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# EYE-BASED HUMAN-COMPUTER INTERACTION (HCI): A NEW KEYBOARD FOR IMPROVING ACCURACY AND MINIMIZING FATIGUE EFFECT

**[a]Ronny Mardiyanto, [b]Kohei Arai**
[a] Electrical Engineering Dept.
Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
[b] Saga University, Japan
E-Mail: [a]ronny_mardiyanto@yahoo

**Abstrak**

Permasalahan penggunaan keyboard dengan kendali mata adalah tingkat akurasi, kecepatan yang rendah, dan kesulitan dalam menggunakan tombol kombinasi. Penggunaan sistem Interaksi Komputer Manusia (IKM) berbasis mata dalam jangka waktu yang lama dapat menyebabkan kelelahan. Pada penelitian ini diusulkan *keyboard* baru dengan sifat bergerak. *Keyboard* yang diusulkan terdiri dari dua bagian yaitu bagian utama (bersifat bergerak, dapat digerakkan oleh pengguna menggunakan mata dalam proses pemilihan hurufnya) dan bagian pengendali gerak (terdiri dari lima tombol besar yang transparan, digunakan untuk mengendalikan gerak *keyboard* bagian utama). Metode pendeteksi keberadaan pengguna digunakan untuk mengurangi kelelahan. Penambahan tombol *shortcut* pada layout utama memungkinkan pengguna melakukan fungsi khusus. *Keyboard* baru ini memiliki kelebihan diantaranya memiliki tingkat akurasi yang tinggi, lebih cepat dalam melakukan pengetikan, memiliki ukuran yang lebih kecil, memungkinkan pengguna menggunakan fungsi tombol kombinasi, dan dapat meminimalkan efek kelelahan saat pengguna menggunakan sistem IKM berbasis mata dalam jangka waktu yang lama. Hasil pengujian yang dilakukan membuktikan bahwa *keyboard* ini memilki tingkat akurasi yang lebih baik (92.26%) dibandingkan *keyboard* jenis tetap (78.57%). Juga, dalam melakukan pengetikan 14 huruf *keyboard* ini lebih cepat (134.69 detik) dibandingkan *keyboard* jenis tetap (210.28 detik). Pada pengukuran efek kelelahan menggunakan alat *Electro Enchephalo Graf* (*EEG*), *keyboard* ini lebih dapat meminimalkan efek kelelahan dibandingkan *keyboard* jenis tetap.

Kata kunci: *Keyboard* Bergerak, Sistem IKM Berbasis Mata, Akurasi, Kecepatan, Kelelahan.

***Abstract***

*The current problems of keyboard on eye-based Human Computer Interaction* (HCI) *are accuracy, typing speed, fatigue, and the use of combination keys. We propose a new keyboard consist of two parts: the moveable layout and the navigator keys (fixed and transparent). The user appearance detection method is used for reducing the fatigue effect. The adding shortcut keys to the main layout allowing user executes a special functions through combination keys. The new keyboard has advantages on high accuracy, fast, allowing combination keys, and could minimize fatigue effect. The experiment results show that the new keyboard could achieve better accuracy (92.26%) compared to the fixed keyboard (78.57%). Also, the new keyboard improved accuracy 134.69% than the fixed keyboard(210.28%) when used for typing fourteen character over eye-based HCI. Moreover, we measured the fatigue effect by using Electro Encephalo Graph (EEG) over both methods and the result shows that the new keyboard could minimize fatigue better than the fixed keyboard. By implementing the new keyboard on real eye-based HCI, user could type characters easily, fastly, and no burdened with fatigue effect.*

*Keywords: Keyboard, Eye-based HCI, Accuracy, Typing Speed, Fatigue.*

## INTRODUCTION

Recently, the number of handicap person is growing annually (especially the number of paraplegics). A study investigated in 2009 by Christhopher and Dana Revee Foundation [1]; the handicap person of American raised 40% compared to 2007 (total handicap person is 5.6 million in 2009). It also reported that in 2009; the number of spinal cord injury raised to five times compared to 2007. It figures out that the number of handicap person will always rise annually since it is difficult to recover them back.

There are several causes of person become a paraplegic. According to Christhopher and Dana Revee Foundation's report, it could be classified as follow: (1) working accident (28%), vehicle accident (24%), and sport accident (16%), fall (9%), victim of violence (4%), born defect (3%), disaster (1%), and others. According to the age distribution, the most potential of person become paraplegic is the person with age in range 40 to 49 years (25.4%) and 50 to 59 years (22.8%).

The increasing of the number of handicap person that explained above insist researcher to develop a new technology for helping them to survive in the daily life. A technology called eye-based Human Computer Interaction (HCI) has been widely used for helping handicap person by replacing half or full missed activities of handicap person with the eye as main controller/input.

Nowadays, there are so many methods being developed by many researchers for improving eye-based HCI. The eye-based HCI still has many difficulties for working in the real environment. The most challenged issue of eye-based HCI is how to improve accuracy perfectly. The accuracy related to many factors such as illumination/light changing, noise from camera, face movement, deformable of an eye due to eye movement, various skin color, various eye type, etc. The aforementioned factors should be eliminated for creating an ideal eye-based HCI.

In this paper, the accuracy is improved by developing a new keyboard. Beside for improving accuracy, the proposed keyboard could also minimize the fatigue effect when eye-based HCI is being used by the user during a long period. The proposed keyboard consists of two main parts: (1) Moveable layout (could be moved step-by-step by the user) and (2) Navigation keys (five expanded and transparent buttons for moving the moveable layout). User hits a key by controlling the position of moveable layout using the navigation keys (operated by using eye). We add shortcut keys to the main layout allowing user executes special functions such as "CTRL+C" and "CTRL+V" for copying and paste respectively, etc. Beside the new interface, we also propose the use of user existence detection method for avoiding the fatigue. In experiments, we test the performance of the new keyboard by conducting several measurements such as accuracy and time speed (conducted by users type fourteen character using the new keyboard under eye-based HCI system), fatigue effect (measuring the fatigue effect/brain-load by using Electroencephalograph), and the accuracy of user existence detection. Same experiments also conducted to original windows screen keyboard as a comparator. By implementing the new keyboard, eye-based HCI could be used easily and accurately without burdening the user with fatigue effect.

The use of eye for connecting human and computer has been gaining a lot of attention by many researchers[2-7]. Unfortunately, the implementation of eye-based HCI under real environment is still difficult to be implemented (limited to laboratory/indoor environment) due to the existence of disturbances. The disturbance such as illumination/light changing, various camera types, various user skin and color, etc have to be eliminated for creating an ideal eye-based HCI. There are two ways for improving the accuracy: (1) improving accuracy through improvement of sight estimation method and (2) interface modification. In this paper, we focus on accuracy improvement through interface modification.

The discussion of interface modification is related to variant of eye-based HCI keyboard. The published modification keyboards could be classified into two types: (1) on-screen keyboard (the keyboard is visible on the display) [4,5,7] and (2) off-screen keyboard (the keyboard is invisible on the display) [3,6]. All types of keyboards will be explained in detail as follow.

In [3], the left-right controller, controlled by eye, has been used for typing a key. The system detected right-left movements of eye by detecting the symmetric relationship between the right and left of eye. The system was successfully installed in a computer game called ”the block escape” and word spelling.

In[4], mouse pointer controlled by sight with virtual keyboard displayed on the monitor to entry the text. The 95% result could be achieved on a key with size more than 25 pixels.

In [5], the used a new keyboard called ”scrollable keyboard” with hidden keys for saving the space and size.

An off-screen keyboard type has been proposed by Isokoski [6]. They designed the bottom on outer side of display for full-used space of display. The Morse code could be used for typing a text under a simple interface.

In [7], they implemented eye tracking by using Tobii eye tracker (commercial tool for tracking eye) and hierarchy menu bottom showing on the screen.

In mentioned proposed methods above, the eye-based HCI is not a new technology. It has been developed by many researchers. In more detail, the technology of eye-based HCI keyboard has been proposed by many researchers. Although many eye-based HCI keyboards have been proposed, it still has many challenges especially in the accuracy improvement. The accuracy goes down if the number of key increases. Moreover, increasing the number of key causes the key size becomes small or size of keyboard become wide. Also, the keyboard should have less fatigue effect. Moreover, it also should allow user executes keys combination for key shortcut function such as “CTRL+C” (shortcut of copy function), “CTRL+V” (shortcut of paste function), etc. The accuracy result relies on the stability of sight estimation output. The maximum stability could be reached by using high resolution of camera without any noises. Unfortunately, the noise always appears in the real situation. Noise may affect the sight estimation result and make it becomes unstable. The decreasing of stability causes accuracy goes down. The relationship of stability to accuracy is shown in Figure 1.

Figure 1 shows that if the instability is high (radius of instability is high), the sight estimation result may be outside of desired key. In this case, user is looking at “G” character, unfortunately the existence of instability make estimation becomes error and hit the wrong character/key.

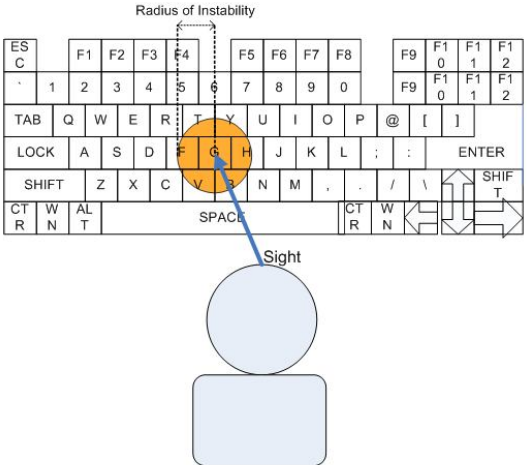


Figure 1. Instability Influences Accuracy

## PROPOSAL METHOD

In this paper, we propose a new keyboard allowing user moves the main layout. Basically, it simplifies the original keyboard with spread keys to looks same keyboard but with different controlling method. In this keyboard, user moves the layout by using eye-based navigator keys. By using eye-based navigator keys, user moves the intended key on layout to the centre and then chooses it using the selection mode (timer or blinking mode). The proposed method aimed for improving accuracy, allowing combination keys, speed up typing speed, reducing fatigue effect, and more reliable in the real environment. The problem of accuracy in eye-based HCI could be explained in Figure 1.

Accuracy level is affected by following factors such as (1) the instability of sight estimation output, (2) size and number of key, and (3) key position. The phenomenon of instability to accuracy has been explained in Figure 1. In Figure 1, if the user looks at a key, the output of sight estimation could be at different key following the radius of instability. The high stability cause radius of instability becomes smalland more accurate. The second accuracy parameter is the size and the number of key. The increasing of key size makes the total size of keyboard becomes bigger. As a result, the screen space on display shrinks. This phenomenon has a disadvantage on the number of application that could be shown in display decreases. If one display usuallycould show five applications simultaneously, the increasing of the size of keyboard makes the allowed applications showing simultaneously reduce. It is the reason of the use of off-screen keyboard in eye-based HCI. The placement of key in the outside of the display allows the use of display in the maximum number of application could be running simultaneously. In another way, we could increase the key size without changing the total size of the keyboard, but it makes the number of key decreases. The increasing of key size become twice bigger insists us to reduce the number of key become half as a result. It means that the original keyboard style could not increase key size and maintain the total size of keyboard simultaneously. In the proposed keyboard, we would increase accuracy of eye-based HCI by increasing key size without changing the total size of key. In the previous investigation, we release a theory that accuracy and key size has a linear relationship. The use of bigger key size has better accuracy than the smaller one. So, we could say that if we want to improve the accuracy, an alternative way is increasing the key size. We make formulas as follow.

$$A \approx \frac{S}{SD} x100\% \text{ , if SD} \geq \text{S} \quad (1)$$

$$A \approx 100\% \text{ , if SD} < \text{S} \quad (2)$$

We determine *A* as accuracy, *S* is key size, and *SD* is the radius of instability. Two formulas above explain that accuracy decrease if the radius of instability increase. The accuracy increases if the key size increases (linear relationship). The 100% accuracy could be reached perfectly if the radius of instability is less than the key size.

According to explanations above, we could say that instability is the most factor for improving accuracy. The instability it self is affected by several matters such as noise from camera, distance between camera and eye, illumination disturbance, deformable of eye shape, etc. The influence of distance between camera and eye to instability could be explained in Figure 2.

Figure 2 shows the radius of instability increase as a result of increasing the distance camera to eyes. This phenomenon is explained in detail as follow. Camera acquires eye image in the same resolution. The move out of the eye makes it become smaller showed in image. Otherwise, the move in of the eye makes it become bigger. Due to the noise, sight estimation result may obtain unstable output. This output has to be gained with the distance camera to eye. It means that the radius of instability also has to be gained with the distance.It means that in farther distance, the multiplier for the radius of instability is bigger. It makes the farther distance has bigger radius of instability compared to the closer one. In Figure 2, we have two kinds of distances d1 and d2. The distance 1 (*d1*) obtains radius of instability SD 1. Also, the distance 2 (*d2*) obtains SD 2. SD 1 is less than SD 2 because *d1* is less than *d2*.

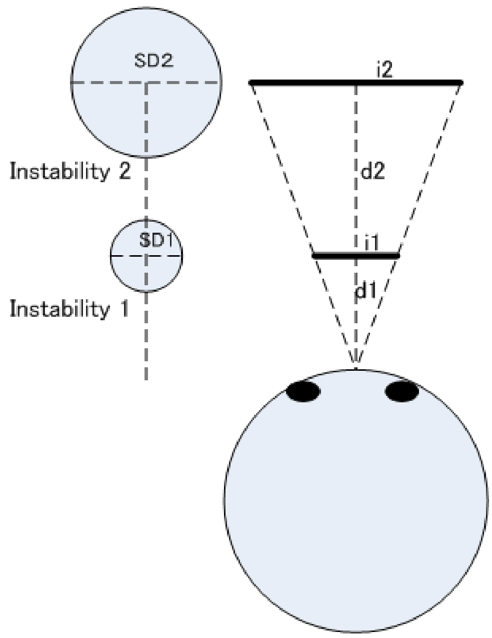


Figure 2. Distance Camera to Eyes Influences Instability.

Another paramater influencing the stability is the deformable of eye shape. If the eye is looking at the center, camera acquires eye clearly. There is no mixing among eye components. We could call it as an ideal eye pose. By using an ideal eye pose, sight estimation method could predict the eye location easily and preciasily. Unfortunately, eye always changes due to sight changing. Every sight changing has an impact in the changing of eye shape. Eye looking at the center has different image with eye looking at the edge. Moreover, if eye looking at the edge, the mixing among eye component occurs. It makes an error in the sight estimation. The sample of deformable eye shape is shown in Figure 3.

In this paper, we propose a new keyboard for improving accuracy, allowing combination keys, speed up typing speed, and minimizing fatigue effect by changing the layout interface and adding shortcut button on the layout. Moreover, the propose keyboard is expected for maintain typing speed when eye-based HCI has worse sight estimation output. In the proposed keyboard, we design the keyboard by maintaining the relationship of accuracy to size of key, position of eye, and radius of instability. We change the original QWERTY layout to bigger keys without changing the total size of the keyboard. We add navigator keys having bigger key size for improving hit accuracy. The navigator keys have five transparent keysallowing it controlled by using human eye. It means that we change the number of key to only five transparent key. This technique has an advantage in increasing the size of key without changing the total size of the keyboard. Moreover, we add other functional keys without burden the accuracy because the key layout is in the second layer. The first layer is navigator keys for controlling the main layout (secondary layer).

The proposed keyboard consists of two main parts: (1) main layout (moveable with QWERTY as the key arrangement) and (2) Navigator keys (static layout and five transparent keys). The function of navigator keys is for controlling the main layout. It means that user controls the movement of main layout by navigating the navigator keys. The navigator keys allow user moves the main layout to Omni-directional such as left, right, downward, and upward. For selection, user could choose two selection modes: (1) timer mode and (2) blinking mode. The proposed keyboard is shown in Figure 4. In the proposed keyboard, we add three additional buttons such as “HLD” for hold, “RLS” for release, and “COM” set to custom combination keys.

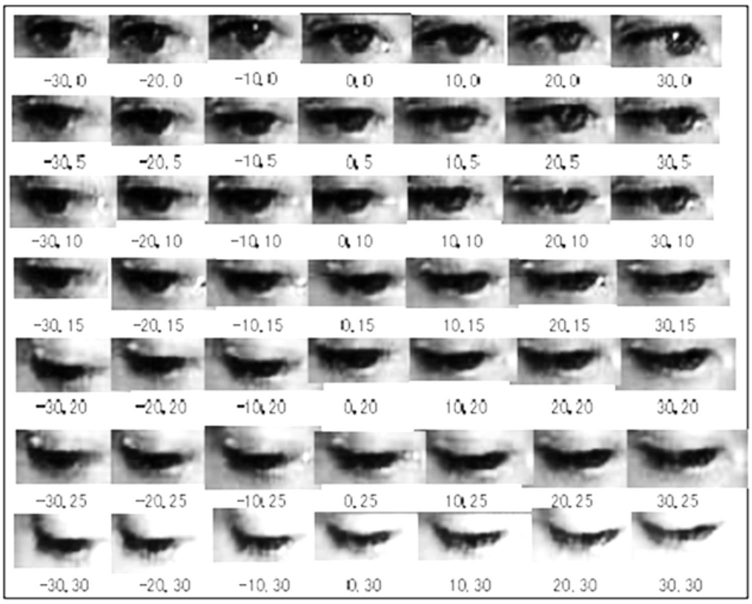


Figure 3. The Changing of Eye Shapes.

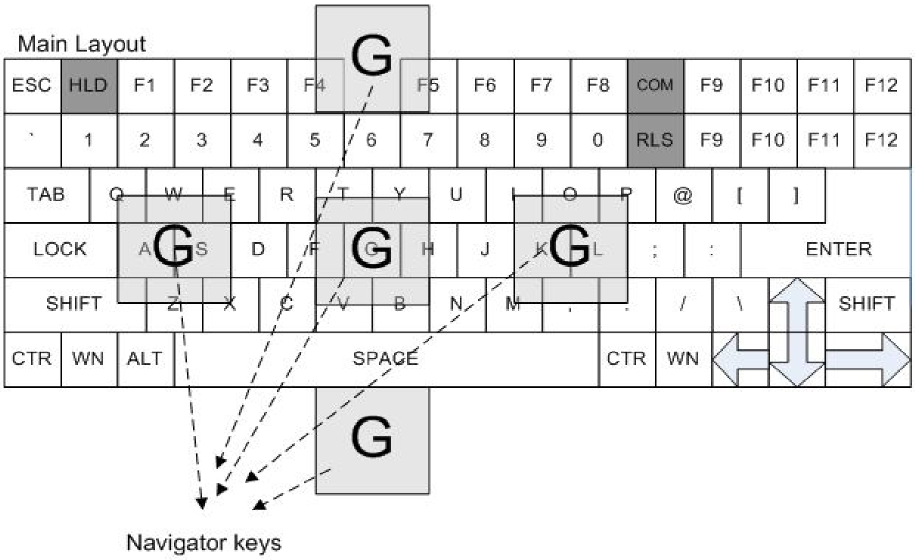


Figure 4. The Proposed Keyboard.

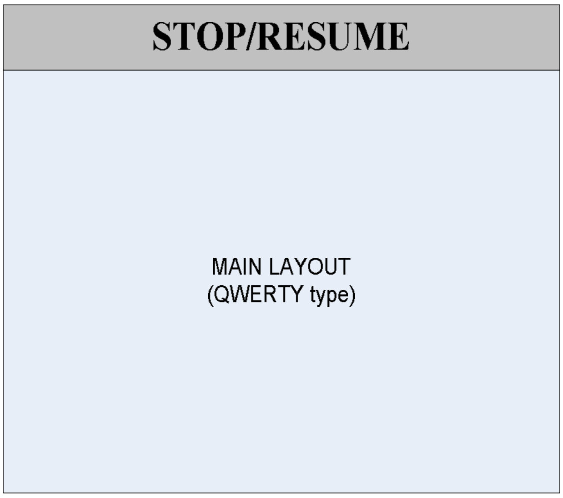


Figure 5. Interface Modification Allowing User Break for A While.

The manual use of the proposed keyboard is explained as follow. The initial position of candidate of selected key is always on "G" character. If the user wants to select the "G", we could use one of our selection mode (will be explained later). If the user wants to select different key, he has to move the main layout until the desired key located in the center. For instance, user wants to select "A" character. From the initial position ("G"), user has to move the main layout to right four steps. To done this, user has to look at right navigator keys. User holds his sight to right navigator key while the main layout moves to right step-by-step. Once the desired key located in the center and the character is shown on navigator key, user has to look at the center of navigator key. The next step is selection mode than will be explained as follow.

In eye-based HCI, there are two famous methods for selection mode: (1) blinking mode and (2) timer mode. The blinking mode means the blinking triggers the selection. The blinking is determined as the user wants to select the candidate of selected key. Another method is timer mode. In this mode, user does not need a special action. User just holds the key until a specific duration time. For instance, user wants to select "A" character while the current center position is "A". To select "A", user just do blinking (for blinking mode) or hold until a specific duration time (for timer mode). In timer mode, selection will be executed automatically until a specific duration time is reached.

Another phenomenon in eye-based HCI is the existence of fatigue effect as result of the use of eye-based HCI in long duration time. In every use of eye-based HCI, the user almost feels tired. It happens because the original function of the eye is not for controlling things. It is just for seeing the scenery. It is why the use of eye for replacing the function of hand always has a side effect in the tiredness.

In order to perform the seeing function, eye also is supported by another action such as blinking. The blinking has the original functions for maintaining moisture of eye and avoiding unwanted things enter the eye. Beside the mentioned functions, blinking is also effective to reduce the fatigue (if a human become fatigue, the frequency of blinking increases). The use of eye-based HCI in long duration makes user become fatigue, especially physiological fatigue. When user is holding the neck and moving head during a long period, the muscle may become tired. Beside the physiological fatigue, the use of eye-based HCI triggers another fatigue such as cognitive fatigue. The cognitive fatigue occurs if the user changes the target point frequently. From the explained type of fatigue, we could categorize the type of fatigue as the effect of the use of eye-based HCI into three categories: (1) eye tiredness, (2) cognitive fatigue, and (3) physiological fatigue.

For avoiding or reducing fatigue, human body already has an effective way to solve it. If body become tired, the effective ways to recover the body condition is by take a rest. It happens also for eye. If eye become fatigue, the effective ways are by making eye take a rest. The take a rest is believed effective to recover eye/body condition. According to this way, we propose a method for avoiding fatigue by making eye take a rest for a while. We provide a way allowing user take a rest for a while when using the proposed keyboard as shown in Figure 5.

In Figure 5, user could drive the layout to upward for breaking a while. If the "STOP/RESUME" button is selected, system will become idle. During the idle condition, user could take a rest until fresh condition is reached. Once user has been recovered, user selects the "STOP/RESUME" button again to continue the typing.

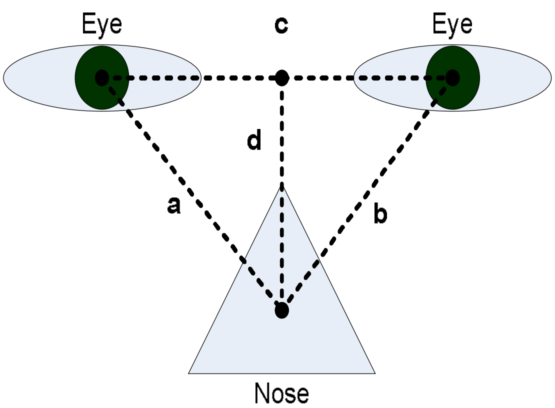


Figure 6. The User Existence Detection Method.

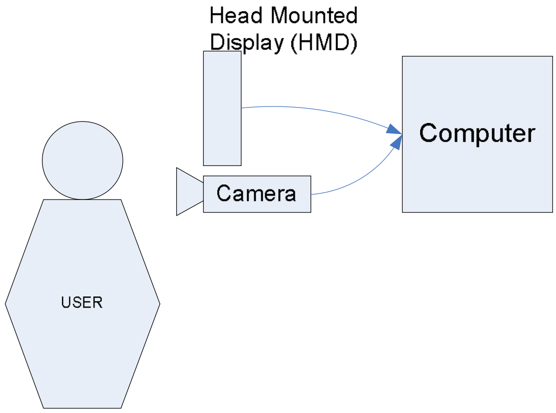


Figure 7. Implementation of Proposed Keyboard in Eye-Based HCI.

Table 1. Key Arrangement for Investigating The Relationship of The Number of Key to Accuracy.

| Number of Target Keys | Key Arrangement |
|---|---|
| 2 | 6, 10 |
| 3 | 6, 8, 10 |
| 5 | 3, 6, 8, 10, 13 |
| 7 | 1, 3, 5, 8, 11, 13, 15 |
| 9 | 1, 3, 5, 6, 8, 10, 11, 13, 15 |
| 15 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 |

Another method for avoiding fatigue is by using user existence detection method. It checks whether user face exist in front of the camera or not. In a situation with the user is feeling fatigue, user could just goes from the chair and take a rest by going to another place. Beside it could avoid the fatigue, the user existence detection method is desired to be effective for error avoiding as a result of the absence of user's face on image. The user existence detection method is shown in Figure 6.

Principally, The user existence detection method checks whether user's face is in front of the camera or not. If there is no face detected on image, system will reset all parameters to the initial condition. This method consists of two parts: (1) detecting face as a result of the shifts of face (face shifts to the outside area of image) and inexistence of face as a result of head rotation. For part one, we detect the shifts by calculating the average location of three reference points (two eyes and nose). For part two, we detect it by using following rules.

1. If |a-b| > threshold, we define it as face disappears horizontally,
2. If d < threshold, we define it as face disappears vertically,

where *a* and *b* are distance between nose and eyes, *c* is distance betwen two eyes, and *d* is distance between center of eye and nose. By using rules above, the user existance could be detected and user may take a rest when he feels fatigue.

## RESULT AND DISCUSSION

Several experiments were conducted for measuring the performance of the proposed keyboard such as measuring accuracy, typing speed, and the effectiveness of the method for avoiding fatigue. We used the standard QWERTY keyboard as a comparator.

### Implementation

We have implemented the proposed keyboard in eye-based HCI system as shown in Figure 7. User's sight was estimated by using a camera mounted on user glasses equipped with Head Mounted Display (HMD). In the system, we utilized an infrared type of camera NetCowBow DC-NCR 131, a computer Optiplex 755 dell having Core 2 Quad 2.66 GHz CPU, and 2G RAM. The aim of the use of IR camera is for maintaining the illumination condition and also extracting the pupil.

### Experiment for Investigating A Relationship between The Number of The Key to Accuracy

In this experiment, an investigation was conducted for explaining a relationship between the number of key to accuracy. As we explained in the last theory, the increasing of the number of the key may decrease the accuracy (accuracy decrease as a result of the increasing of the number of key). Otherwise, the eye-based HCI with a small number of the key has better accuracy than the larger one. In this experiment, we would like to explain this relationship through experiments. Experiments were conducted by user hits several target keys, and we recorded the error. The number of target keys is adjustable from two keys until fiftheen keys. The arrangement of the target keys is shown in Table 1, and the key layout is shown in Figure 8.

After we made an investigation, we got the relationship of the number of key to the accuracy as shown in Figure 9. In Figure 9, it shows that the accuracy decreases (error increases) as a result of the increasing of the number of key. It proves the theory about the relationship of the number of key to accuracy.

### The Accuracy and Typing Speed

To prove that the proposed keyboard has better accuracy than the original standard keyboard, we made the experiment by the user typing a word while we recorded the accuracy and typing speed. The result compared to the original QWERTY keyboard.

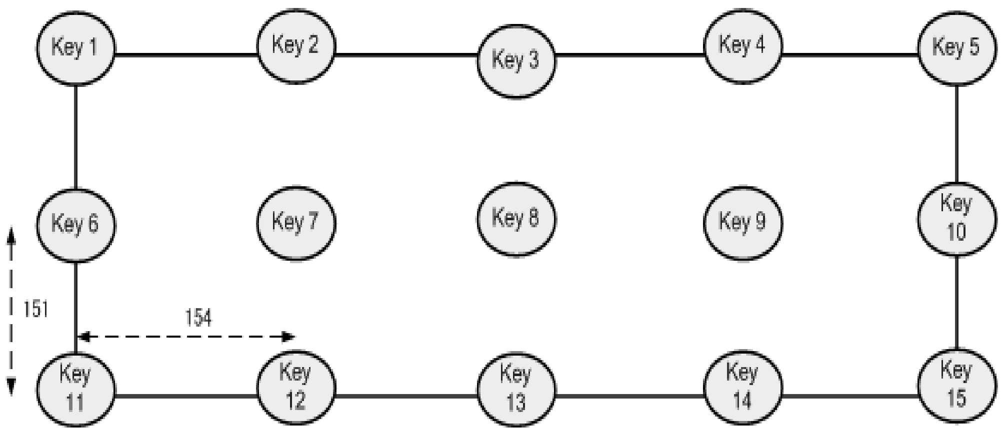


Figure 8. Key Layout.

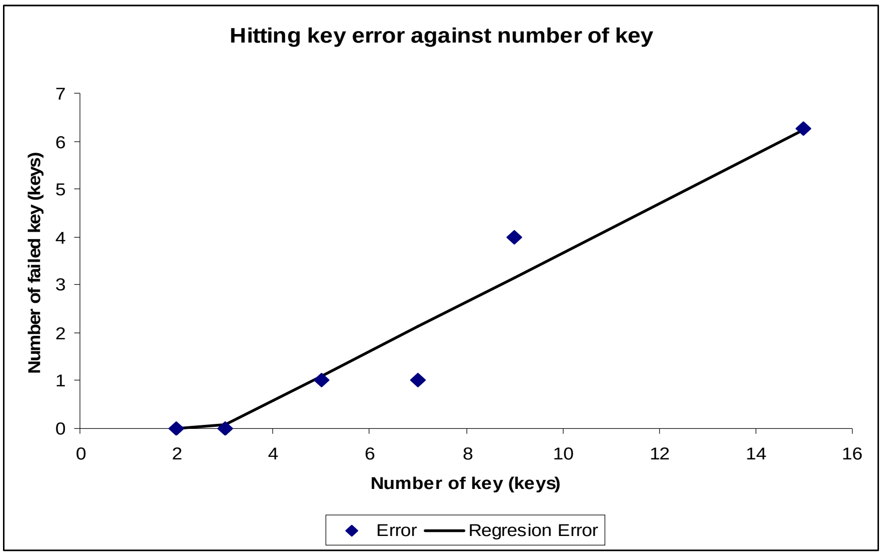


Figure 9. Relationship of The Number of Key to Accuracy.

Table 2. Accuracy.

| User | Type of user | Our Keyboard (%) | QWERTY keyboard (%) |
|---|---|---|---|
| 1 | Expert | 100.00 | 92.86 |
| 2 | Expert | 100.00 | 76.19 |
| 3 | Beginner | 82.14 | 71.43 |
| 4 | Expert | 100.00 | 85.71 |
| 5 | Beginner | 71.43 | 78.57 |
| 6 | Expert | 100.00 | 66.67 |
| Average | | 92.26 | 78.57 |

Table 3. Typing Speed.

| User | Type of User | Our Keyboard (s) | QWERTY Keyboard (s) |
|---|---|---|---|
| 1 | Expert | 117.50 | 154.00 |
| 2 | Expert | 138.67 | 195.33 |
| 3 | Beginner | 180.50 | 275.00 |
| 4 | Expert | 101.00 | 197.33 |
| 5 | Beginner | 161.50 | 213.00 |
| 6 | Expert | 109.00 | 227.00 |
| Average | | 134.69 | 210.28 |

In the experiment, we have an limitation in eye-based HCI system can not be used by original QWERTY keyboard (due to its instability). If we force the experiment by using real eye-based HCI, it looks not fair for original QWERTY keyboard. Considering the mentioned reason, we conducted the experiment by using head-based HCI system (we grounded the eye sight parameter, as we know that the real eye-based HCI output is obtained from two parameters: (1) eye sight and (2) head pose. So, head's pose controlled the output to drive pointer for selecting a key using both methods. The same HCI system was run by using both keyboards. By using the same HCI system, we think that it is a fair comparison for the proposed method.

The experiment involve six volunteers as users. Our volunteers consist of several types of ages start from 30 years to 41 years. Also, they could be classified into two types of users: (1) beginner and (2) expert. We determine beginner user if they ever used the proposed system maximum ten times. Otherwise, we determine expert user if they ever used the proposed system minimum ten times. In the experiment involving expert users, we did not give a briefing and practice before the experiment. Otherwise, we gave beginner user a briefing about how to use the proposed system and practice.

The experiment results of accuracy is shown in Table 2. Table proves that the proposed keyboard has better accuracy than the original QWERTY keyboard with the average of accuracy is 92.26% (The original QWERTY keyboard only has the average of accuracy 78.57%. It means that the proposed proposed keyboard has 16.69% better accuracy than original QWERTY keyboard. In Table 2, it has opposite result to the average in user 5. In user 5, he is a beginner user. He had difficulty operated the proposed keyboard.

We also made an experiment for measuring typing speed. We recorded the typing speed of all users when using both keyboards. Users have to type fourteen characters using our HCI system. The experiment result is shown in Table 3. Table 3 shows that the proposed keyboard is faster than the comparator one. It was caused by the instability of sight estimation result triggers the typing correction. Due to typing correction, users had to repeat the hitting key until right key was selected. Otherwise, the instability does not influence the accuracy of the proposed keyboard. It was caused by the proposed keyboard uses bigger key size. The result proves that simplifying the number of keys to five keys (navigator keys) is effective and make user could type characters under eye-based HCI easily and fastly.

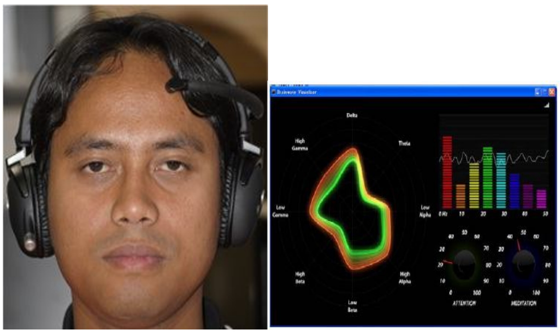

Figure 10. The Use of EEG Neurosky and Its Output.

Table 4. The Most Relax Condition Shown by Highest PAF.

| User | Maximum of PAF | |
|---|---|---|
| | Proposed Keyboard (Hz) | Original QWERTY Keyboard (Hz) |
| 1 | 11.95 | 11.64 |
| 2 | 11.65 | 11.58 |
| 3 | 11.44 | 11.62 |
| 4 | 11.34 | 11.32 |
| 5 | 11.57 | 11.37 |
| 6 | 11.43 | 11.46 |

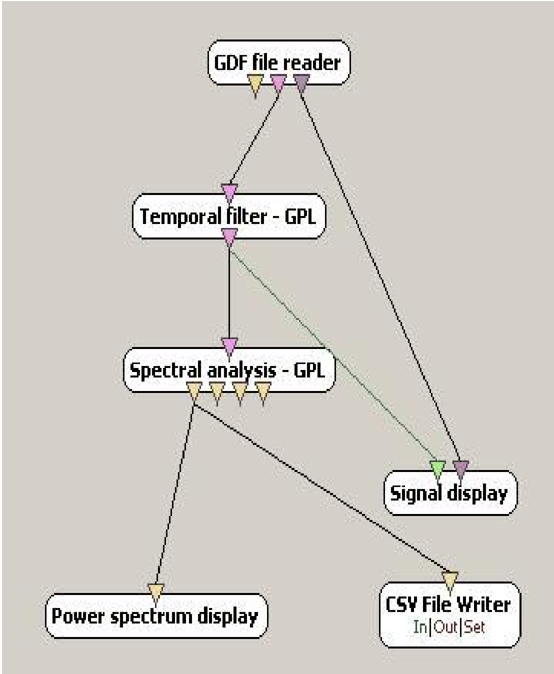


Figure 11. Scenario for Calculating PAF.

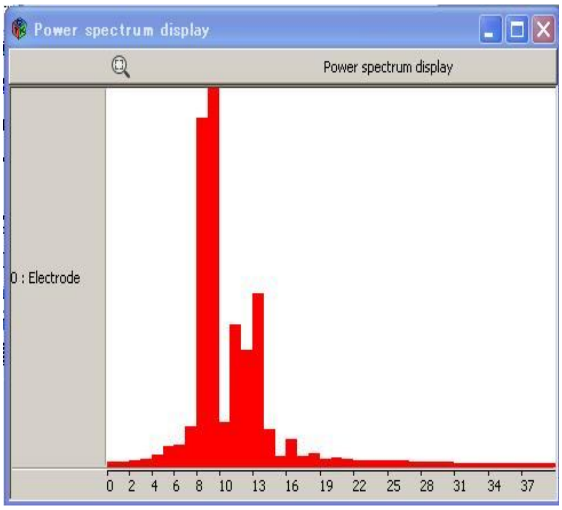


Figure 12. Output of Open Vibe.

Table 5. The Most Stress Condition Shown by The Lowest PAF.

| User | Minimum of PAF | |
|---|---|---|
| | Proposed Keyboard (Hz) | Original QWERTY Keyboard (Hz) |
| 1 | 9.87 | 9.73 |
| 2 | 9.86 | 9.65 |
| 3 | 9.92 | 9.77 |
| 4 | 9.75 | 9.38 |
| 5 | 9.77 | 9.36 |
| 6 | 9.60 | 9.72 |

### Tiredness

In the last experiment, we conducted an investigation of fatigue effect as a result of the use of both keyboards in eye-based HCI. The experiment will proves which is the most effective keyboard for reducing fatigue effect in eye-based HCI. As we explained before, the use of eye-based HCI during a long period may cause fatigue effect. It may occurs when user choosing key (sight changing) or user using eye-based HCI during a long period.

For testing fatigue effect, we measure it through the brain signal. We recorded brain activity signal when users are using both keyboards under eye-based HCI. Both recorded signals were compared for claiming which is the best keyboard for minimizing fatigue effect.

For brain activity measurement we used Electroenchepalograph (EEG). The EEG sensor NeuroSky was used in the experiment. The recorded EEG data was proceeded by using OpenVibe for calculating the Peak Alpha Frequency (PAF). The use of EEG NeuroSky and its output is shown in Figure 10.

In this experiment, the fatigue was measured based on methods published by [8-9]. According to these methods, the fatigue could be measured based on Peak Alpha Frequency (PAF). The PAF calculation was done by using OpenVibe with a scenario as shown in Figure 11 and the result is shown in Figure 12.

The experiment involved six volunteers then each PAF results of both keyboard were compared as shown in Table 4 and Table 5. The results consist of relax/rest condition and most stress condition.

In the experiment result, it is shown that in user 1, 2, 4, and 5 feel more relax and do not burden them when using the proposed keyboard. Otherwise, the original QWERTY keyboard loads user brain shown by lower PAF. Different results occur in user 3 and 6, they felt more relax when using original QWERTY keyboard. It was caused by they are beginner users, it makes them are difficult to use the proposed keyboard. Fortunately, they could improve their skill to operate the proposed keyboard by practice.

### User Existence Detection

We measured the time for recovering system if face disappears. Once face could not be detected, system will become idle. If the system detects face again, the recovery process is started. We conducted the experiment by system recognizes invisible user's face and recover it back. We recorded the time of the recovery process for ten trials. We got the average time is 8.7 seconds.

### Implementation Of Proposed Keyboard In Eye-Based Helper Robot System (HRS)

One of application of proposed keyboard is for controlling eye-based HRS. In our research, we developed an eye-based HRS allowing could be controlled remotely. The aim of our HRS is for helping handicap patient in hospital. By using eye, a stroke patient could be served by HRS for self service in the hospital environment. Daily activities in hospital such as calling a nurse, having a meal or drink, etc could be done by patient in itself with the help of our eye-based HRS. User does it by looking at display equipped by camera. A camera estimates user's sight and used it for controlling HRS. User could see the scenery in front of robot by using another camera setup on the robot. In this system, the proposed keyboard is used for typing a text then will be translated and converted to voice by using Text to Speech function. It will allow user send a command via voice to a nurse or other helper in the hospital environment. The HRS block diagram and hardware is shown in Figure 13 and 14, respectively.

## CONCLUSION

The proposed keyboard has been successfully implemented in eye-based HCI. It successfully improved the accuracy though the use of navigator keys. Also, the accuracy is significant better compared to the original QWERTY keyboard. Moreover, the proposed keyboard successfully skipped typing correction and makes it types faster than the original QWERTY keyboard. In the fatigue effect, the proposed keyboard successfully minimized the user tiredness when using eye-based HCI during a long period.

Even the proposed keyboard has successfully improved accuracy; we still could improve the accuracy through improving sight accuracy method. Therefore, our further work is an improvement in sight estimation method.

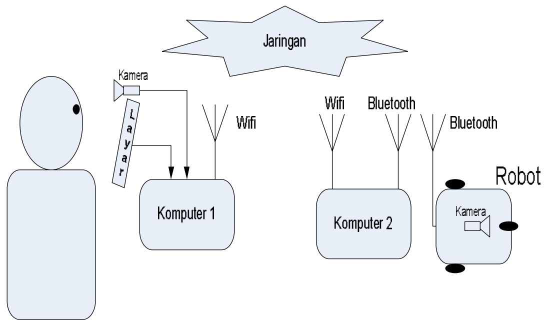


Figure 13. Block Diagram of Eye-Based HRS.


Figure 14. Our HRS Hardware.

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