Journal of Information Systems Engineering and Management
2025, 10(16s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Internet of Things (IoT) Based Keyboard Learning Application Model For Preventing Carpal Tunnel Syndrome

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ARTICLE INFO

Received: 10 Dec 2024

Revised: 28 Jan 2025

Accepted: 13 Feb 2025

ABSTRACT

The keyboard is a computer hardware device used for typing. Generally, individuals who are not accustomed to typing tend to use one finger at a time to press the keys, resulting in repetitive and pressing movements of the fingers. This can be one of the contributing factors to carpal tunnel syndrome. Carpal tunnel syndrome is a condition that can affect the functionality of the hands and fingers, causing symptoms such as tingling, pain, numbness, and even finger weakness. This occurs due to the compression of the median nerve in the carpal tunnel. In keyboard learning, there is a technique that is commonly used to perform typing tasks more effectively and efficiently, known as the 10-finger typing technique. This technique involves placing each finger in a specific position to target certain keys, with each finger having a specific role in directing movements on the keyboard. By understanding the function of each finger, one can master and improve typing skills more quickly and efficiently. This research focuses on developing a sensor-based keyboard learning system capable of recording fingerprints to capture the typing patterns inputted into the application

Keywords: Keyboard, Internet of Things (IoT), Sensor, Security System, Learning Model

1. INTRODUCTION

A keyboard is a computer input device that consists of various keys with different functions or commands. Keyboard is one of the computer hardware that has an important role in providing input. With the keyboard, users can enter characters and functions into the computer system by simply pressing a button [1]. There are several standard keyboard layouts used, including the DVORAK and QWERTY layouts. Currently, the QWERTY key arrangement is the most commonly used for typing, allowing for more efficient typing. Generally, individuals who are not yet proficient in using the keyboard tend to use a single-finger technique, where the finger repeatedly presses the keys, potentially leading to carpal tunnel syndrome. Carpal tunnel syndrome (CTS) is a condition that causes the hands to experience sensations of tingling, numbness, pain, or weakness. This syndrome is caused by the compression of the median nerve within the carpal tunnel [2]. The study titled [3] "Physiotherapy Management of Carpal Tunnel Syndrome in Office Workers" stated that prolonged typing activity leads to the occurrence of CTS, as fingers used for typing at a speed of 60 words per minute can exert more than 25 tons of pressure on the fingers per day. The incidence of CTS continues to rise among long-term computer users engaged in routine typing activities. Typing using all ten fingers is known as touch typing, which means typing without looking at the keyboard keys. More specifically, typists use muscle memory to identify the keyboard keys indirectly. The habituation of motor skills initially starts by relying on cognition and vision to influence motor performance, which eventually leads to motor muscles and self-correction to enhance precision [4].

The skill of ten-finger typing requires regular practice. Once ten-finger typing becomes a routine, the typist can become highly skilled, typing quickly and accurately [5]. A sensor is a device that receives and measures physical input from its environment and converts it into data that can be interpreted by humans or machines. For example, a door security system uses a fingerprint sensor based on the Arduino UNO R3 microcontroller, allowing the door to

open and close automatically[6]. Then, the automatic cabinet lock security system using a fingerprint sensor based on Arduino UNO was analyzed by [7]. Additionally, the research conducted by [8] on the use of a biometric attendance system with a fingerprint sensor demonstrated that it can reduce motorcycle theft problems..

2. METHOD

A website is a series of web pages that are specifically designed as a medium for information related to certain interests, such as in agencies, organizations, businesses, and many more [9]. A website is a collection of site pages, usually contained in a domain or subdomain, located on the World Wide Web (WWW) on the Internet. A web page is a document written in HTML (Hyper Text Markup Language) format, which is almost always accessible via HTTP, a protocol that conveys information from a website server to users via a web browser. All publications from these websites can form a very large information network [10]. A website can be defined as a collection of pages used to display information in the form of text, still or moving images, animations, sound, or a combination of all of them. Within a website, there is a page known as the home page. The home page is the first page viewed when someone visits a website [11]. XAMPP is a software that functions to run PHP-based websites and uses MYSQL data processing on a local computer". XAMPP acts as a web server on a local computer. XAMPP can also be called a virtual Cpanel server, which can help to do a preview so that the website can be modified without having to be online or accessed by the internet [12]. XAMPP is free software, which supports many operating systems, is a compilation of several programs. Its function is as a stand-alone server (localhost), consisting of the Apache HTTP Server program, MySQL database, and language translator written in the PHP and Perl programming languages. The name XAMPP is an abbreviation of X (four operating systems), Apache, MySQL, PHP and Perl. This program is available in the GNU General Public License and is free, is an easy-to-use web server that can serve dynamic web page displays. To get it, you can download it directly from the official website[13].

PHP stands for "PHP: Hypertext Preprocessor" is a script that is run on the server. The result is sent to the client, where the user uses the browser. The advantage of PHP is that the code that makes up the program does not need to be distributed to the user so that the confidentiality of the code can be protected[14]. PHP is a server-side scripting language used to create dynamic and interactive web pages. During development with simple PHP, business logic is mixed with database queries and presentation tags. Due to this mix of development modes, application maintenance and scalability become difficult. PHP has brought different development frameworks to address this issue. PHP frameworks help developers build web applications faster and easier by providing a basic framework model, as well as a complete set of APIs, libraries, and extensions, and help developers become more productive by reducing repetitive code in projects [15]. The advantages of PHP are:

a. PHP is a scripting language that does not compile when used. Unlike other application programming languages

b. PHP can run on web servers released by Microsoft, such as IIS or PWS, and also on Apache which is open source.

c. Because of its open source nature, changes and developments in PHP interpreters are faster and easier, because there are many mailing lists and developers ready to help with its development.

d. In terms of understanding, PHP has so many references that it is very easy to understand.

e. PHP can run on 3 (three) operating systems, namely: Linux, Unix, and Windows, and can also be run at runtime on a console.

f. PHP is free to use [16]

PhpMyAdmin is a freeware software written using the PHP programming language, which is intended to handle MySQL database administration through a Web interface. PhpMyAdmin supports various operations on MySQL and MariaDB databases. The most frequently used operations such as managing databases, tables, columns, relations, indexes, users, permissions, and others, can be done through the user interface, while we can also write SQL commands directly for database management operations. PhpMyAdmin application is a member of the Software Freedom Conservancy. SFC is a non-profit organization that helps promote, improve, develop, and maintain free and Open Source Software (FLOSS) applications. PhpMyAdmin itself supports MySQL, MariaDB, and Drizzle databases [12]. MySQL is a database server program that is able to receive and send data quickly using SQL commands. MySQL has two forms of license, namely Freesoftware and Freeware. MySQL Freeware is licensed

under the GNU/GPL (General Public License). In addition to being a free and open source database program, there is also commercial MySQL, namely MySQL AB. In MySQL, there are 3 sublanguages, namely Data Definition Language (DDL), Data Manipulation Language (DML), Data Control Language (DCL). DDL is used to build objects in the database, such as tables and indexes. DML is used to add, search, change, and delete rows in a table. While DCL is used to handle security issues in the database. MySQL is an RDBMS (Relational Database Management System). Relational databases store data in separate tables, rather than storing data in large storage spaces. This adds speed and flexibility. MySQL is open source software. Open source means that anyone can use and change the software. Anyone can download MySQL software from the internet and use it without paying [12].

According to the Galton system, fingerprint patterns are classified into three types: arch, loop, and whorl. The arch pattern features parallel curved lines resembling an arch, rising in the center and then descending to the other side. The loop pattern has a hook-like curved line with more than one line coming from the opposite side. Lastly, the whorl pattern consists of lines that form a circular formation [17]. One of the natural characteristics of humans that is unique and can be used to distinguish between one person and another is fingerprints. Some of the advantages of fingerprints include:

a. Perennial nature, namely the lines on the fingerprints that are attached to the skin are lifelong.

b. Immutability, namely a person's fingerprints never change, unless they have a serious accident.

c. Individuality, fingerprint patterns are unique and different for each person.

A normal fingerprint pattern consists of ridges and valleys that generally run parallel to each other, and this pattern can be analyzed at local and global levels. At the local level, analysis is carried out based on minutiae features. minutiae features consist of ending, core, and bifurcation. Ending is the end of a ridge, bifurcation is the branching part of the ridge, and core is the center point of the fingerprint [18]. A fingerprint sensor is a device used to detect fingerprint patterns. Initially, fingerprint sensors used an LED, a prism lens, and a camera (CCD or CMOS). The technology of fingerprint sensors continues to evolve, one of which employs Fiber Optic Plate (FOP) technology, consisting of an array of optical fibers, as shown in Figure 1. [19].

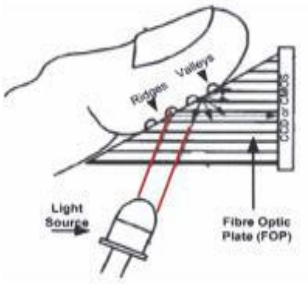

Figure 1. Fiber optic-based fingerprint sensor

Arduino is the name of a family of microcontroller boards originally created by the company Smart Projects. One of its creators is Massimo Banzi. This board is an "Open Source" hardware device so it can be created by anyone [20]. Arduino IDE is software used to create programming sketches or in other words Arduino IDE as a medium for programming on the board to be programmed. Arduino IDE is useful for editing, creating, uploading to the specified board, and coding certain programs. Arduino IDE is made from the JAVA programming language, which is equipped with a C/C++ (wiring) library, which makes input/output operations easier [21]. Arduino is an electronic kit or board equipped with open source software that uses the ATMega microcontroller family and functions as a single-board microcontroller designed to facilitate the use of electronics in various fields released by Atmel. Where the hardware has an Atmel AVR processor and the software has its own programming language [22]. The Arduino Mega 2560 has 54 digital input/output pins, of which 15 can be used as PWM outputs, 16 analog inputs, and 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This is all that is needed to support the microcontroller. The use of this Arduino Mega is simply by connecting it to a computer via a USB cable or power is connected to an AC-DC adapter or battery to start activating it. The Arduino Mega 2560 is compatible with most shields designed for the Arduino Duemilanove or Arduino Diecimil [23]

2.1. Problem Analysis

After conducting an analysis of the existing system, a more in-depth problem analysis was performed. The results of the system analysis revealed that many users are unable to utilize all ten fingers correctly while typing on the keyboard. This is caused by various factors, one of which is the bad habits that develop from the beginning of the user's typing learning process. Users tend to focus more on increasing typing speed rather than paying attention to proper techniques. As a result, although several typing applications are available, they have not been fully effective in teaching the correct ten-finger typing method. This issue is exacerbated by the lack of a validation system that ensures that the fingers used for typing are in the correct positions on the keyboard. Even when users attempt to use all ten fingers, their techniques are often inconsistent and inefficient. Users who type inconsistently, both in terms of order and finger positioning, create suboptimal typing patterns. This leads to excessive strain on certain fingers while others are rarely used, potentially causing long-term problems such as muscle fatigue or even injury.

One of the main issues that arises is the lack of user awareness regarding the importance of proper typing techniques, particularly the even distribution of ten-finger usage. Users tend to feel satisfied with their typing results if speed and accuracy are achieved, without considering the long-term impact of improper finger usage. For instance, many users often rely only on their index and thumb fingers, while not optimizing the use of other fingers in the typing process. This is a serious problem because this incorrect typing method, although it may be fast, prevents users from reaching their full potential for higher efficiency and reduced risk of injury. The inability of existing applications to validate finger usage is also an important issue. Although many typing training applications provide instructions on finger usage, there is no concrete feedback on whether users are actually using the correct fingers according to the rules. Applications only measure speed and typing errors, but do not validate whether typing is performed with the correct technique. As a result, users may continue to repeat the same mistakes without realizing that they are not typing efficiently and ergonomically with all ten fingers.

Therefore, it is crucial to develop a system capable of automatically validating finger usage while typing. This system will not only help users improve their typing techniques but also provide clear feedback regarding incorrect finger usage and areas that need improvement. In this way, users will receive more comprehensive guidance in effectively and efficiently enhancing their ten-finger typing skills.

2.2. System Analysis

In conducting the requirements analysis for the system to be developed, the system requirements are divided into two main parts: functional requirements analysis and non-functional requirements analysis. The functional requirements analysis discusses the features that the system needs to provide in order to achieve the desired outcomes, while the non-functional requirements analysis encompasses technical aspects such as the hardware and software needed to support the system's implementation. Both of these aspects must be met for the system to function effectively and align with its objectives. The functional requirements of the system are as follows :

a. The system must validate the correct fingers when keyboard keys are pressed: The system should be able to detect which finger is pressing a specific key on the keyboard and ensure that the finger used complies with the rules of ten-finger typing. This validation is essential for providing feedback to users about their typing techniques. The system also needs to identify incorrect finger usage and offer suggestions for improvement so that users can correct their typing methods in real-time.
b. The system must accurately validate the user's typing: The system should have the capability to monitor and validate the accuracy of the user's typing in terms of both speed and accuracy. As the user types, the system will record typing errors and provide alerts based on the expected typing standards. Additionally, the system can display statistics regarding the user's progress, such as the error rate during typing quiz sessions.
c. The system provides real-time feedback: This feature allows users to receive immediate feedback whenever they press the wrong key or use the incorrect finger. The feedback is in the form of notifications that inform users that the finger used does not comply with the correct typing rules.
d. The system can track and store user data: The system must be capable of storing data related to the user's typing sessions, such as the number of errors and typing speed during quizzes. This data can be used to provide progress reports to users and help them identify areas for improvement.
e. The system provides practice mode and quiz mode: To facilitate the improvement of typing skills, the system must have two main modes. In practice mode, users will be guided through a tutorial on proper ten-finger usage

with clear instructions. In quiz mode, users can test their abilities by typing text while still receiving feedback on speed, accuracy, and finger usage.
The non-functional requirements include the hardware needed to build this system, as follows::

a. Arduino Mega
b. Fingerprint sensor
c. Flexible pressure sensor
d. Gloves
e. Jumper Wires
f. PCB Board
g. Laptop
h. Server
i. The required software includes::
j. Windows Operating system
k. Arduino IDE
l. Fritzing
m. Visual Code
n. Xampp
o. Google Chrome Browser
p. Hosting

3. RESULTS AND DISCUSSION

3.1. System Design

In the design of this system, there is a web-based user interface that utilizes a fingerprint sensor to read each keyboard key that will be pressed by the fingers. The user interface can be seen as follows:

1. Login Page Appearance

In this view, users will create a new account to use the application, as shown in Figure 2.

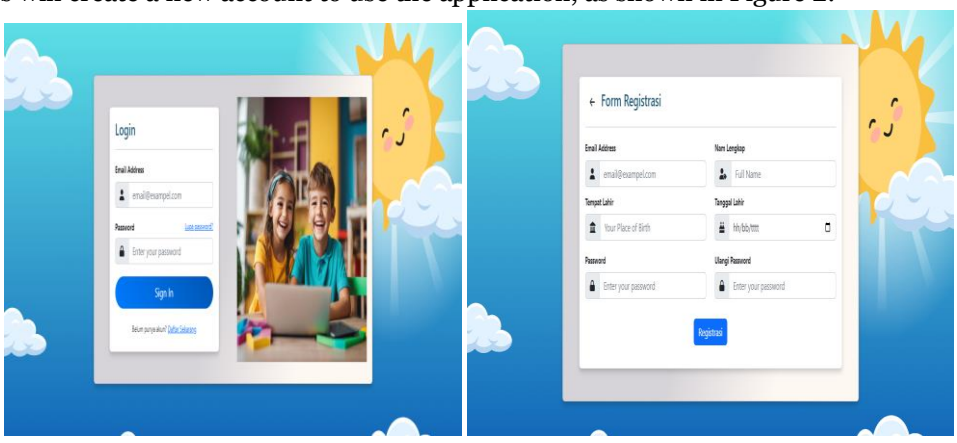

Figure 2. Login Page Appearance

After the user completes the registration form, they can proceed with the registration process by pressing the "Register" button at the bottom of the notification. Next, a notification will appear, and when the user presses the "Save" button, all the data entered by the user will be saved into the system. Once the data is successfully saved, the next step in the registration process is the sending of a verification code. The system will automatically send the verification code to the email address registered by the user. This code serves as an additional layer of security to ensure that the user truly has access to the email they used for registration.

2. Home Page Appearance

In this view, there will be a welcome message and guidance for using the system, as shown in Figure 3.

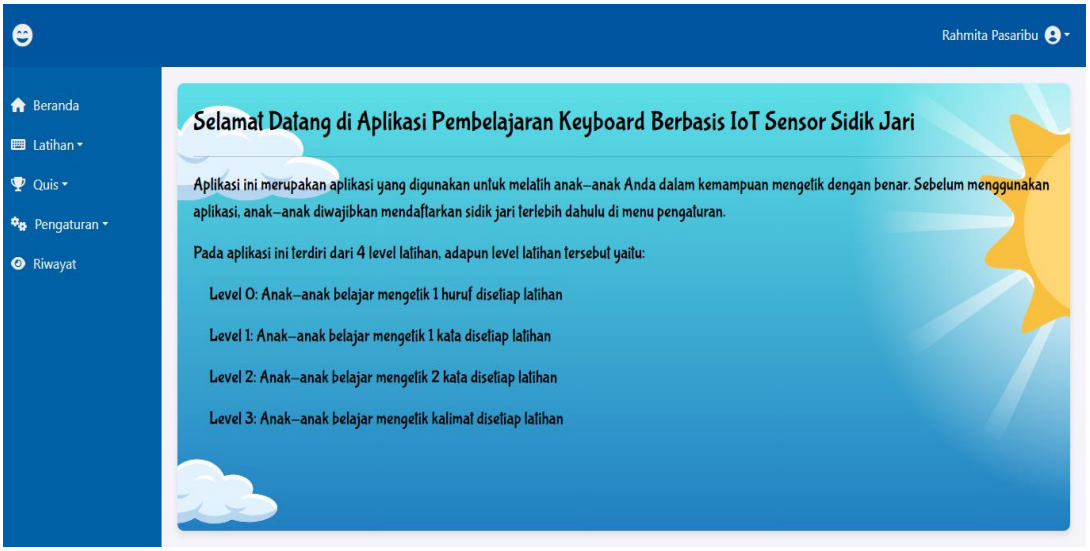

Figure 3. Home Page Appearance

In the settings menu, users will find three important sub-menus designed to help manage and personalize their accounts. These sub-menus are Identity, Password, and Fingerprint. Each of these sub-menus offers different functionalities, allowing users to manage personal information, secure their account, and customize fingerprint-based authentication features. These sub-menus can be easily accessed through the settings menu located on the left side of the page. When users select the Identity sub-menu, they will be directed to the identity editing page. On this page, users can make various changes related to their personal data. Editable information includes full name, place of birth, and date of birth. This feature is especially useful if users need to update or correct any errors in the information they entered during registration..

3. Fingerprint Registration Page Appearance

In this page view, each user will input 10 fingerprints in their respective entry menus. This is to ensure that each key can read whether the pressed finger corresponds to the keyboard key. This can be seen in Figure 4.

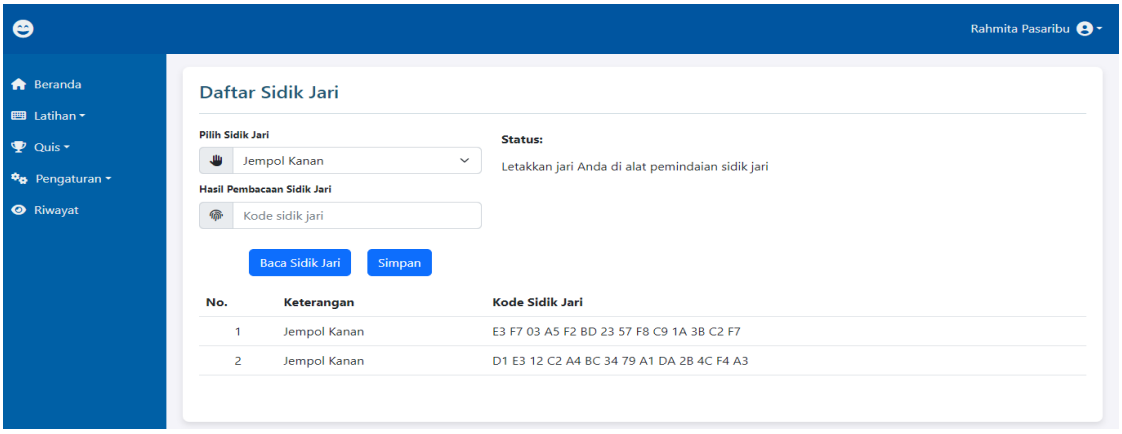

Figure 4. Fingerprint Registration Page Appearance

4. Pratice Page Appearance

In this view, users engage in initial exercises to familiarize themselves with the fingers and keyboard keys. The practice page contains 4 levels. In Level 0, there is 1 type of alphabet letter, and if the user types it correctly, they can proceed to the next exercise, as shown in Figure 5.

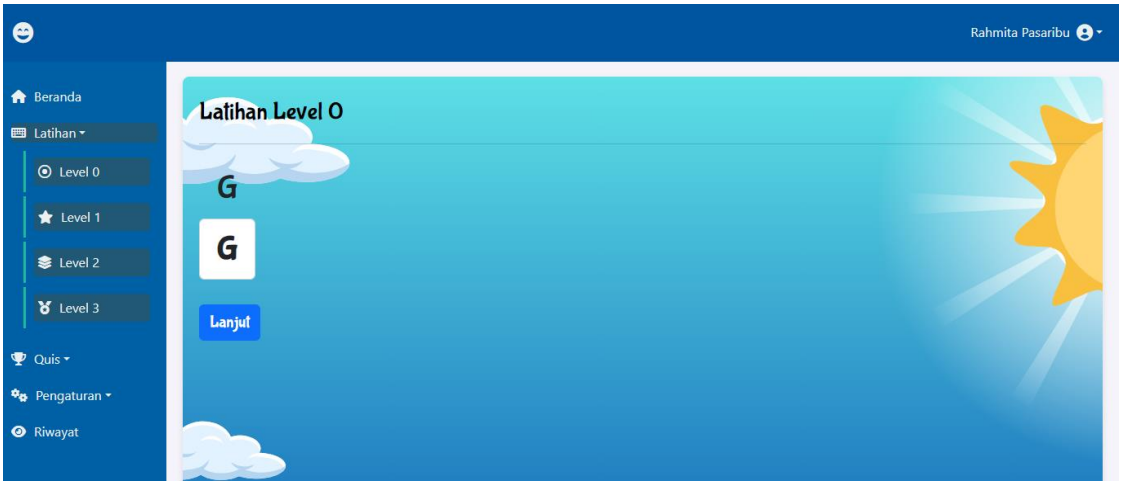

Figure 5. Practice Page Appearance Level 0

In the Level I practice page, there are several letters arranged into words. In this practice session, each letter pressed must correspond to the fingerprint assigned to each keyboard key in order to proceed to the next letter, as shown in Figure 6.

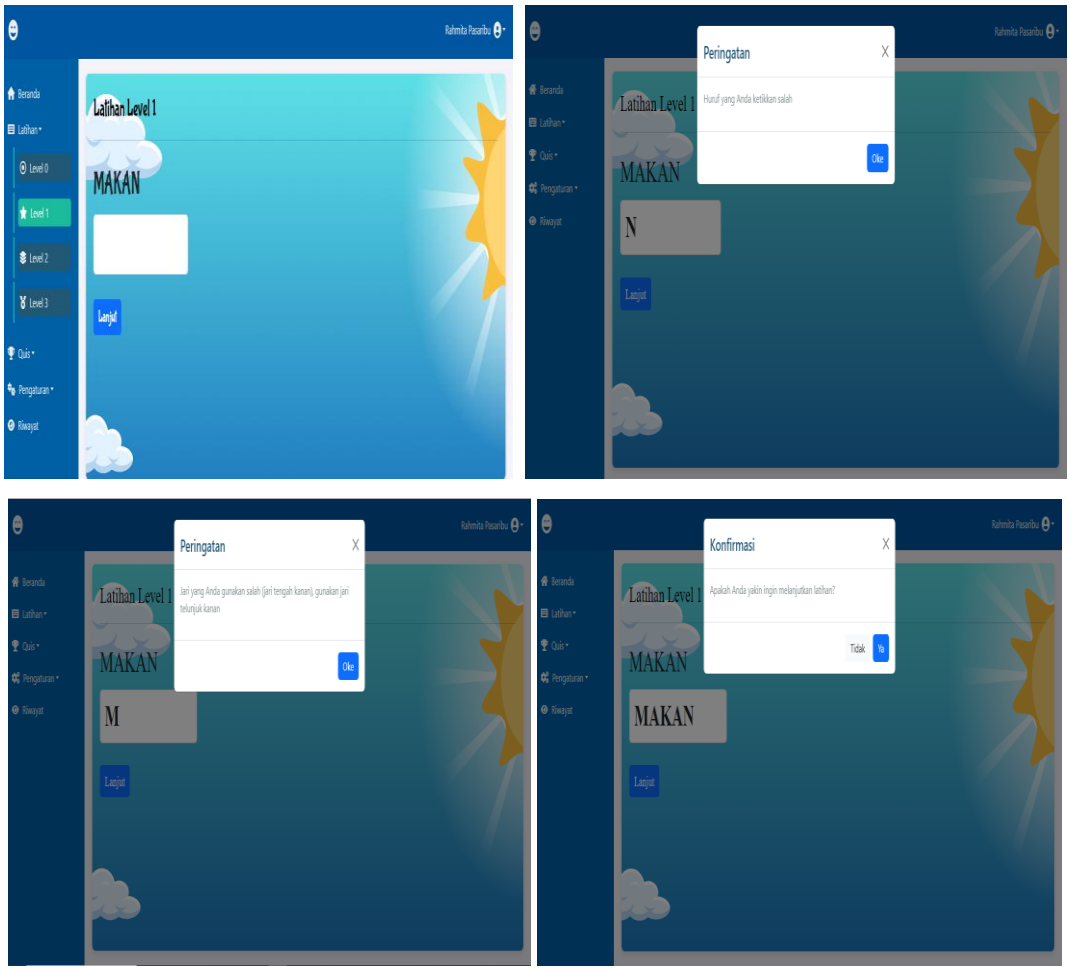

Figure 6. Practice Page Appearance Level 1

In the Level 2 practice page, there are 2 words. At this level, it is expected that users are more accustomed to the typing process according to their fingers and the keyboard keys. The appearance of the Level 2 page can be seen in Figure 7

Below

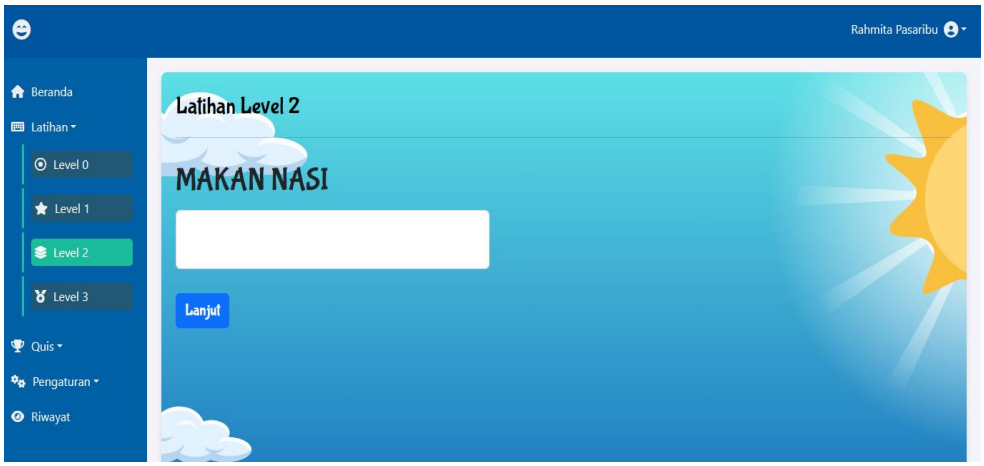

Figure 7. Practice Page Appearance Level 2

The Level 3 practice page displays several words combined into a single meaningful sentence. At this level, users are expected to be proficient in typing with the correct fingers and keyboard keys. The appearance of the Level 3 page can be seen in Figure 8 below.

Figure 8. Practice Page Appearance Level 3

5. Quiz Page Appearance

The Quiz page shows four levels available for users: Level 0, Level 1, Level 2, and Level 3. Users can select any level they want without starting from the lowest one. The appearance of the Quiz page is shown in Figure 9 below.

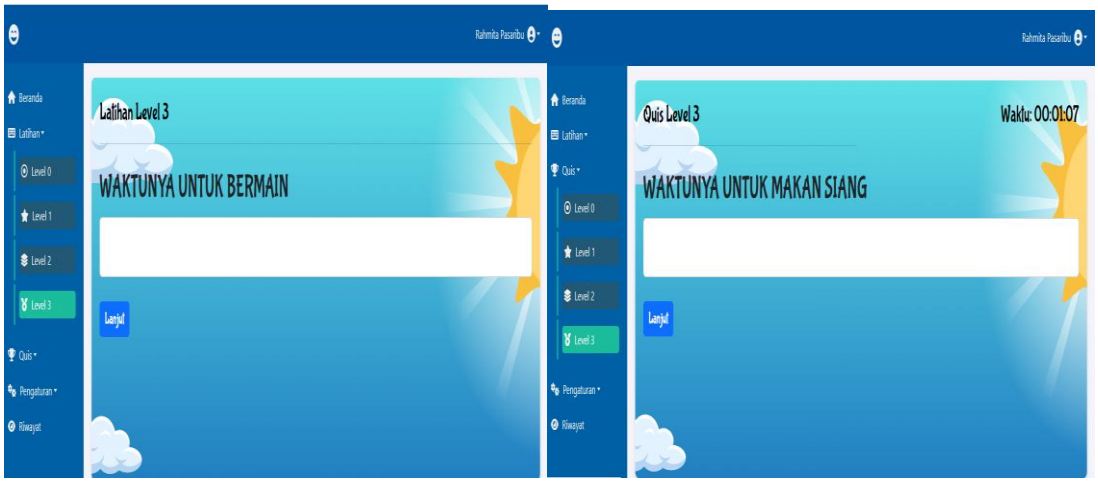

Figure 9. Quiz Practice Page Appearance

6. History Page Apperance

This page displays the user's testing history for each level, allowing them to see any typing mistakes made. The History menu is one of the most useful and informative features in this application. Not only does it help users track their progress, but it also provides in-depth insights into their performance across various aspects of typing. With a simple yet comprehensive table view, users can easily access quiz data and use this information to continuously improve and optimize their typing skills over the long term. This feature makes the typing learning process more structured and measurable, allowing users to see real and directed progress over time. The appearance of the quiz history page can be seen in Figure 9.

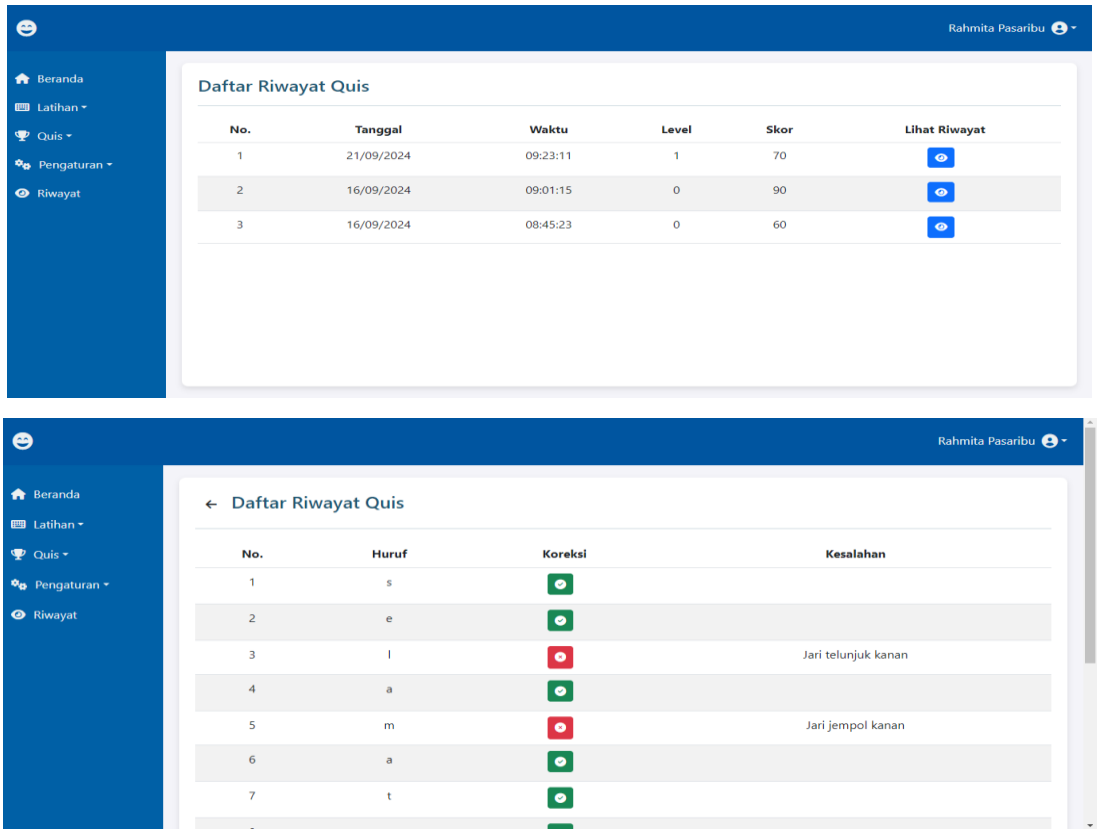

Figure 10. Quiz History Page Appearance

On the quiz history details page, users are provided with a deeper and more detailed view of the quiz results they have completed. This page is designed to give a clearer overview of each letter typed during the quiz session, allowing users to analyze where they made mistakes and understand their typing patterns in more detail. One of the main features of this page is the visual indicator that shows which letters were typed correctly and which ones were incorrect. Each letter typed by the user is compared to the correct letter that should appear in the quiz question. If the typed letter is correct, the system will display a checkmark (√) inside a green box, indicating the correct keystroke. However, if the user types the wrong letter, the system will display an "X" inside a red box as an indicator of the error.

Additionally, the quiz history details page provides supplementary information about the mistakes made by the user, particularly regarding the incorrect finger used during typing. Every time the user types a letter incorrectly, the system not only records the mistake but also detects which finger was used during the error. Information about the finger used will be displayed as an additional note, appearing next to the "X" symbol indicating the mistake. For example, if the user was supposed to use their right index finger but instead used their left ring finger, the system will log and display this information on the page. This finger usage detection feature is crucial because it helps users understand not only where they made typing errors but also identify patterns of incorrect finger usage. Users can see if they tend to use the wrong finger for specific letters or if there is a consistent pattern in the errors. This allows users to focus more on improving their typing technique in areas that need the most attention.

In addition to providing detailed feedback on typing mistakes and finger usage, this page also enables users to reflect and evaluate their own progress. By reviewing their typing results letter by letter, users can assess how well they have mastered proper typing techniques. This is highly beneficial for the learning process because users can identify recurring mistakes and take concrete steps to correct them in future quizzes. For example, if a user notices that they often make mistakes with letters on the left side of the keyboard, or if they frequently use the middle finger for keys that should be pressed with the index finger, they can develop a focused training strategy to address these issues. This page acts as a personal analysis tool that enables users to truly understand their weaknesses and work on improving their typing skills in a more specific and targeted way.

Therefore, the quiz history details page is not just a page displaying quiz results but also a valuable learning tool for users. It helps them understand their mistakes in more depth, identify incorrect finger usage, and ultimately improve their overall typing skills. This page enables users to enhance their typing accuracy, speed, and efficiency, helping them achieve better performance in the future.

3.2. Analysis Result

Current typing applications mainly focus on training speed and accuracy but often overlook the correct and technical use of fingers. These systems typically only evaluate typing speed and error count without assessing whether users are using the appropriate fingers for each key. As a result, users tend to rely on their comfort, often using incorrect fingers, which prevents them from achieving optimal ten-finger typing skills. While some typing applications offer basic instructions on finger usage, they lack an effective validation system to ensure the correct finger is used for each key. For instance, users can complete typing exercises using incorrect fingers according to the standard ten-finger technique and still receive good scores, as long as their speed and accuracy are adequate. This reveals a gap in the system's validation, which should also prioritize correct finger use based on ideal keyboard positioning.

Without proper finger usage validation, users develop inefficient habits, potentially leading to finger fatigue and reduced productivity in the long run. Systems focusing only on typing speed and accuracy do not provide enough feedback for users to improve their finger positioning and technique. As a result, while users may type quickly, they may not do so with maximum efficiency or proper technique, which can lead to errors or discomfort over time. This analysis clearly shows that existing systems fail to ensure optimal use of all ten fingers on the keyboard. Therefore, a more advanced and comprehensive system is needed—one that not only assesses typing speed and accuracy but also automatically validates finger usage for each key pressed. Such a system would help users improve their typing technique, achieving truly effective ten-finger typing. Consequently, users would not only type faster but also with correct and efficient technique.

3.3. System Testing

The next step involves testing the IoT keyboard with the system that has been developed. This testing aims to ensure that all functions and features of the IoT keyboard operate correctly and meet the specified requirements. The testing will involve several scenarios to evaluate the system's performance, responsiveness, and reliability. The scenarios and test results of the device and system are presented in Table 1 below**.**

Table 1 Results of Device and System Testing

No.	Testing Scenarios	
1	**Connectivity Testing**	
	Objective	To ensure IoT keyboard is connected to the computer
	Result	The IoT keyboard device successfully connects
	Description	The IoT keyboard device is properly connected, as indicated by the fingerprint sensor's indicator light blinking blue
2	**Basic Keyboard Functionality Testing**	
	Objective	To ensure all keys are functioning
	Result	All keys are functioning.
	Description	There are no stuck or unresponsive keys.

3	**Durability Testing**	
	Objective	To test the durability of the keyboard in long-term use.
	Result	No issues were encountered during 30 minutes of use.
	Description	The keyboard continued to function properly after the test
4	**Fingerprint Sensor Functionality Testing**	
	Objective	To ensure the fingerprint sensor functions properly.
	Result	The fingerprint sensor works well
	Description	During the test, several fingerprints were registered. The sensor performed well, even with multiple fingerprints stored in the system
5	**Glove Functionality Testing**	
	Objective	To test the functionality of the gloves
	Result	The gloves functioned properly
	Description	There were no issues during the glove testing, and the gloves were highly responsive.

4. CONCLUSION

Conclusion Based on the Study: "Internet of Things-Based Keyboard Learning Application Model for Preventing Carpal Tunnel Syndrome":

1. The IoT-based application successfully identifies and monitors user activity while using the keyboard. With integrated sensors, the application can provide early warnings and exercise guidance to prevent Carpal Tunnel Syndrome.
2. This application not only teaches correct typing techniques but also educates users about ergonomics and the importance of taking breaks while typing. This makes typing practice more effective and safer for hand and wrist health..
3. Using IoT technology, the application can be easily implemented on existing computer devices, making it accessible for a wide range of users.

Acknowledgment

We extend our heartfelt gratitude and pride to the Ministry of Education, Culture, Research, and Technology (Kemdikbudristek) for their generous support in providing research funding under the 2024 Fundamental Research Scheme through the Directorate of Research, Technology, and Community Service.

Declarations

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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