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Finger Sleeve: A Wearable Navigation Device

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***Abstract*— In this paper we present a novel wearable navigation system along with implicit HCI (iHCI) model, where interaction with technology is dissolved into a day-to-day activity. In this type of HCI model a computer takes the input and tries to output an action that is a proactive anticipation of next action of a user. Usually, in urban areas people use voice assisted navigation systems or navigation guidelines displayed on a mobile phone. Some navigation systems are already installed on car dashboard, which needs explicit attention in order to make driving decisions. A navigation system using haptic perception to guide a user throughout a journey is the key contribution of this paper. It does not ask for explicit user attention and demonstrates the indolent form of technological interaction. This wearable device is an index finger sleeve, which consists of vibrator modules, Bluetooth communication module and Microcontroller Unit (MCU). A working prototype has been built and tested.**

***Index Terms*— implicit HCI, haptic perception, wearable device, vibrator module, MCU, navigation device**

I. INTRODUCTION

Wearable computing enables human to wear a computational device on body. Wearable devices can be of many types, and each addresses specific use case, such as smart glasses, smart wrist watch, heart monitoring headsets and many more. With the advent and growing popularity of wearable devices like the Google Glass, Fitbit Flex, Nike fuel Band, LG life Band and the Oculus rift, wearable computing is proving to be one of the major technological advancements in the 21st century. These body mounted devices are able to monitor various activities in real-time. For a wearable navigation device the success factor lies in the accuracy of navigational signalling and unobtrusive interaction.

With Implicit Human Computer Interaction model, user need not necessarily be interacting with the computing system. Moreover, interaction with limited visual attention is often emphasized as a design goal for wearable input [1], [2], [3]. Finger Sleeve, a wearable navigation device, works along with the Android Smartphone. Android Operating Systems (OS) based Smartphone covers largest consumer market share, which helps us choose Android Smartphone as a GPS navigator. Here android OS based Smartphone is running a Google Map like application and providing the navigational signals to the Finger Sleeve. The user has to wear Finger Sleeve and pair it with the Smartphone running a navigational application. Finger Sleeve provides easy navigation throughout a journey. Further, while driving a car or riding a bike, the user is relieved from peeking into Smartphone to get current directions, saving a lot of time and avoiding un-necessary hazards.

The contributions of this paper are – (1) to determine the feasibility of the Finger Sleeve; (2) a proof-of-concept, to use the Finger Sleeve for eyes-free navigation; (3) Validation of potential benefits of Finger Sleeve in real life scenario.

II. LITERATURE SURVEY

As Albrecht Schmidt has discussed to bring implicit HCI through context [4], the context can be extracted from the information about user's geographical location, state of the device and the surrounding environment. Context can help find a proper time for an interruption to get the input from users as well as reduce the number of inputs. We are utilizing the GPS present in Smartphone to locate the user. Once the user sets the destination point, he is relieved from peeking into the mobile phone for direction. Finger Sleeve will take over the task of navigation and continue to operate till destination has been reached. Previous research by Thomos J. Pingel and Keith C. Clarke [5] has indicated that wearable computer system has had a positive impact on navigation system. With the smart device development, technology has shrunk into a size of a coin, which helps computation to be almost invisible. Factors thought to be influencing outdoor navigation have been explored by Bruce Thomas et al. [6], but the proposed navigation system is for a user who is traveling by foot.

Our approach is an illustrative example of calm computing, where interaction with the device is almost invisible and device proactively decides on what driving decisions user may take in immediate future. Here retrieving context based on geographical location is a major factor. With the availability of 3G (3rd generation) as well as 4G (4th generation) communication technology data rates have been significantly more. B.H. Thomas and W. Piekarski have discussed glove based user interaction techniques [7], which are very specific to the outdoor Augmented Reality (AR) application and practically not feasible to be used in day-to-day activities because of the bulky nature of the system. Sevgi Ertan et.al. [8] has experimented the haptic navigational signals with wearable vest, which lags in terms of GPS capabilities in the system.

In the real world scenario, environmental noise is a constant distraction. Yet a person driving a car or riding a bike has to consider auditory signals from other cars. This makes audio based navigational systems somewhat a liability for the user. We hypothesize that the Finger Sleeve by using haptic based navigational signalling enhances the navigational experience. Furthermore, fingers are most dextrous and sensitive, specifically the index finger [9], which makes it best suit for Finger Sleeve.

The finger sleeve does not require Smartphone to download additional information from the Internet, thus no overhead on data usages. Though, user has to download a map before starting with the navigation. A navigation application running on Android OS based Smartphone is the minimum requirement for Finger Sleeve to function as expected. It also stands a basis for user's current geographical position on the map in real time.

III. DESIGN OF FINGER SLEEVE

In this section, an abstract design of a finger sleeve is discussed.

A complete operational system using Finger Sleeve has two major parts –

a) Android OS based Smartphone Application.
b) A Finger sleeve device.

Circuit diagram of Finger Sleeve is as shown in Figure 1.

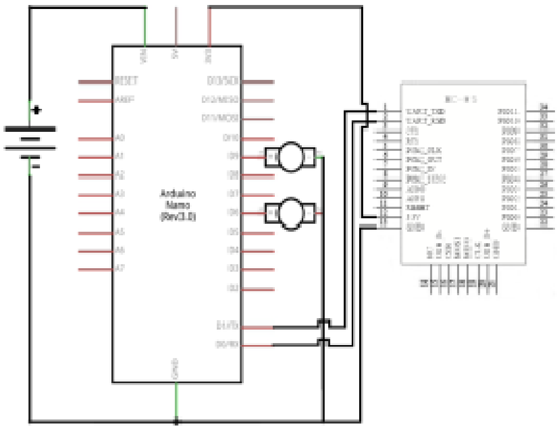


Fig. 1. Circuit diagram of Finger Sleeve

A. High Level Design of Finger Sleeve

A working prototype of Finger sleeve has four modules; every module is responsible to perform a specific opera-tion as described below:

1. HC-05: It is used to send and receive data wirelessly to/from android OS based Smartphone. Another alternative is to use Bluetooth Low Energy (BLE) module.
2. Arduino Nano: It has ATmega168 microcontroller with 16KB memory to store the code. It is responsible to run computational tasks.
3. Micro Vibrators: Two micro vibrators are used to provide a vibrational indicator of respective direction. Each vibrator corresponds to particular haptic navigational signal viz. Right or Left.

Li-ion Rechargeable Battery Pack: Battery pack is responsible to power the Arduino nano. It is a rechargeable battery capable to maintain 80% capacity after 800 cycles. The smallest size of a battery pack, micro vibrator, Microcontroller Unit (MCU) and Bluetooth module helps Finger Sleeve to be worn easily.

Design traits of Finger Sleeve- straightforward operation, context aware input and social acceptance are inspired from Rekimoto's design guidelines for unobstructive wearable technology [10].

Fig. 2. Position of micro vibrator modules

The micro vibrators will be so embedded into sleeve, one each to left, and to right side of a finger, that they are almost invisible. The arrangement of micro vibrators is shown in Figure 2.

The finger sleeve should ideally be worn on proximal phalanx and some part of proximal inter-phalangeal joint. It is comfortable to use and indolent form of interaction.

B. Android OS based Smartphone mobile Application

We developed a Bluetooth coomunication module, the mobile application, which is compatible to run on android OS version equal to 4.0 and above, that connects Finger Sleeve with a Smartphone. The Android application utilizes the map service provided by Google APIs and triggers the micro vibrators. Example scenario is shown in Figure 3.

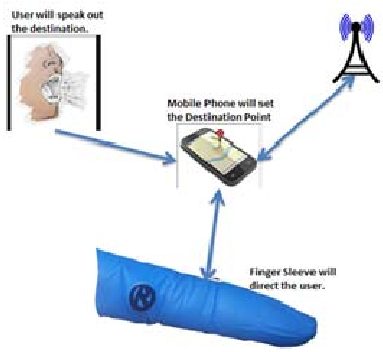


Fig. 3. Scenario of using a finger sleeve along with Smartphone application

There are few pre-requisites to be done on the Smartphone prior to start the application:

1. Start the Bluetooth and pair the Finger sleeve with Smartphone. However, this is done only once and henceforth Bluetooth connection will be automatically established.
2. Enable the GPS of Smartphone.

3. Wear Finger sleeve into the index finger.

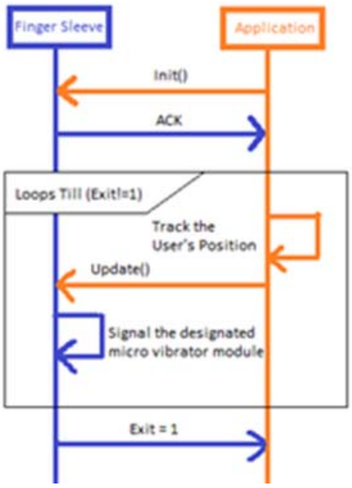


Fig. 4. Sequence diagram under normal operation

C. Android OS based Smartphone mobile Application

1. Start.
2. Set the destination point on map.
3. Draw a navigational path over a map. (Application will perform this automatically)
4. Signal the finger sleeve.
5. Start sending navigational signals to Finger Sleeve.
6. Detect the change in positions of User's current location.
7. Repeat the steps 5 and 6 until the user arrives at the destination or application is explicitly closed.
8. Stop.

In case of normal operation above algorithm is followed, which is shown as a sequence diagram in Figure 4.

We have successfully experimented with the working prototype of Finger sleeve. The design of the first prototype is bearable by the user. After productizing the Finger sleeve, it will be almost invisible and difficult to trace the underline hardware modules used. This leaves a trail for a professional PCB designer to make a final Finger Sleeve Device using flexible.

A navigational android application is running as expected. Thus an android application and Finger sleeve completes the navigation system. PCB design.

IV. Pilot Study

We carried out a pilot study on total ten different participants with ages ranging from 17 – 30 years and with different professional background to determine the length of vibrational signal to indicate each direction viz. left and right. No participant had ever used Finger Sleeve like device before.

Moreover, based on prior study conducted by Kaaresoja, Topi, and Jukka Linjama [11] and Saket Bhador et. Al [12], we explicated that the duration of an On-Off pair should be 200 ms to indicate left and 400 ms to indicate right.

Few participants contributed to both the tasks which are stated below –

1. Walking
   a. Blind Folded Walk
   b. Naked Eye Walk
2. Car Driving

V. Experiments and Results

A. Experiment 1 – Walking Task

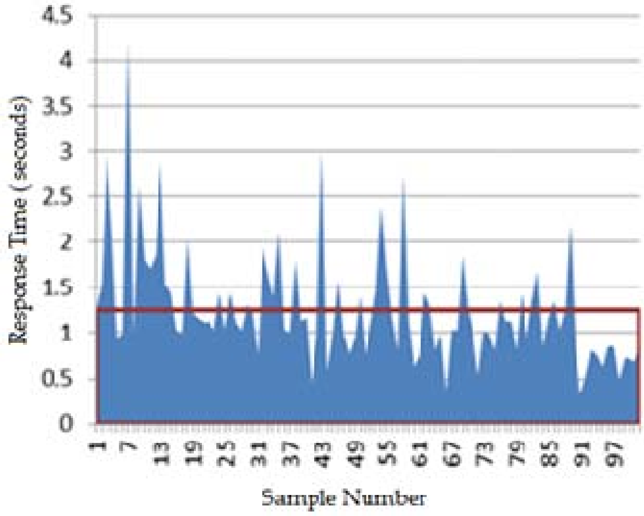
Participants: Six participants (3 Male, 3 Female) with ages ranging from 17-25 years took part in this experiment.

1. Blind Folded Walk

Procedure: Initially, we expounded the method of operation and then asked participants to interpret the vibrational signal corresponding to each direction. Then we explained that he/she has to follow the directional signals from Finger Sleeve while walking blind folded.

As a part of experiment, we asked participants to walk on the path, which was already drawn on ground and participants were unaware of it. We recorded the response time, duration between signal sent to the Finger Sleeve and direction changed while walking, of participants for each directional signal sent to the Finger Sleeve. The total numbers of responses were 102 (Mean 1.2491, S.D. 0.62028).

The data gathered in experiment is plotted in graph 1.

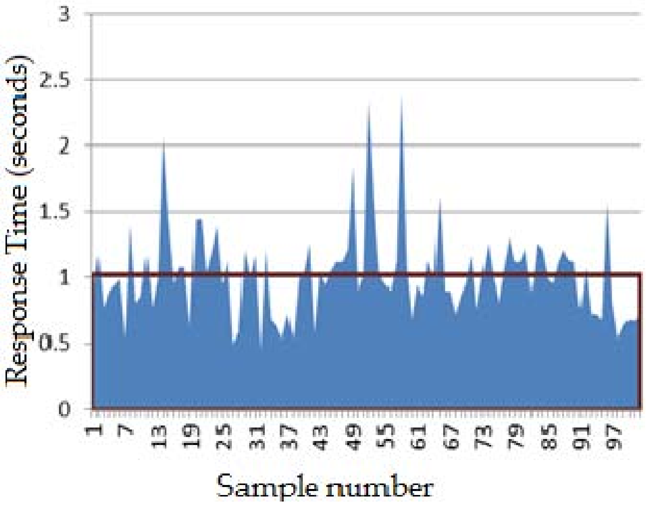


Graph 1. Statistical Detail of Blind Folded Walking Task.

2. Naked Eye Walk

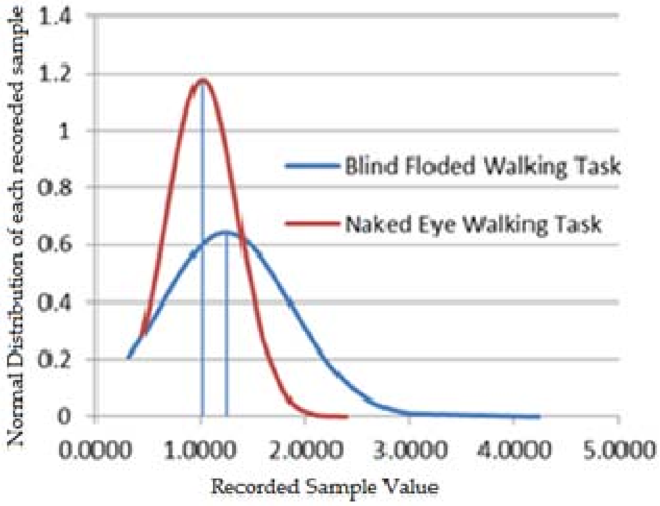
Procedure: In the naked eye walking task, participants were told to follow same set of directions, as in blind folded walking task, but in this task participants were subjected to other visual and acoustic distractions as well as the path lines were wiped out.

We recorded response times for the same set of directions as used in blind folded task to substantiate the comparison between these two tasks (Mean 1.0210, S.D. 0.33855). The collected data is plotted in graph 2.



Graph 2. Statistical detail of Naked Eye Walking Task.

Results: We calculated a normal distribution of all recorded response times and plotted it against response times. A comparison of average response times in both the above walking tasks concluded that Finger Sleeve delivered promising results as speculated. The graph 3 shows that there was minuscule of difference between mean response times recorded in Blind fold and Naked eye walking task, no momentous deterioration was observed. Results corroborate two implications – (1) User has perceived the directions accurately; (2) Visual distractors, as in a real world scenario, had insignificant impact on operation of Finger Sleeve.



Graph 3. Normal distribution of each recorded sample (Y- Axis) Vs. Recorded sample value (X – axis)

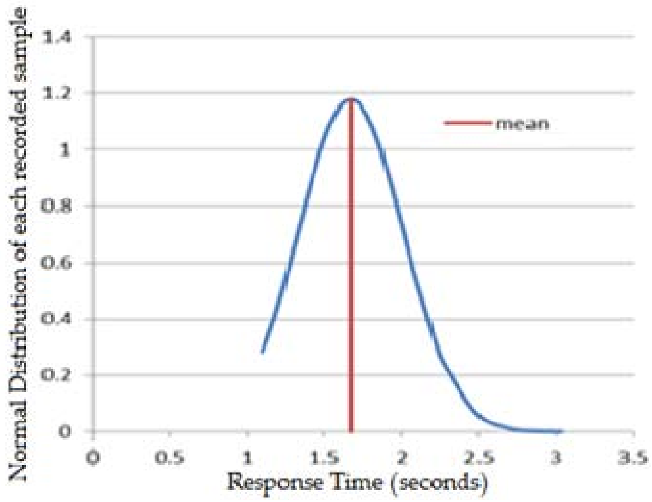
B. Experiment 2 – Driving A Car Task

Participants: Six participants (4 Male, 2 Female) took part in this task with ages ranging from 22 – 30 years. For this task we used only one car and asked to drive the car at moderate speeds.

Procedure: At the start of the experiment, participants were briefed about the operation of Finger Sleeve and then acquainted about unknown path that needs to be followed while driving.

In order to record the accurate response time we sat on passenger seat while participant performed the task. To measure the response time, participants were asked to speak out the direction of immediate turn to be taken after receiving a haptic signal from Finger Sleeve.

The recorded data is plotted in graph 4 (Mean – 1.67095, S.D. – 0.33855).



Graph 4. Statistical Detail of Car Driving Task.

Graph 4 depicts that the recorded mean response time during car driving task, is almost proximate to the mean response time recoded in the task of walking.

VI. Finger Sleeve Vs. SmartPhone

To ascertain how many Smartphone users make use of Screen-Lock and which GPS navigation application they often use and their degree of satisfaction with it, we conducted an online survey, in which we got response from 53 people and found that 85% (approx.) of users lock the phone as shown in table 1; 83% (approx.) used Google maps for outdoor navigation as shown in table 2.

TABLE I. Baseline Screen-Lock Usage (Online Survey)

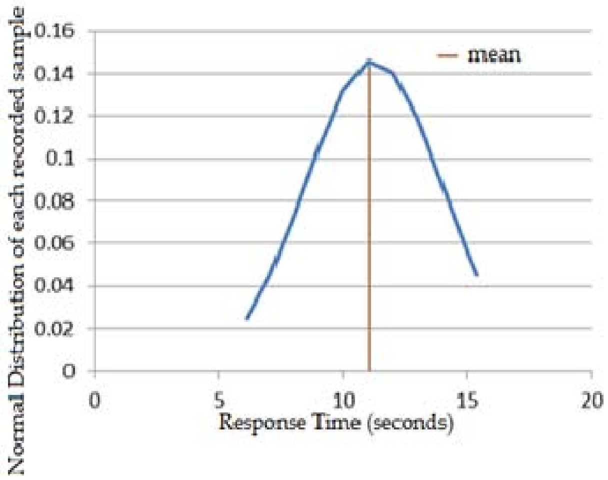
What Type of Screen-Lock people use?		
Type of Lock	***Number of Users***	
Pattern	32	60.36%
Pin	10	18.87%
Password	3	5.66%
None	8	15.09%

TABLE II. GPS navigation Application used and user rating (Online Survey)

Which GPS Application people use?			
Application Name	***Number of Users***		***Average Rating***
Google Maps	44	83.01%	Good
Nokia – here	3	5.66%	Good
Other	6	11.32%	Satisfactory

The total number of steps to initiate a GPS navigational application on smartphone usually takes following steps – unlock a phone, go to the desired application, click the icon and initiate the navigation. After that, while user is on the move, he/she frequently repeats following steps – unlock a phone and check visual maps in Smartphone. Graph 5 shows average amount of time required to do above stated operations. The average amount of time spent on these operations (unlocking the phone and peeking into visual maps) is directly proportional to the total number of turns in the path.

In contrast, Finger Sleeve is designed to be an eyes-free navigational device and practically takes minimal number of steps to operate – Initiate the maps application and pair the Finger Sleeve with smartphone only once. After that, Finger Sleeve takes over the task of navigation relieving user to peek into Smartphone while he/she is on the move. Moreover, total number of turns doesn't affect the duration of travel. Proving Finger sleeve saves significant amount of time as well as allow user to focus on road without being distracted.



Graph 5. Normal Distrubution of each recorded sample.

Graph 3, 4 and graph 5 reveal that the difference between mean response times recorded during walking, car driving experiment and the mean response time recorded during navigation without the Finger Sleeve is equal to 9.91 seconds. Thus, confirming the initial hypothesis - Finger Sleeve is a great enhancement to present navigational system.

VII. LIMITATIONS

A. Data Connectivity

In case of limited data connectivity smartphone GPS will not work as expected, leading to an ineffective use of Finger Sleeve.

B. Complex Topography of Roads

In case of complex converging nodes, Finger sleeve operations needs to be ameliorated and more stringent tests should be conducted.

C. Cars with GPS enabled dash boards

The car driving experiment discussed in this paper was carried out in a car, which had no GPS navigation unit installed on car dash board. Hence user was dependent primarily on the Finger Sleeve for directions.

While, in case of a car with GPS unit installed on dash-board, we surmise testing results might show a small deviation.

VIII. CONCLUSION & FUTURE WORK

A. Conclusion

In this paper, we have presented the experimental results and in depth analysis of the Finger Sleeve prototype for navigation during walking and driving a car tasks. Finger Sleeve, a wearable navigational assistant, shows the potential of being effective navigational beacon. Preliminary studies of user reactions and feasibility of using such wearable navigational device suggest that it is an easy to use and apropos for the navigational needs of the user in present era.

B. Future Scope

Such navigational system stands a base for multiple applications, which can be extended from the basic version, such as –

1. Media controller for a Smartphone.
2. A wearable pointing device.
3. Customizable keys to be used along with the mouse.
4. Finger sleeve can help visually impaired, but it has to be integrated with obstacle detection systems.

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