A Laser Projection-based Tele-guidance System Embedded on a Mobility Aid

Goshiro Yamamoto^{*†}, Angie Chen^{*}, Petri Pulli[†], Jaakko Hyry^{*†},
Muhammad Zeeshan Asghar[†], Yuki Uranishi[‡], and Hirokazu Kato^{*}

^{*}Graduate School of Information Science, Nara Institute of Science and Technology
Ikoma, Nara, Japan Email: {goshiro, chen-a, jaakko-y, kato}@is.naist.jp

[†]Department of Information Processing Science, University of Oulu
Oulu, Finland Email: {petri.pulli, zeeshan.asghar}@oulu.fi

[‡]Graduate School of Engineering Science, Osaka University
Toyonaka, Osaka, Japan Email: uranishi@bpe.es.osaka-u.ac.jp

Abstract—This paper presents a tele-guidance system for elderly people so that they can walk outdoors without an escort and their caregivers can monitor them or guide them from remote site when they are in a need of help. The feature point of the proposed system is to adopt laser projection with consideration for use outdoor. Because the laser projection shows the arrow, which indicates a direction, all a user needs to do is to follow it intuitively. The goal of this study is to realise a tele-guidance system, which provides easy understanding for elderly users with mild dementia, with laser projection. The whole system including this proposed system aims to make preparations for a super-graying society by connecting elderly people and caregivers effectively via ubiquitous network. As a first step, a prototype system was developed and a user test was conducted with elderly participants. In the result, some technical problems and visibility problems on the projected arrow were found.

Index Terms—laser projection, remote assistance, elderly with dementia, mobility aids

I. INTRODUCTION

We must prepare support systems for a super-graying society as a global issue. Currently, the population of elderly persons 60 years old or older in China is estimated to reach into 200 million in 2013. Finland and Japan are also facing an increasingly aging population due to low birth rates and improved life expectancy. It is estimated that by 2050, the percentage of the population of Finland and Japan over the age of 65 will be 27% and 33%, respectively [1], [2]. The number of elderly people who suffer from varying memory impairments is also going to more than double during the next 30 years [3]. Then, the increase of elderly population requires more caregivers inevitably. However, there has been already a problem that a lot of home caregivers a physical and mental burden even nowadays [4], [5], [6]. Additionally, long-term care would make more problems where are an increase of the burden of caregivers or a deterioration of a health of caregivers [7]. It might be difficult to care enough for elderly people. Finally, these above things would make a negative feedback loop that causes an increase of a number of the elderly people with dementia. Therefore, it is considered to be an urgent need to realise safety-supporting system which can give many mild demented elderly persons normal life, which they can keep

Fig. 1. Safety navigation system overview. Elderly users can get support with laser projection-based indication from remote caregivers.

qualities of life and society members without feeling anxieties, with support from a few caregivers.

In this research, a challenging point is to find suitable solution of the above problem to support demented elderly people using information and communication technology. Especially, it focuses on an outside activity of elderly people because they go out sometimes in their daily life as with people without dementia. Figure 1 shows overview of safety navigation system which is a goal of this research. A mobile phone with wireless communication function is an important key in this structure. Mobile communication devices can make connection between clients (elderly users) and servers (remote caregivers) easy anytime. Through this network, it might be possible to realise that a small group of remote caregivers support a big number of elderly people. In such system, this paper describes a novel user interface on a cane which is one of mobility aids for elderly people.

In this paper, the aim is to realise a guidance system onto a mobility aid device that indicates the direction of the arrow, drawn by laser projection onto the ground, to guide the user by remote caregivers.

II. RELATED WORKS

Most of studies, which apply mobility aids as target things which be embedded intelligent function, have been conducted as similar as this study. About only cane-typed mobility aids, there are mainly two types of support way. One of them is a navigation system for blind users [8]. The camera, which captures the scene in front of the user, is attached on tip of the cane. The system can detect a risk of fall instead of the blind user and guide them to take another route. Another one has studied a smart cane system for elderly people to avoid risk of fall [9]. Accelerometers or gyro sensors are equipped into the cane. Using movement data from these devices, the remote caregivers can monitor the elderly users' behaviour and give guiding information to them. These ways are not any better for elderly people with mild dementia because they are required to think by themselves to maintain their conditions. The former system navigates them beyond the definition of "mobility aid". It is necessary that a system gives them a chance to choose which way they would like to go. In addition, the display function is also needed for users.

There has been previous research about walker-type mobility aids [10], [11]. Most of them apply a way, in which the user is escorted by the mobility aids. This way is not any better for mildly demented people for the same reason as described above. Although other methods, which guide users by using haptic vibrations or sound directions, have been reported [12], [13], [14], a visualising method to indicate a direction a user should go is applied for the elderly people with dementia in this study.

A projection-based visualising method, which can show various information on the real world, has been developed. In these days, mobile projectors are useful for wearable or mobile applications [15], [16]. However, mobile projectors have very weak light intensity for outdoor. This is why laser projection method is applied in this study. How the laser projection method gives guidance information to a user using few variations of projection figures is also one of challenging points.

III. SYSTEM DESIGN

The devices designed to be used as radical novel application is not friendly to elderly people in some cases. It should be realized as routinely-available devices and should be equipped to be portable and functional. This study focuses on mobility aids, which are used by lots of elderly people in their daily lives. These mobility aids with support of ICT has possibilities to be able to connect elderly users with remote caregivers closely by ubiquitous networking.

A. Survey of Mobility Aids

At first, a pre-survey was conducted to find what type of mobility aids is friendly to elderly people. There are a cane, a crutch, a walker, a gait trainer, a wheelchair, and a scooter as popular and common mobility aids in the main. They also have possibilities to add some options depending on user's particular requirements. As the results of a reference [17], a

cane was the most frequently used device (72%), followed by a walker (16%) and a wheelchair (7%). Another reference [18] also reports that a cane was the most widely used mobility device. However, many elderly people use rollators and nordic walking sticks according to the authors' observations in Finland. A rollator, also called wheeled walker, consists of a frame with wheels, handlebars and a built-in seat. In the result, it was concluded that the mainstream mobility aids were walker-type and cane-type although shapes or functions of these devices might be thought to differ depending on countries, areas, or life style. This paper describes the cane-type mobility aid, which should be friendly to elderly users.

B. Proposed System

This proposed system provides a guidance interface, which is connected to remote caregivers via the Internet, to elderly users. The main function is to display the arrow, indicating a direction the user should go to, on the ground directly by laser projection-based drawing when the user gets lost. In order to display visual information by light projection, projectors are often used. However, current projectors are not suitable for use case of outdoor or bright spaces because they don't have enough strong lights to show information to the user. This is the reason why it is decided to use a laser projection method, which can produce stronger light projection, in this study. A laser pointer can be modified to draw simple figures like an arrow by using slit filters and a lens although in normal use cases it is realised as a spot. In that case, it is necessary to take into account the reduction of light quantity when using a lens. On the other hand, there is another display method, in which a laser device is used to draw figures based on moving the laser with motors. This method is not used in this research because actuators to move a laser pointer need much power and are often too large for comfortable use. The worst demerit of using lasers is the danger it proposes to the eyes. In the proposed system, a safety mechanism is embedded to avoid the danger.

The main components of this system are actuators with a laser module to display an arrow, sensors to acquire orientation and position of the device, a mobile device that can connect to the Internet, and a controller as shown in Fig. 2. This system can calculate the direction that the arrow should head to according to orientation data and operated direction of remote caregivers. The orientation data is acquired by a digital compass, and the operated direction is received through wireless communication connecting to the Internet. After calculating, actuators are moved to rotate the laser module toward the direction. Additionally, a safety mechanism, where a laser light is turned on only when the cane tip is touching the ground, should be equipped. Because a pressure sensor, a distance sensor, or a button switch can measure a condition between the tip of the cane and the ground, they could be applied to realise the safety function. A server side system gets the position information of the elderly user from a positioning sensor like GPS so that the remote caregiver can use it to give guide information to the elderly user interactively.

Fig. 2. Architecture of the proposed system.

IV. OBSERVATIONS

This section describes user test observations using a prototype system. The goal was to find improvements for the system. Experiments were conducted to get usability of this proposed system and a visibility of an arrow by laser through observations. Elderly people with mild dementia participated as test subjects.

A. Prototype System

This prototype system consisted of a cane, a laser module, servomotors, a micro controller, a digital compass, a wireless communication chip, a pressure sensor, batteries, and a computer. Figure 3 shows system overview and main components of the system. The cane is an old nordic stick made of bamboo. The laser module was taken out from a commercially released laser pointer which already had arrow drawing functionality. To cover every direction for an arrow rotation, two servomotors are combined in series without gears because one servomotor can rotate just 0 to 180 degree. Another servomotor can be used to change an angle of laser projection. A digital compass module HMC6352 is applied to acquire the head direction of the cane. A micro controller, Arduino UNO, manages these all sensors and actuators. The position information from GPS sensor is not used in this prototype, but the function should be added to next version. Although it is also desirable for practical purposes to let mobile devices communicate with the micro controller directly, a structure where the micro controller connects to the laptop computer, which is MacBook Pro 13inch 2.7 GHz Intel Core i7 with Processing to run operation program, is used without a mobile phone in this user tests. XBee provides wireless communication of ZigBee between the micro controller and the computer.

In this prototype system, the laptop computer is used as remote site server to communicate interactively with the micro controller embedded on the cane. A remote operator can select

Fig. 3. Overview of prototype system. a) the system is used as a normal cane and shows a laser projected arrow, b) the main components, c) whole image of the proposed system, d) and e) the projected arrow turns off and on according to the condition of the cane tip, respectively.

one from eight directions to give it to a tele user as guidance information. The micro controller calculates the angles which the servomotors should rotate using the selected direction and a current cane's head direction. The system keeps the correct direction of the projected arrow from continuing that calculation even if the cane is moved.

B. User Test Design

The aim of this user test is to confirm visibility of a projected arrow on the ground and usability of the proposed system. A simple task is prepared for test subjects in this user test. The task is to walk from start point, follow the projected arrow, and reach the destination. This path has two corners on the way. To verify the visibility, two parameters are set as conditions to the user. One of them is whether the subject can recognize the shape of the projected arrow. Another one is to find out what distance between the cane tip and the projected arrow was easiest to see for the user. For this purpose, the prototype system is also implemented to provides four kinds of position to display an arrow for the elderly subject as shown in Fig. 4. Usability was measured with a questionnaire.

At the beginning of the user test, experimenters explained to a test subject how the system works, what are their tasks, and what is the procedure of this test. After the subject understood everything, the experimenters let him/her to fill up a pre-

Fig. 4. A variable distance between the cane tip and the projected arrow. The system provides the four kinds of position to display an arrow.

test questionnaire to gather general information and measure their height and muscle strength. After that, four trials which had variable positions for the projected arrow, were carried out. The route in each trial was constant. Finally, the subject needed to answer some questions and provide comments if they wanted to.

C. Results

This user test was held at the health care centre (ODL: Oulun Diakonissalaitos) in Oulu. There were six participants whose age range is 89 – 94 years old. Five persons use canes, three persons rollators, and one person uses nordic walking sticks. Three of them use multiple mobility aids. The data of two participants were excluded because they couldn't complete their tasks as described below. During this user test, one Finnish therapist supported the subjects for any questions and observed the whole test.

Answers for questionnaire provide results that one prefers projected position of 30cm, one prefers 60cm, one prefers 120cm, and one has no preference. And one of them did point out that the subject does not like when the arrow was too close to him/her. The therapist also said that it was not good for the subject if the arrow's position was located at 30cm because their heads were always down and hunched all the time. In a contrasting situation, if the projected position was longer, the subject would straighten up their back. As the result, the best position was not figured out.

Results of observations were that some problems occurred on guide function. Most of subjects lost sight of the projected arrow sometimes. Especially, they were likely to lose it in case where the distance between the cane tip and the arrow was far. On the other hand, some subjects followed not to a direction which the arrow indicated but to a direction which the arrow existed even if they were able to see the projection. Moreover, these subjects ignored the indication of the arrow and walked as they like. In this experiment, laser was always on without safety mechanism. To avoid the danger the experimenter had prepared to stop the experiment just in case. One of the subjects concentrated too much to watch the arrow and had lifted the cane up.

V. DISCUSSION

The reason why the answers for the questions on which distance was better were distributed, according to observations and the therapist's opinion, is that the test subjects preferred the position after they used the device for a while and started to get use to it. Because this kind of computer-supported device is a new thing to them, at the beginning, they were more concentrated on how to use or follow the arrow rather than paying attention to the position. Therefore, the suitable projection position could not be figured out from subjective ranking of test subjects. To reduce these above noises, increasing the number of test subjects or suppression of the order effect are desired.

The observations give mainly three things as problem points; the device is shaking, cane might not be suitable for every user, and the system is not robust enough. The shaky problem is divided into two parts. The first part is that cane handling of the elderly subjects were more rough than expected. These subjects often put some muscle into the cane for supporting their own bodies while walking. It would be caused by physical problems from aging. This rough handling swings the cane, so the projected arrow would also swing wildly according to the canes behaviour.

The second shaky problem is because the elderly subjects tremble. A cane has high degree of freedom to move because the cane normally stands at just one point on the ground. Thus, the position of the arrow, which is projected from top of the cane, is sensitive to the cane motion inevitably. Especially, it is difficult for them to hold the cane steady in the air. To solve the shaky problem, an accelerometer or some sensors, which can get the cane status, should be applied to reduce the shaky noises as a filter.

Some test subjects got confused when by watching the moving arrow while the system was rotating servomotors to a correct angle. If the subjects moved in the time, recalculating the angle makes the arrow shaking, then the situation will get worse. For this problem, it is necessary to add a mechanism such as laser light turning on after rotating to a correct angle.

Other comments were given about visibility including the size and the shape of the arrow. Some subjects provided their opinions that the tail of the arrow would be better to be longer, or the size might be too small for a user who have eyesight problem. One of the subjects mentioned that if the distance between the arrow and the user's eyes are too far, the elderly user might have problem to see it clearly. Because most of the subjects lost sight of the arrow also in the user test, improvements of arrow's visibility must be done. Additionally, it is supposed be get better result might be gotten by not only changing the appearance of the arrow but also an ingenuity which makes the user's attention to the arrow.

The place where the user test was held also has a problem. All the participants who stay the health care centre think they do not need this kind of navigation because they have helpers and can get supports all the time. Feedback might be different if this user test is carried out with the elderly people who live

at their own home. Indeed, this study should focus on such elderly people who hope to get this kind of support as targets.

VI. CONCLUSION

This paper mentioned that a super-graying society will become more serious from present to the future and described the needs of developing network environment connecting elderly people and caregivers with ICT. As one of the important systems under the environment, a tele-guidance system for elderly users was focused on. This system can get guide information from remote site to support elderly user's outdoor activities by using laser projection, which has strong light and can draw a figure on the ground. In order to confirm the possibility of the system, prototype system was developed and a user test was carried out with real elderly participants. In the result, there were some improvement points on the arrow view. One of them is a shaky problem and other one is a visibility problem. For the former problem, it is necessary to add mechanism, which does not confuse elderly users, by filtering noises or devising visualising way. And hardware improvement is needed for the latter.

It is also important to consider properties of test users. It is expected to find more important improve points if user tests are held in ideal environment with ideal test subjects. Then it might provide some advices feedback on what the proposed system should be.

As future work, at first, the problem the paper pointed out should be solved. On the other hand, these improvement points will be applied to the rollator typed mobility aid, which is often used by elderly people.

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