A Navigation Aid for People Suffering from Dementia Using a Body Worn Laser Device

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***Abstract*— This study presents a body worn laser device as an appropriate navigation aid for the people suffering from dementia. The wearable mobile system which consists of a camera and a laser pointer is a chest worn device equipped with laser projection-based arrows to guide the people suffering from dementia in indoor/outdoor mobility. This device is able to provide navigation aid to the people suffering from dementia in complex and unknown areas; it also helps the user to identify the real objects. A remote caregiver can easily get the scene where the demented person seeing and can guide the directions with laser projected arrows and directly pointing at the real objects with a laser pointer. In this paper we will explain the usability of chest-worn system in indoor/outdoor environments. The results of an indoor field test conducted with real end users are presented. Results reveal the validity and effectiveness of the chest-worn system in the complex and unknown areas.**

Keywords—dementia, wearable, laser, navigation, chest-worn, remote assistance, tele-presence

I. INTRODUCTION

Population is aging globally, with the percentage of those aged 60 and over expected to double between 2009 and 2050. The aging of the population, along with increasing numbers of people with memory disturbances, creates challenges to develop and design guidance technologies that assist persons in their daily activities [1]. Persons suffering from dementia are prone to getting lost and have lower ability to understand signs [2]. Also the concentration of a dementia person is easily disturbed by external factors such as other people or environmental disruptions [1].

One of the more common behavioral manifestations of dementia-related disorders is severe problems with out-of-home mobility which is critical for numerous aspects of older persons' quality of life [3]. It is important to balance the patients' safety and family well-being with the potential for abuse and threat to civil liberties [3]. People with cognitive impairments prefer to live and function as independently as possible. When they cannot navigate safely and freely, the burden on caregivers and community services increases and the opportunities to act independently and participate fully decreases [4]. Previous research has shown that laser-pointing enables smooth remote collaboration for simple tasks, such as selecting and specifying real-world targets and better visibility helps wandering outside in the harsh environments for example in dark, and slippery wet conditions or to unknown places.

The innovative and state-of-the-art technologies applied in this study will allow the demented person out-of-home and indoor mobility, independence and better quality of life. This system also provides real time monitoring which may in turn reduce the distress and burden of family caregivers and allow them to continue caring for the elder in the community for a longer period of time.

This system enables caregivers an ability to watch the demented person view on a mobile as well as on the web using the remote view. Using this view, caregivers can easily guide the person with the help of chest-based laser pointer which is attached to a microcontroller and a smart phone. The smart phone camera shows the path to remote user on which the demented person is walking on. Using the laser projected arrows the remote person can guide them easily and efficiently. The aim of this study was to develop a technology aid which helps the demented person to navigate safely and autonomously.

II. Related Research

An iWalker[5] solution is created for way finding with dementia based on RFID sensors and a walker. The restriction of this [5] system is that the routes of the user must be tagged along the way with multiple tags thus making it impractical to be used in outdoor environments. Further the use of a walker is impractical for persons who are able to walk by themselves without an aid. The RFID based system, however, solves the problem of correct timing of the turn cues which was found essential by [1]. Liu (6) presented another possible solution for timing the turn cues using landmark-based cues instead of turn-based ones; the results of this system are similar what [7] suggests. However, most of the related studies are not fully applicable to the current research since none of the cognitively impaired persons suffered from dementia and the special needs of such person were not considered.

III. System Design

To help concentrate on the design, the concept was divided in two logical domains; the hardware domain and the software domain. The hardware domain has factors of more physical nature. The laser and the mounting for example have an impact to the hardware implementation as the physical safety of the device must also be considered. Factors such as the weight and mounting method have heavy impact on the design as the user has to bear the consequences of bad choices. The sensors and camera have to align perfectly in order to provide usable information.

The powering and the controls make most of the size on the software side, factors such as delays and processing power are not tacit factors but invisible and indifferent to the physical design. Another important components relevant to this work are the remote assistance user interface from which the aid device is controlled and the navigation aid device, which is worn by the demented person.

The device is to be operated in any environment at any time, the source for the visual cues must be of high contrast and the device also needs to project the direction information for the user. Therefore, laser is a preferred technology for this application. Although lasers are dangerous because of the high intensity of energy they create on a small area, for this reason it was essential to design the system in such a way that it is not possible to point the laser upwards and possibly cause accidents. Figure 1 illustrates the whole design of the system.

The laser navigation aid module is consists of 1) the main controller, 2) Battery, 3) Lasers and 4) Servos. The main controller unit handles the operation logic task and communication with the smartphone. In the smartphone a simple Android application is running which connects to the micro controller via TCP/IP. The controller board is equipped with power management to which the battery is connected and with a USB host controller. The USB host chip enables easy communication with the smartphone. Battery is a 9V battery pack which powers the controller board and the peripherals.

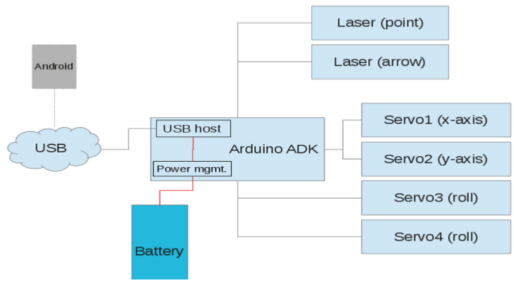

Fig 1: Whole design of the system

Two laser modules are connected to the general purpose Input/output pins on the microcontroller. The lasers are operating as outputs and can be switched on or off. Four servos provide the physical interface from the system to the user. Two of the servos move the laser beams in X and Y axis and two are used for rotating the projection.

IV. Implementation

A. Main Components

The main hardware components of the system are shown in the Figure 2. HTC One X (1) smartphone is used as the primary processing and communication device. Arduino mega 2560 ADK prototyping platform, (2) handles the task of providing users with visual cues using laser modules (3,4) from a laser pointer device (10) and the servo motors (5,6,7,8). The device is powered by two batteries; LiPo cell battery which is inside the smartphone and the battery pack (9) consisting of six alkaline batteries.

B. Interface between components

1) Universal-Serial-Bus

The USB consist of two different type of devices: Host and devices. The important distinction between the two is that the host supplies the operating power to the bus, enumerates devices, assigns address and controls data traffic whereas the device reports communication end points and accepts the address assigned by the host.

2) Communication over internet

The device uses basic TCP sockets to communicate with the network client. The client-server model in the system was implemented in a way that the navigation aid device acts as a server and the remote assistance as client. The software of the navigation aid implements socket based communication scheme between the remote assistant and the aid device.

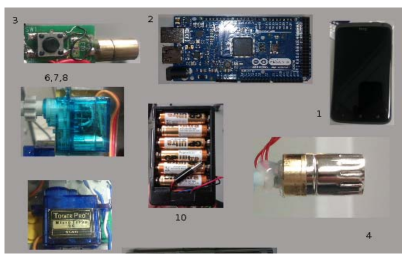

Fig 2: Main hardware components of the system

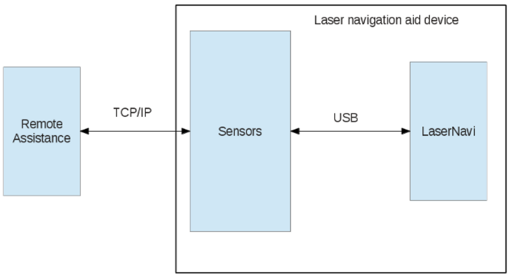

Fig 3: Modes of operation

C. *Modes of Operation*

Two different modes of operation were implemented for the device. First through remote control via turn cues and the second is the direct operation of the laser to point at real objects. Figure 3 shows how the remote assistance communicates with laser navigation aid device and vice versa.

1) *Remote Control*

Controlling the device remotely is done by a remote assistant or a caregiver via their personal computer or mobile devices. The caregivers' user interface is supplied with an image feed from the navigation aid device and also with sensor data from the various sensors.

2) *Pointing*

In order to point at the real objects accurately, the distance to the target must be known. Figure 4 demonstrates a situation which uses separate modules for a camera and a laser, the offset between the camera and the laser pointer lead to a problem when trying to point accurately at something that the camera can detect in the middle of the frame. The remote assistance person is responsible for showing the directions with the help of the image feed from the camera and GPS coordinates from the sensors on the smartphone.

Heading is managed in two parts: the target heading is received from the remote assistance and the current heading is received from the sensors carried by the user. Left part of the Figure 5 shows the actual device and on the right, a person wearing the device outdoor.

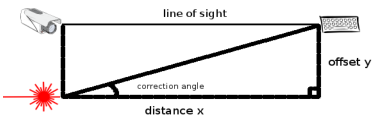

Fig 4: The angle of correction when the laser and the camera have offset between them

Fig 5: (Left) actual device and (Right) a person wearing the device

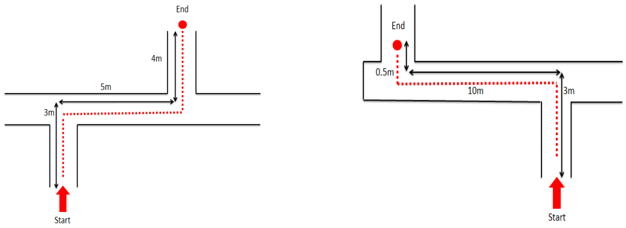

Fig 6: (Left) Route 1 and (Right) Route 2

V. TESTING

The team of five members visited the rehabilitation center for testing the device. The goals of testing included arrow guidance, laser pointing to objects, remote user's ability to control the device, visibility of the laser and interviews of senior citizens before and after testing. The results of these tests will be used to develop a more efficient and stable device.

A. *Participants*

Five participants ranged in age from 81-93, four of them male and one female participated in the user study at a rehabilitation center in Oulu, Finland. Their severity of dementia ranged between mild and moderate and walking abilities were normal.

B. *Route setup*

Two different routes were setup each included two turns. One route was 12 meters long and second was 13.5 meters long. Figure 6 on the left depicts the route1 and on the right depicts the route 2. The test event data was collected by videotaping, participatory observation, taking notes and interviewing the subjects. For data analysis the videotapes, audio recording and research's notes were transcribed.

C. *Arrow shape test setup*

Test team printed four red arrow shapes on the paper and those were shown to the participants at a distance of approximately 3 meters, to see which arrow shapes participants preferred the most and also color of the arrow. The arrow shapes are presented in the Figure 7.

Another purpose of this arrow shape test was to match the size of the arrows with the size of the laser arrow that the device prototype was casting. Figure 8 shows the arrow shape test setup.

D. *Pointing test setup*

For the pointing test, test team chose three real objects: a black mug, a black TV-remote and a reddish-brown book on a table at approximately 1.5 meters away from the participants. Using the device the spotted laser pointed at the objects at least once for each participant. Figure 9 shows the arrangements of the test.

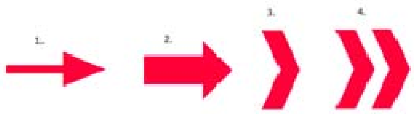

Fig 7: Arrow shapes used in the arrow shape test

Fig 8: Test team member showing the arrows to one of the participant

Table 1: Participants route completion details with time

No	Age	Gender	Medical Condition	Route	Time
1	88	M	no problem with memory	1	1m30s
2	93	M	slight problem with memory	1	34s
3	88	M	mid-stage Alzheimer's	2	1m10s
4	81	F	mid-stage Alzheimer's	2	1m18s
5	90	M	mid-stage Alzheimer's	1	not reached

VI. Study Findings

The participants were interviewed before and after the tests, regarding the acceptance and usefulness of the device. In general, the device could be helpful in case they need guidance. Participants were willing to use and adopt the new technology and the device was not heavy for them to carry. The researcher controlling the remote controller device was who developed the device and had former experience of controlling it. Thus, it may have affected the user experience.

Most participants in the route test succeeded to complete the defined route using the device with a few misinterpretations. The subjects followed the arrows well. Table 1 shows the results of the route tests along with the completion time. Participant 1 had a pacemaker so he could not wear the device on the chest; one of the test team members carried the device alongside the participant. Participant 2, 3 and 4 succeeded to complete their routes , while participant 5 informed about the lights being too bright to see the laser arrow clearly and due to this problem he couldn't complete the test. Figure 10 shows the four types of direction arrows.

The test results of the preferred arrow shapes are presented in Table 2. The results show that the traditional arrows (1 and 2) were considered better than the special ones (3 and 4). Three of the participants stated that they prefer the traditional arrow (1) while two of them preferred thicker traditional arrow (2).

Fig 9: The arrangement of pointing test

In the pointing test all the participants felt that the laser spot seemed to be an effective way of showing the objects as none of the test participants gave a wrong answer during this test. The test team chose three real time objects a book, a TV-remote and a black mug.

However test results indicate that the laser spot was difficult to see on the black colored mug. The material of the mug was somewhat reflective and it affected the visibility of the laser spot. Time measured during these tests were rounded to the nearest half of second and presented in Table 3. Average measured time is presented in Table 4 which indicates that the black colored mug have the highest average time.

Overall results of this initial testing session shows that the device is quite usable for the navigation and identification purposes. Though device has some shortcomings which test team discovered during these test sessions i.e. Depending on the orientation of the chest device there was a chance to have a short circuit, the laser arrow was not bright enough for some test participants to see it clearly, it had about 2 second latency between chest device and the remote controller, laser needs to be more stable and the chest device seems to drain batteries fast. In future research more stable and efficient device will be developed to remove these shortcomings and user testing will be done in outdoor environment i.e. in dark, rainy or snowy circumstance.

Table 2: Results of arrow shape test

Participants	»(4)vs. ›(3)	➡(2) vs. →(1)	Best of All
1	3	2	2
2	4	1	1
3	4	1	1
4	3	1	1
5	4	2	2

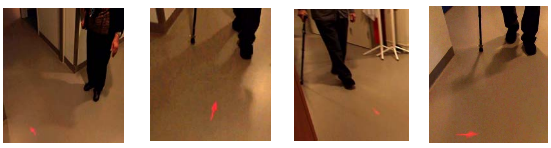

Fig 10: Arrow shows the directions (left, back, forward and right).

Table 3: Measured time from the pointing test, multiple values in a cell separated by semicolon (;)

Participants	Book	TV-Remote	Mug
1	3.5s	3s	3.5s
2	1s	1s	2s;2s
3	1s;1s	1s	2.5s
4	0.5s	1s;1s	1.5s;1.5s
5	2s;1s	1.5	6.5s;2s

Table 4: Average time of the pointing test

Object	Average Time
Book	1.67 seconds
TV-Remote	1.625 seconds
Mug	3 seconds

VII. Discussion

We developed a system which helps the demented person during indoor/outdoor navigation. Since the chest-worn device provides navigation cues using laser-projected arrows and helps in identifying real objects using a laser pointer, demented persons were ready to use this device and found the device very efficient and intuitive. The affordance and effectiveness of this device was based on test results of 5 participants.

However we performed the experiments with relatively few subjects in an indoor environment, so we will have to perform more experiments in outdoor environment especially in harsh conditions like snow, slippery and in bright conditions as well.

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