

# Wearable Computing System with Input-Output Devices Based on Eye-Based Human Computer Interaction Allowing Location Based Web Services

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**Abstract**—Wearable computing with Input-Output devices Base on Eye-Based Human Computer Interaction: EBHCI which allows location based web services including navigation, location/attitude/health condition monitoring is proposed. Through implementation of the proposed wearable computing system, all the functionality is confirmed. It is also found that the system does work well. It can be used easily and also is not expensive. Experimental results for EBHCI show excellent performance in terms of key-in accuracy as well as input speed. It is accessible to internet, obviously, and has search engine capability.

**Keywords**—eye based human computer interaction; wearable computing; location based web services

## I. INTRODUCTION

For many years, wearable computing system has been studied. Not so small number of wearable computing systems has been proposed so far. One of the difficult problems on wearable computing systems is input and output devices in particular input device. There are some proposed input devices for wearable computing systems such as “Project Glass”<sup>1</sup> and “Contact Lens”<sup>2</sup>. These require relatively expensive devices such as projector which allows display a keyboard on hand or arm, and contact lens which has keyboard layout in the lens. On the other hand, Eye-Based Human Computer Interaction: EBHCI is proposed together with camera mouse [1]-[27]. EBHCI can be used as computer input device with human eyes only. Also camera mouse allows the entire mouse operations (click right and left button and drag and drop operations) with human eyes only. Computer input can be done with just by sight. EBHCI requires just web cameras, and display with Bluetooth capability. Furthermore, only thing users have to do is just looking at the desired key which is displayed onto Head mount Display: HMD. Also users can easily manipulate mouse with their eyes by looking at the icons. Therefore, EBHCI based wearable computing system can be created with not so expensive cost. Furthermore, it is easy to use.

In this paper, EBHCI based computer input device is proposed together with wearable computing system utilizing

EBHCI based device. Users may use web services including search engine during making actions. For instance, users may use search engine when they are walking. A variety of applications is available with the proposed wearable computing system. For example, users are navigated with the proposed system. One of key issues here is computer key-in devices, camera mouse, and indoor location estimation. Key-in accuracy of the proposed system, therefore, has to be clarified together with indoor location estimation accuracy.

The following section describes the proposed wearable computing system and examples of the applications of the proposed system. Then key-in accuracy assessment results is followed by through some experiments together with the indoor location estimation accuracy evaluation results. Then conclusion is described together with some discussions.

## II. PROPOSED METHOD

### A. Configuration of the Proposed Wearable Computing System

Configuration of the proposed wearable computing system is shown in Figure 1.

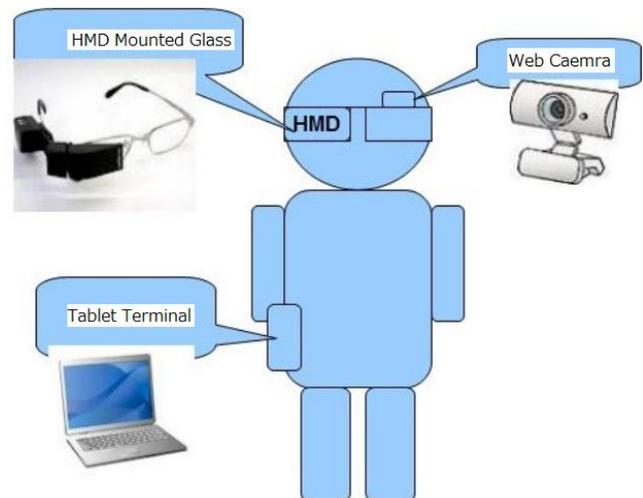


Fig.1. Configuration of the proposed wearable computing system

Users wear the Head Mount Display: HMD mounted glass. The glass also carries backward looking camera. The backward

<sup>1</sup> <http://arkouji.cocolog-nifty.com/blog/2013/01/googleproject-g.html>

<sup>2</sup> <http://commonpost.boo.jp/?p=19724>

<http://japanese.engadget.com/2008/01/17/researchers-put-circuits-on-contact-lenses-freak-out-rabbits/>

looking camera looks users' eye. Users' line of sight can be estimated with the acquired images of the backward looking camera. The HMD and the backward looking camera are connected to tablet terminals through wire and / or Bluetooth communication as shown in Figure 2.

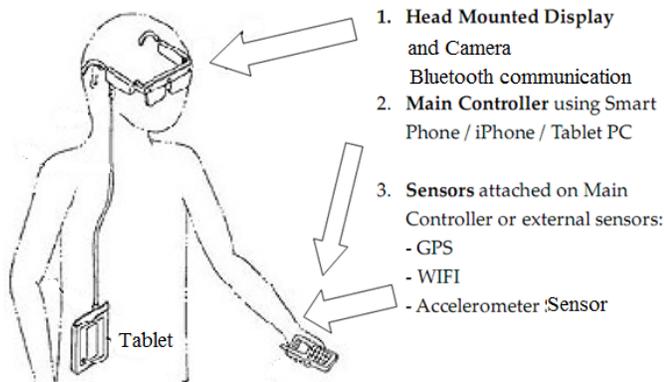


Fig.2. Connections HMD and the backward looking camera to tablet PC and / or mobile phones

The required processes for estimation of the position at which users is looking on the display screen of the HMD through line of sight estimation are done in the Tablet PC. Also gathered data of the user's location and accelerometer data are handled in the mobile terminals or Tablet PC. Therefore, user's location can be known with the GPS receiver data. Even if the user is situated indoors, WiFi capability allows estimation of the user's location by using signal lengths from the nearest three WiFi access points



Fig.3. Single HMD and backward looking camera mounted glass

**B. Computer Key-in with Eye Based Human-Computer Interaction: EBHCI**

One of the key issues here is computer key-in with Eye-Based Human-Computer Interaction EBHCI and Eye-Based mouse as well as location estimation based on the received signal lengths from WiFi access points.

EBHCI uses moving keyboard which is shown in Figure 4. On the typical key layout, there is five enlarged keys. The key at which user is looking is shown at the center key of the enlarged five keys. The character of the center key, therefore, may change depending on the gaze location where user is looking at. When user looks one of the four surrounding keys, left, right, top and bottom, then characters for the five enlarged keys are changed in accordance with user's gaze location. For instance, if user is looking at the right key, then the keyboard moves to the right direction with one key step and the

characters of the five surrounding keys are changes simultaneously as shown in Figure 5.

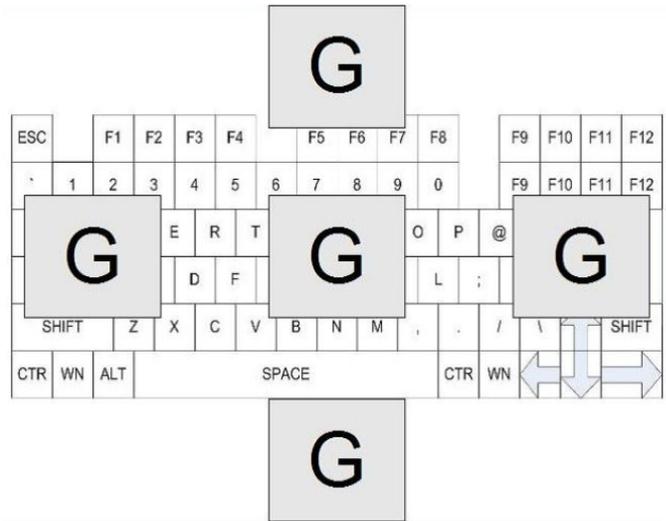


Fig.4. Key layout of the moving keyboard

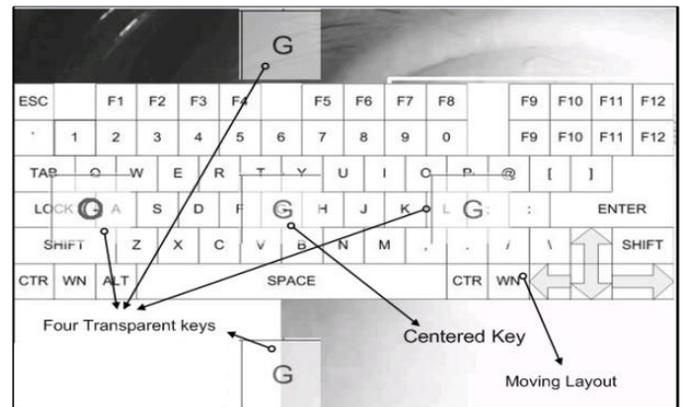


Fig.5. Key layout for the proposed moving keyboard (Circle denotes gaze location)

If the keyboard does not move, then the gaze location has to be determined precisely because key size is too small in comparison to the proposed moving keyboard. User has to retry key-in when the selected key is not intended key due to mis-identification of key location results in it takes much longer time in comparison to the required key-in time for the proposed moving keyboard. Therefore, the proposed moving keyboard does not require precise gaze estimation accuracy and makes high success rate of key-in performance with relatively short time period.

**C. Camera Mouse**

All mouse event and key-in can be done with human eyes only [1]-[15]. In the camera mouse, comparatively high gaze estimation accuracy is needed for identifying icons which are displayed onto HMD screen. Icon hold is available to keep the previous click event by using one additional key for hold. Thus right or left button clicks and multiple key selections are available. For instance, Ctl+Alt+Del for task manager activation can be selected by using the hold key operation. Thus all the icons for application software including search

engine can be activated. Therefore, user can use web services with the proposed wearable computing system.

D. Indoor Location Estimation

Some of the web services need the location information. When user is situated outdoor, GPS receiver included in smart phone, iPhone, or some other mobile devices is used. Location estimation accuracy of GPS receiver, however, is not good enough. It is not always that user is situated outdoor. Therefore, indoor location estimation is needed.

The authors proposed the indoor location estimation method and system. It achieved 2.5m of location accuracy [16]. It would be enough for web services. The first step is to draw a two-dimensional map of the building for data collection and tracking.

Based on the map, we create the grid in a rectangle shape and data gathering route is determined. Each route is stored as one path, and the collected signal data can be stored for each Access Point (AP) on each grid.

The signal strength information collected in the operation outlined above, needs to be processed for noise reduction as well as for the purposes of building a signal strength distribution model. The signal strength data collected from the APs is processed using an adaptive Kalman filtering algorithm to eliminate the noise and interference effects. In building the signal distribution model, interpolation is applied. The signal distribution at each point on the data gathering route is stored in the Radiomap database of the server computer.

In the tracking phase, signal data are processed in real-time by the filtering algorithm of the RSSI is compared with that stored in Radiomap. Based on this comparison, the optimal location is determined and marked on the map efficiently using color representative visualization approach. Thus geolocation utilizing web services are available with the proposed wearable computing system.

III. IMPLEMENTATION AND EXPERIMENTS

A. Hardware

Table 1 shows the major specifications for HMD while Table 2 shows the specification of the backward looking camera. These are attached to a glass. User wears the glass together with tablet PC and / or mobile device as wearable computing system.

TABLE I. SPECIFICATION OF SINGLE EYE OF HMD

|                   |                            |
|-------------------|----------------------------|
| Resolution        | SVGA(800×600pixels)        |
| Supposed distance | 2m                         |
| Supposed size     | 60inch                     |
| Field of view     | 42degree                   |
| Input type        | RGB                        |
| Operable temp.    | 0~40°C                     |
| Size              | 28mm(W)×35.24mm(H)×56mm(D) |
| Weight            | 20g                        |

TABLE II. SPECIFICATION OF NEAR INFRARED CAMERA

|                      |                         |
|----------------------|-------------------------|
| Resolution           | 1,300,000pixels         |
| Minimum distance     | 20cm                    |
| Frame rate           | 30fps                   |
| Minimum illumination | 30lux                   |
| Size                 | 52mm(W)×70mm(H)×65mm(D) |
| Weight               | 105g                    |

B. Software

Figure 6 shows an example of the screen shot of displayed image onto the HMD display. Just behind the moving keyboard, there is an acquired face image. At the bottom right corner, there is an extracted eye image. White circle denotes the detected pupil. The extracted pupil image is situated just beside the bottom enlarged key “F” on the left. Also black circle which indicated the estimated gaze location is situated just bottom right corner of the left enlarged key “F”. In this case, moving keyboard moves to the left key “D” just 0.5 second after user looks at the left enlarged key “F”.

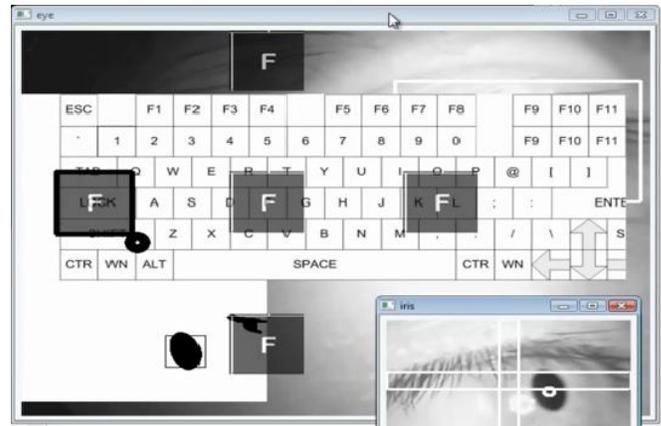


Fig.6. Example of the screen shot of displayed image onto the HMD display

C. Time Required for Key-in

If user looks at the center of enlarged key “F” for more than 0.5 second, then the key “F” is to be selected and determined. Therefore, it takes 0.5 to 5 seconds for one key-in results in approximately 2.5 seconds in average because key array consist five times ten keys typically. Figure 7 shows the time required for eye detection.

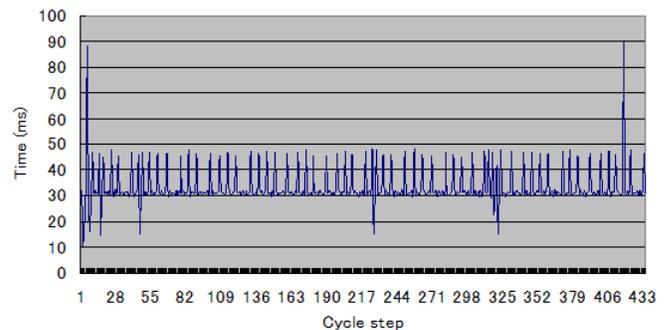


Fig.7. Processing time of eye detection and tracking on steady state condition, it looks faster than transient condition.

Meanwhile, Figure 8 shows the time required for key-in.

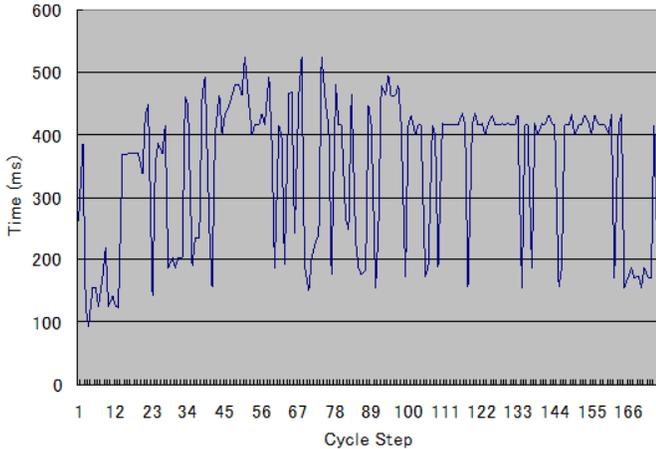


Fig.8. processing time of Eye gaze method

**D. Mouse Operation**

Mouse events are available for the proposed wearable computer. Therefore, application software can be activated by eye based mouse. At the bottom of Figure 9, there is the window for the word processing software is situated. User may confirm the character of which user selected and determined in the opened window.

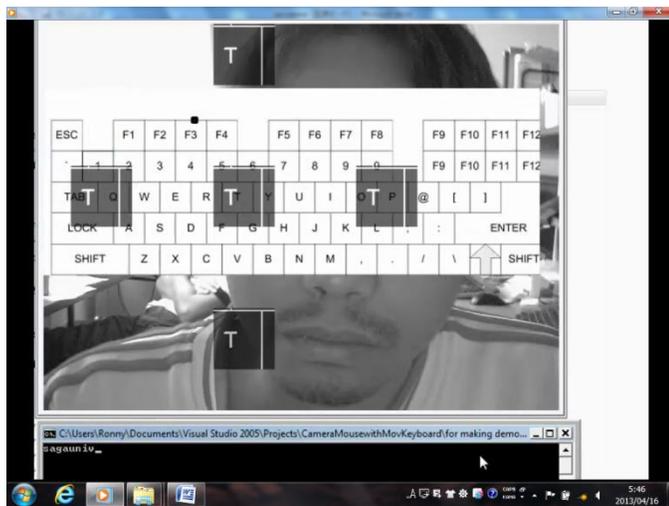


Fig.9. Another window can be opened by using the eye based mouse

**E. Key-in Success Rate**

Key-in success rate depends on the gaze location. Success rate for four corners are much worth than those for center and top, bottom right and left. Due to the fact that enlarged five keys are situated at center and top, bottom right and left of the screen display. Therefore, key-in success rate is almost 100 % for the key location of plus minus 15 degree in pitch direction and for the key locations of plus minus 30 degree in roll direction. The success rate in the horizontal direction is better than those in vertical direction. Meanwhile, success rate for the case that pitch angle is more than 20 degree gets worth as shown in Table 3.

TABLE III. KEY-IN SUCCESS RATE

|                      |                  | Yaw Angle (degree) |     |     |     |      |     |     |
|----------------------|------------------|--------------------|-----|-----|-----|------|-----|-----|
|                      |                  | -30                | -20 | -10 | 0   | 10   | 20  | 30  |
| Pitch Angle (degree) | Success Rate (%) |                    |     |     |     |      |     |     |
|                      | 0                | 100                | 100 | 100 | 100 | 100  | 100 | 100 |
|                      | 5                | 100                | 100 | 100 | 100 | 100  | 100 | 100 |
|                      | 10               | 100                | 100 | 100 | 100 | 100  | 100 | 100 |
|                      | 15               | 100                | 100 | 100 | 100 | 100  | 100 | 100 |
|                      | 20               | 95                 | 99  | 99  | 99  | 85.5 | 39  | 25  |
|                      | 25               | 6                  | 15  | 63  | 72  | 36   | 5   | 2   |
| 30                   | 4                | 15                 | 26  | 54  | 18  | 3    | 2   |     |

**F. One of Applications of the Proposed Wearable Computing System**

One of the applications of the proposed wearable computer is Google search. By using the proposed eye based mouse, Google search engine can be activated. Then keywords also be typed in the dialog box as keywords for Google search as shown in Figure 10..

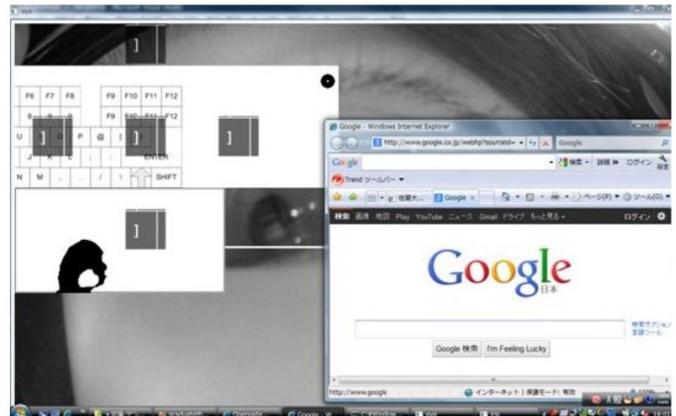


Fig.10. Google search as an example of applications of the proposed wearable computing system

**G. Location Based Web Services**

Another example of applications of the proposed system is location based web services. Even if user is situated in house at where GPS signal cannot be reached, indoor location estimation can be done by using the signals from the near WiFi access points. The experiments are conducted for the building situation as shown in Figure 11. There are three access points in the building. User has mobile devices with WiFi receivers and walks in the buildings. Six locations are tested for evaluation of location estimation accuracy. User may recognize the WiFi access point ID. Therefore, discrimination of the signals from each access point can be easily done. Figure 12 shows an example of the received signal from each access point. By using signal strength differences from the different three WiFi access points, user may estimate own location as shown in Figure 13. Evaluation results of location estimation accuracy are shown in Table 4.

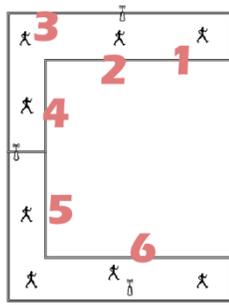


Fig.11. Experimental situation of user location and WiFi access point locations (Position #1: 3 meters, #2: 15 meters, #3:46 meters, #4:72 meters, #5:92 meters, and #6:132 meters)

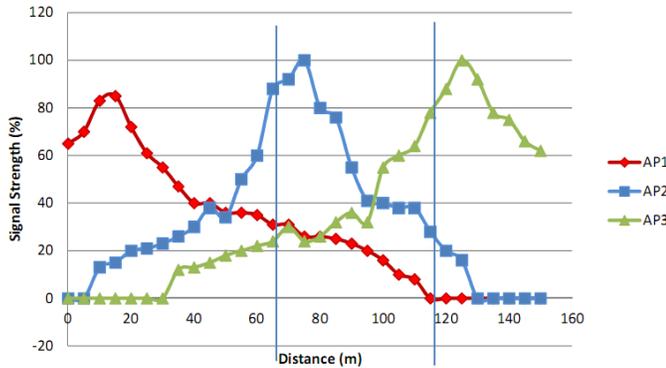


Fig.12. Received signals from each WiFi access point

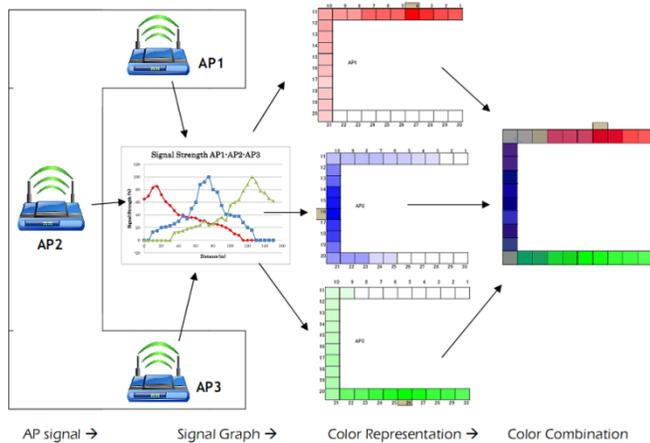


Fig.13. Three color coded received signals make estimation of user's location

TABLE IV. GRID ESTIMATION RESULTS FOR 6 SAMPLES WITH ERROR

| No | Online Position (meters) | Estimated Grid      | Min Error (meters) | Max Error (meters) |
|----|--------------------------|---------------------|--------------------|--------------------|
| 1. | 3                        | Grid 1 [0m-5m]      | 2                  | 3                  |
| 2. | 15                       | Grid 2 [15m-20m]    | 0                  | 5                  |
| 3. | 46                       | Grid 10 [45m-50m]   | 1                  | 4                  |
| 4. | 72                       | Grid 15 [70m-75m]   | 2                  | 3                  |
| 5. | 92                       | Grid 19 [90m-95m]   | 2                  | 3                  |
| 6  | 132                      | Grid 27 [130m-135m] | 3                  | 3                  |

#### IV. CONCLUSION

Wearable computing with Input-Output devices Base on Eye-Based Human Computer Interaction: EBHCI which allows web services, location/attitude/health condition monitoring is proposed. Through implementation of the proposed wearable computing system, all the functionality is confirmed. It is also found that the system does work well. It can be used easily and also is not expensive. Experimental results for EBHCI show excellent performance in terms of key-in accuracy as well as input speed. It is accessible to internet, obviously, and has search engine capability.

It is also found that location based web services are available with the proposed wearable computing system because the location estimation accuracy of 2.5 m is a good enough for the services.

#### ACKNOWLEDGMENT

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