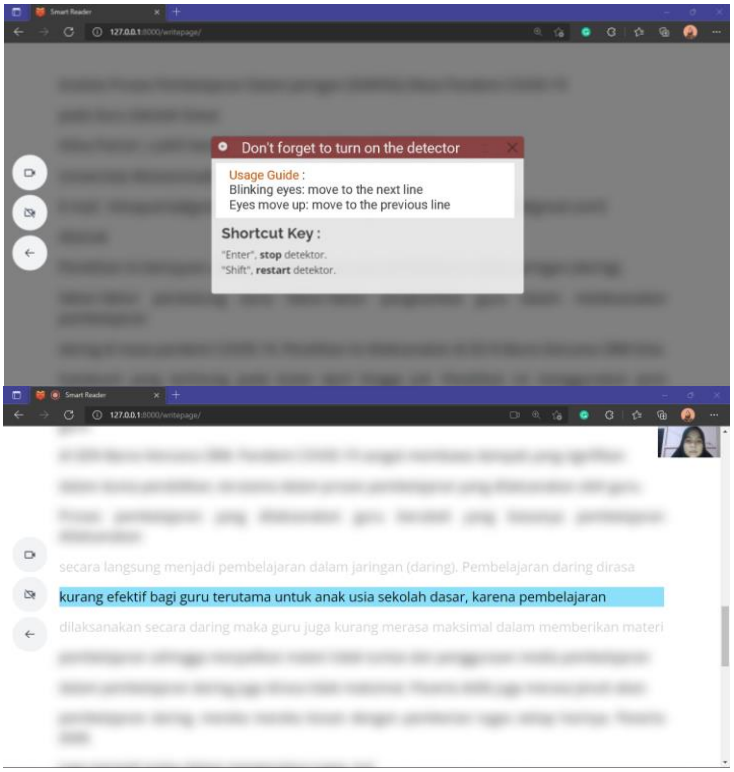

Figure 4. Interactive reading page interface

Table 3 is a summary of the black box test results that are explained in the method section. A total of 5 out of 8 test scenarios produced test case outputs 100% matching the expected output results. However, in

scenario 2, the user who wears glasses to read ebooks in a room with poor light intensity and uses a built-in webcam for their laptop, only 6 of 9 test cases matched the expected output results. Then in scenario 5, in which the user reads ebooks in rooms with poor light intensity and uses an external webcam for their laptops, and scenario 6, in which the user who wears glasses read ebooks in rooms with destructive light intensity and use an external webcam for their laptops, only produce 7 test case outputs that are matched the expected output results.

Table 3. Blackbox testing results

Scenario	Suitable test case	
	Total	(%)
1	9	100
2	6	66.7
3	9	100
4	9	100
5	7	77.8
6	7	77.8
7	9	100
8	9	100

The usability test stage was held for three days. The total participants were 30 people divided into two groups, namely the experimental group, the participants who read reading material using an interactive reader system, and the control group, which is the participants who read reading material using the PDF Reader application. After participants read the reading material given, participants will fill out a short quiz containing ten questions related to the reading material to test the level of participants understanding of the content of the reading text. In the reading comprehension test results, there is a difference of 1.27 points from the average value of the two groups, with the average value of the experimental group being 8.6 points, which is higher than the average value of the control group is 7.33 points as can be seen in Figures 5 and 6.

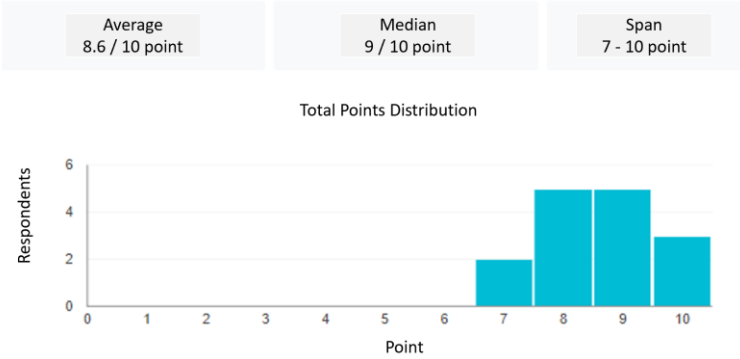

Figure 5. Experimental group reading comprehension test results

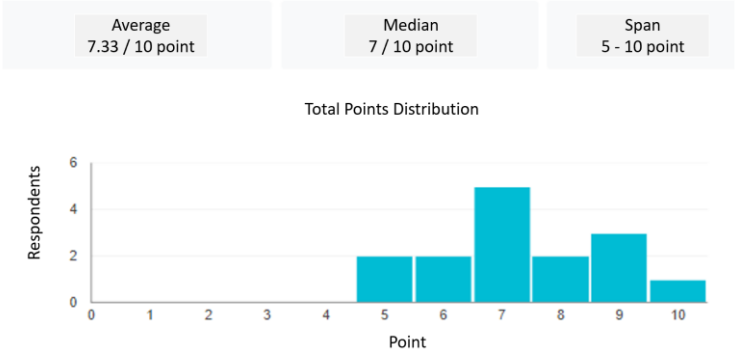

Figure 6. Control group reading comprehension test results

Figures 7 and 8 present a comparative analysis of the average reading duration among participants in the two groups. The results indicate a notable disparity of 3 minutes and 23 seconds, with the experimental group exhibiting a longer reading duration than the control group. These findings suggest that the implementation of the experimental intervention may have influenced the reading pace and duration of participants in the respective groups.

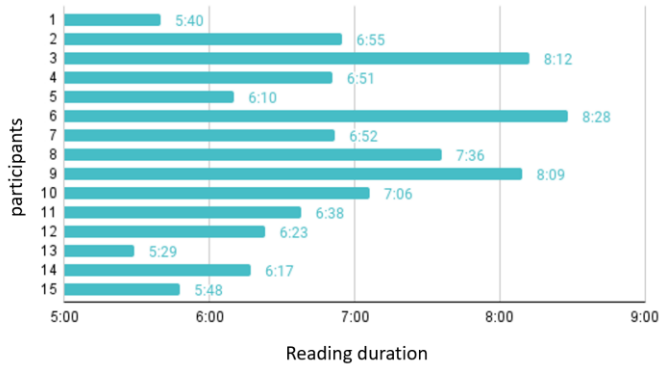

Figure 7. Participants' reading duration in experimental group

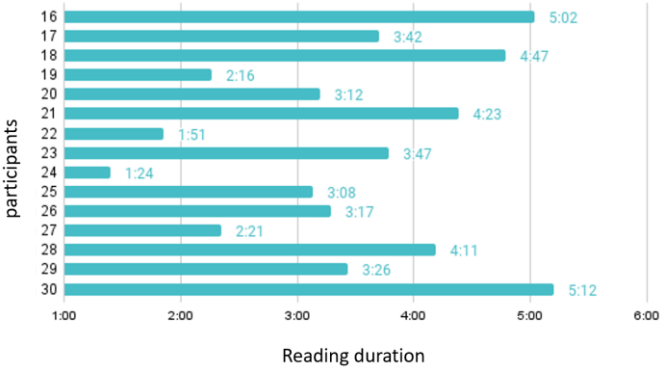

Figure 8. Participants' reading duration in the control group

Therefore, this interactive reader system can affect the level of user reading comprehension by increasing the user's understanding of the reading even though the duration required for reading is longer. The following testing stage is when participants in the experimental group fill out the UAT questionnaire. The results of each participant's response to each usability aspect are then calculated and converted to the feasibility percentage using the usability measurement formula and the criteria for the eligibility category. In measuring the usability of this interactive reader system, measurements are made on each usability aspect, as described in Table 4.

Table 4. Usability aspect measurement results

No	Usability aspect	Total score	Score in percent (%)	Eligibility category
1	Usefulness	427	79.07	Eligible
2	Interaction	476	88.14	Very eligible
3	Ease of use	534	84.76	Very eligible

The score is obtained for measuring usability after calculating the percentage of participants' answers. The total score of all responses from 15 participants is 1437, with a maximum total score of 1710 which is obtained from the maximum score multiplied by the total number of statements times the total

number of participants. Therefore, the percentage of usability of the interactive reader system is 84.03% and can be categorized as very feasible.

Many people are so disadvantaged that they need the help of tools in their daily activities, including people with limb disabilities who cannot use their hands to use a mouse to read digital text. This research will be able to help them to read digital text more easily. Furthermore, attention detection based on brain waves is required to diagnose learning-related conditions, such as inattention and hyperactivity [24]. Combining with brainwave attention detection [25] is a further challenge to create a better system.

4. CONCLUSION

Interactive reader system is an interactive system that can display highlights on the line of text and detect eye movements as input commands to move the highlight by integrating eye tracker technology. The functionality of each process in the interactive reader system can run well, including the text extraction process and eye detection feature based on the black-box testing results. The use of an interactive reader system in reading activities can help increase the user's concentration, as evidenced in the usability testing results, where the results of the reading comprehension test show the use of an interactive reader system in ebook reading activities increases the reading comprehension level but spends longer reading time. As well as the UAT score on the usefulness aspect also shows that the percentage of the system's eligibility is 79.07%. Some things that can be developed in future work include developing an interactive reader system for people with dyslexia, a person who have learning disorders and reading difficulties; analyzing more deeply the cognitive learning level of interactive reader system users; adding additional features that can maximize the function of the system, such as the ebook history feature, and ebook recommendation feature.

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