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Twinkle Megane: Evaluation of Near-Eye LED Indicators on Glasses for Simple and Smart Navigation in Daily Life

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Abstract

We present an eyeglass-type wearable device that has light emitting diode (LED) indicators on the frame. The device produces lighting patterns of 14 RGB LEDs near user's eyes as guiding information. Since installed LEDs are light and saving power, it is feasible to develop it for daily use. On the other hand, it cannot provide rich information such as text or images. In this study, we aim to realize a remote assistive system that provides assistive commands by visual cues from remote sites. Especially, we consider elderlies who are suffering from mild cognitive impairment as users. They would be one of potential user groups since the device does not block their sights by text or images and it can be worn in daily life without the additional sense of restraint. This paper explains our conceptual assistive system structure, a prototype eyeglass-type device with near-eye LED indicators and usability experimentation in simple detecting and walking navigational tasks.

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1. Introduction

Aged society is one of the common crucial issues in the world. In this study, we mainly focus on elderly-user-friendly interface in a telepresence caretaking system. A.J. Bharucha *et al.*[1] estimated 28 million people suffered from dementia in 2009, and it costs 156 billion dollars annually for caretaking them directly. The analysis of the elderly adults demographic suffering from memory loss has drawn attention to the use of technologies, to involve less human and financial resources in the caretaking process. Symptoms of memory problems are categorized into several stages. In most of cases, elderly in an early stage is shifted to a severe stage because of an aggravation of their condition. Considering the increasing population of elderly suffering from memory problems, this study aims to restrain the aggravation by supporting elderly in an early stage of memory problem such as mild cognitive impairment. [1]

In the last decades, wearable technologies have been developed to support human activities. Recently, wearable devices can have cameras, display, and some of the sensors on itself. One of the most significant aspects of development is light weight design since it needs to be comfortable for wearing in daily life. In this paper, we show near-eye LED indicators on the frame of glasses as a light-weight wearable device for an assistive interface. Although most of the elderlies suffering mild cognitive impairment can live by themselves, it is necessary to support them in different cases to avoid the aggravation of their condition due to anxiety, etc. Above-mentioned motivation has derived many researchers to design sympathetic customized devices to assist senior citizens in their daily tasks. Considering the population of elderly suffering from

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memory loss and cognitive decline, this paper aims to design a wearable navigational tool to assist them in their simple daily navigational tasks.

2. Related Work

K. K. Zakzanis *et al.*[2] conducted a study to investigate the effects of age, gender and dementia on navigation and dexterity ability of people. The result shows dementia such as Alzheimers disease deteriorate the potential abilities in the spatial navigation tasks and using functional tasks such as working with the smart phones. L. Sorri *et al.*[3] conducted a set of navigation experiments with the people suffering from memory loss. The subjects received the visual, audio and tactile signals in three different modules to walk in different directions. The visual cues and the audio messages made the most efficient guidance to the subjects while the tactile signs were not as efficient as the visual cues and the audio messages. [2–4]

One of the assistive applications for a daily tasks is navigation. In wearable computing research field, navigation has been studied as a major topic. B. Thomas *et al.*[5] have developed a hands-free navigational aid by implementing head-mounted display system for outdoor guiding and they believe wearable technology has the potential for way-finding application [5]. In recent, there are many advanced head-mounted displays such as Google Glass or Epson Moverio BT-200 and so forth. Google company manufactured the high-tech Google Glass to be replaced as a wearable smart-phone. It has demonstrated high potential for practical use in educational and medical settings. D. Sedgwick *et al.*[6] conducted an industrial study on the use of Google Glass as a cost-effective collision warning and navigation tool in the driving tasks. The study unveiled controversial issues that threaten the safety while using the device in the navigational tasks [6]. T. Danton *et al.*[7] stated that users need to focus on the small display on the up-right corner of the eyeglassesâĂŹ lens to get the information. It needs user's foreground of attention, and it stays out of the direct ïňĄeld of the vision. It may cause the distraction in a situation that the user need the full attention in the physical environment [7]. Furthermore, K. Kunze *et al.*[8] conducted an explorative studies on the use of Google Glass in the daily life routine of the older adults. They stated that the current size of the display is not eligible enough for the senior citizens to read the information from it clearly [8].

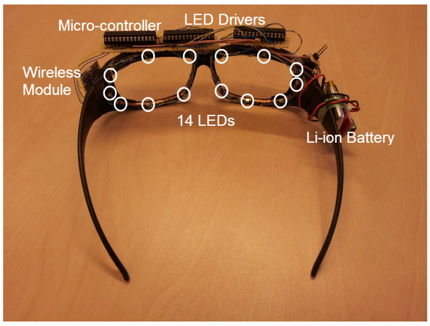
On the other hand, the Epson Moverio Smart Glasses provide the users with a head up transparent display, which is more efficient in the navigational tasks since the users could still keep the foreground of attention on the physical environment. However, the use of head-up display for the senior citizens suffering from dementia can be challenging. The augmented reality images may completely overlay the imagery display on the top of the field of view and mask the elderly user's vision. One reason is that the head-up display is usually small and do not cover whole field of vision.

B. Poppinga *et al.*[9] used off-the-shelf ambiglasses to provide users with notification with LED indicators and intuitive navigation instruction. Our near-eye LED indicator prototype is similar to ambiglasses and it can be customized and combined with advanced head-mounted and give simple navigational instruction. In addition, LED indicators do not disturb a user to see objects located at the center of the user's sight. An augmented reality glasses with wide display and covering whole field of vision, can simulate our system with virtual indicator augmented on the user's vision. [9]

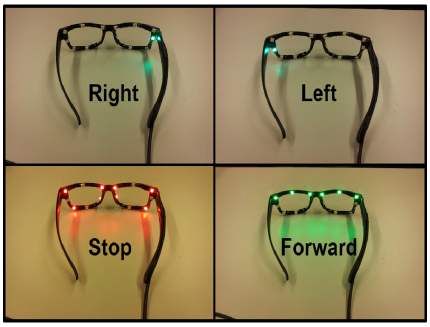
3. Design of Assistive System with Eyeglass-type Device

We have developed the prototype of the indicator-based smart glasses to provide users with the visual cues, which do not interfere with their vision on the physical environment. Android applications are developed to form messages and send them as binary data to the prototypes. The application has been improved iteratively. The communication protocol between the application and device is promoted to Bluetooth low energy to provide faster communication and consume less power. The prototype has 14 indicators to widen different form of blinking patterns and more meaningful messages. After conducting experimentation phase, test subjects complained about physical design and weight of the device, and it derived us to design more fashionable and light-weight prototype.

Figure 1(a) and 1(b) show the first and second prototype respectively, while the white circles demonstrate the position of indicators. We followed a similar approach to poppinga *et al.*[9] to form four main navigation commands. However, since our prototype cover more parts of the frame, we achieved different results. In addition to LED indicators, the conceptual prototype includes the mounted camera, global positioning system, gyroscope, and step detector sensors. The above-mentioned sensors and cameras help the remote caretaker to localize the senior citizens in home and city environment, while the glasses



(a)



(b)

Figure 1. (a): Second constructed prototype; white circles depict the position of LED indicators implanted on the frame of the eyeglasses. (b): Lightweight and user friendly design of the prototype

provide the visual cues to guide the users. [10]

4. Experimentation of Near-Eye LED Indicators

The design science research method is used in this study, and the experiment phase evaluates the usability of the device for further improvement [11]. We designed experiments with two different user groups, which are students and elderlies. As part of future work, next round of experiment will be conducted with bikers and cyclists while using OpenStreetMap API for mobile navigation application. The Wizard of Oz method with unstructured interviews, living lab approach, and video recording are used to collect and interpret the data [12].

We previously published a paper to explain settings, protocols and different steps of experimentation with near eye indicator display. The first step is to measure visibility of individual indicators; then forming meaningful notifications with different combination of indicators, and finally evaluate the efficiency of the notification in real life tasks. We conducted controlled experiments to measure satisfactory LED frequencies, brightnesses [13].

In the first experiment, Bayesian analysis indicates what indicators on the frame might be missed when they are blinking, and what indicators might be mistakenly chosen as blinking. In addition, the results clarify the satisfactory blinking pattern for blinking indicators including optimized brightness and frequency. In the second experiment, different sets of LED indicators' combinations blink simultaneously, and users choose interpreted navigational command such as left, right, stop and so on. We found optimized frequency, optimized brightness, and most distinguishable indicators on the frame. We formed most meaningful indicators configurations to convey navigational commands. Figure 1(b) shows the four most simple and intuitive navigational commands.

The last experiment evaluates the usability of the visual cues in a navigational task, which is a real life problem for elderly suffering from dementia. We simulate simple navigational tasks for the subjects in an open indoor environment. The users are supposed to walk on a predefined map while the visual cues guide them. The map contains a specific number of stops and turning left and right with different rotation degrees. Figure 5 shows the predefined map. One of the main objectives of the experiment was to evaluate the simple guidance system in 90-degree and 180-degree turning point.

Two main user groups participated in the experiments and Figure 2 demonstrates the order of the conducted experiments. Eleven student subjects participate in the pilot tests with the average age of 26.05 and the range of 20 to 33. The results of the Bayesian analysis for the localizing indicators test unveil lowest sensitivity and specificity for nasal indicators (indicators close to the nose). In another

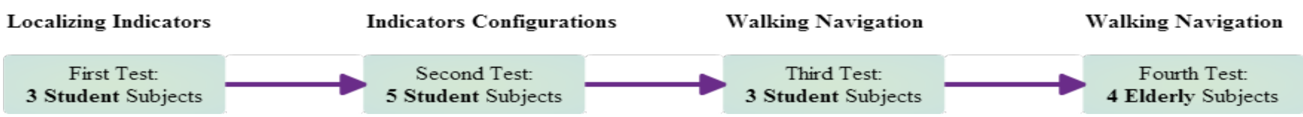


Figure 2. It shows the sequence of the experiments and the number and type of subjects in the experiments.

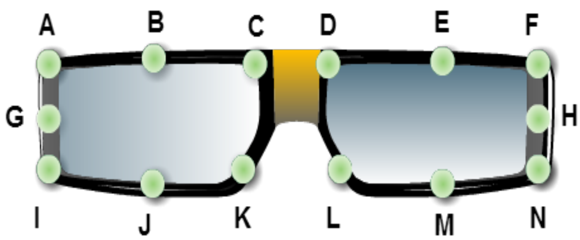


Figure 3. Assigning specific symbols to each indicator to measure visibility of them while conducting the Bayesian analysis.

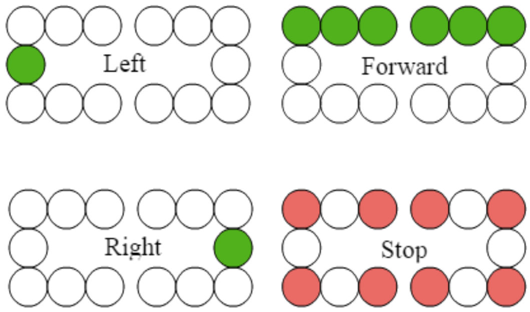


Figure 4. Four main navigational commands correspond to combination of indicators.

word, the nasal LED indicators can be missed while blinking, and they can be mistakenly considered as blinking while they are not. In the next experiment, four out of 48 combinations are chosen as the navigational commands based on the users' preferences. In the last experiment, the student users accomplish their task by following the navigation guidance to walk the predefined route.

Figure 3 shows specific letters that are assigned to the indicators. Each indicator blinks six times for each participant in a random order, and subjects are supposed to select blinking indicator, while the selection is recorded.

Table 1 shows sensitivity and specificity of detecting individual indicators. Low sensitivity means higher possibility user miss a blinking indicator, while low specificity means higher probability to mistakenly select an indicator while it is not actually blinking. The data shows nasal indicators have low sensitivity and specificity, and we tried to use less number of them while forming navigational commands.

In the next experiment, 48 different combinations of indicators are shown to each subject. They corresponded each combination to a navigational command. Then we analyzed the most selected combination for main navigational commands, and they are shown in Figure 4.

In the last experiment with student subjects, three subjects were asked to walk a predefined route by following turn-by-turn navigation instruction of the glasses. In an optimistic situation, a total of 28 commands on the glasses is triggered. While in the case of mistake occurrence, more navigational commands are needed to navigate the user in the predefined map. All subjects accomplished their task to reach the destination, only by following the glasses instruction (without human intervene). Table 2 demonstrates results from walking experiment with student subjects. The same map with different scale is used in walking experiment for students and elderlies.

Eight elderly subjects participated in the usability experiments. Mini-Mental State Examination was conducted to diagnose the severity of dementia for the subjects. Four subjects suffered from severe dementia

Indicator	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Sensitivity	1.000	1.000	0.500	0.833	1.000	1.000	1.000	0.833	1.000	1.000	0.666	0.666	1.000	0.833
Specificity	0.990	1.000	0.993	0.993	0.987	0.993	1.000	0.987	1.000	1.000	0.993	0.993	1.000	1.000

Table 1. Sensitivity and specificity of the individual indicators are calculated.

Variable	Subject A	Subject B	Subject C
Mistakes by subjects	0	9	0
Correction via device	0	9	0
Correction via human assistant	0	0	0
Accomplishment time	76s	124s	73s
Average speed	0.355m/s	0.217m/s	0.325m/s
Path length	27m	27m	27m

Table 2. The relevant descriptive statistics and factors are measured for three student subjects in walking experiment.

Variable	Subject A	Subject B	Subject C	Subject D
Age	81	80	83	74
Gender	Male	Male	Female	Male
Using eyeglasses	No	Yes	Yes	Yes
Mistakes by subjects	8	7	7	5
Correction via device	6	0	3	4
Correction via human assistant	2	7	4	1
Accomplishment time	220s	390s	286s	136s
Average speed	0.068m/s	0.038m/s	0.052m/s	0.110m/s
Path length	15m	15m	15m	15m

Table 3. The relevant descriptive statistics and factors are measured for four elderly subjects suffering from mild dementia in walking experiment.

and four subjects suffered from mild dementia [14]. The severity of dementia deteriorates following the track of topic and concentrating conditions [15]. These difficulties prevent severe demented elderly subjects from accomplishing their tasks in experiments. Before conducting the walking test, we requested all the subjects to identify individual blinking indicators and confirm the meaning of navigational cues. The subjects with severe dementia fail in preliminary test and withdraw the experiment.

All the subjects suffering from mild dementia accomplished their tasks by following the visual cues and walking on the predefined route. Table 3 shows the most important collected data in the experiment. The subjects reacted more accurately to the visual cues at the end part of the walking task. It shows high adaptability to the system in performing the tasks. Figure 5 depicts the map of the navigation area in an open indoor environment. Considering turn-by-turn navigation, the result of the experiment proves that conveying different degree angles rotation with simple navigation instruction is the most challenging part. In turning points, subjects can detect the direction that the glasses indicate while the amount of rotation confuse them. The perception of turning commands differ in the subjects, and it means that some subjects always consider turning command as a 90-degree turn and some subjects turn continuously until the stop command is triggered.

The indicators blink with the frequency of 1Hz, 1,5Hz, and 2Hz in the pilot and usability experiments. The subjects achieve the best results while indicators blink with the frequency of 1Hz. Nevertheless, the unstructured interviews uncover that the elderly adults would rather the frequency less than 1Hz. The test subjects also highly emphasize on the common-shape design of the glasses and they prefer the visual cues not to be seen by outsider to preserve their dignity in real life.

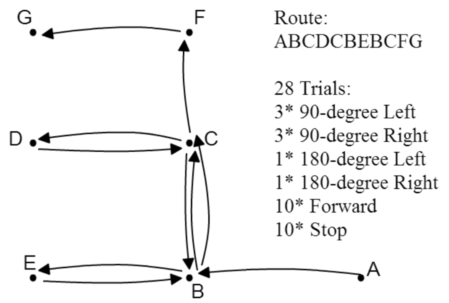


Figure 5. The predefined map contains number of rotations to the left and right in an open area.

5. Conclusions

We have implemented an interface as eyeglasses which are common among senior citizens, and we have implanted LEDs on the frame since it does not interfere with the field of vision and distract less than any other type of rich HMD display. Augmented reality devices are suitable for navigational guidance if the visual cues do not block field of vision. Our prototype is similar to an augmented reality device with an extended display to provide visual cues on the edge of the screen.

The device has the potential to be used in diverse scenarios by different target user groups. Most of the users suffering from cognitive decline fail to interact with advanced user interfaces, while our prototype can be used to generate simple notifications for them. There are some tasks such as driving and biking which should not be interrupted, and meanwhile, the user needs to receive information in the attention background. We proposed the mentioned prototype to provide users with simple notifications without distracting them from main tasks.

The future plan includes the evaluation of colors' combinations, indicators' positions, light intensity and blinking pattern to form meaningful notification in different real life challenges and scenarios for both elderly and young users. Conducting way-finding experiment with bikers and cyclist in the outdoor environment is the next step for validation of the prototype.

5.1. Acknowledgment

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