Towards affordable Mobile Crowd Sensing device

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ABSTRACT

In this paper, we describe first prototype of mobile crowd sensing device. The device serves as a source for signals in the potential crowd sensing studies. Presented device has no intention to compete with the existing mobile devices, such as mobile phones, but to complement them where they lack of the features like affordability, simple use and new opportunities in different segments of our lives. Our main goal was to develop a device, which can cover all aspects of mobile crowd sensing and at the same time to keep the device cost at very affordable level. The described device is capable of integration into most widely available sunglasses. The complete device consisting of two separate "lenses" forms distributed ecosystem serving as source for sound, light, acceleration and temperature signals while at the same time providing actuator function with integrated LED matrix display.

Keywords

Mobile crowd sensing, wearable interface, affordable electronics.

1. INTRODUCTION

Mobile crowd sensing (MCS) is a new paradigm [1]. The signals in the crowd sensing studies are transferred from pervasive mobile devices. The collected data serves as the source for numerous largescale applications, which can be classified into three groups: environmental, infrastructure and social. Each group has own requirements and operating conditions. Typical *environmental* mobile crowd sensing application is pollution monitoring [3]. The MCS application is a two-step process: to assign sensing tasks to users and to wait for results [3]. The interaction relies on active participation of each individual in the process loop, which can be sometimes cumbersome. Example of the *infrastructure* MCS application is use of the data in the emergencies where individuals try to support the actions of emergency services and volunteers, especially in time-critical situations [4].

Main obstacle in such situations is the availability of the existing infrastructure, which is usually compromised or even completely destroyed (in environmental disasters). Such situations void mobile phones useless. The *social* MCS applications enable individuals to share sensed information among themselves. The majority of the social MCS applications seem to be limited to social media and networks. There are applications where such applications improve the quality of life in elderly people by collecting biological sensor and activity data to adjust and gain the comfort condition [5]. The main issue in such application is limited use of smart phones with elderly people which prevents sensing possibilities.

Sensing individuals in a large group can be achieved by using existing smart phones and several sensors available in such mobile devices. The overview of some devices providing MCS applications is listed in Table 1. However there are several issues when using people-centric mobile phones as sensory devices: reliability of the sensed signals, lack of actuators and feedback, awkward use and lack of wider use due to relatively high cost of the currently available devices. In this paper we describe our first step towards many new opportunities in crowd sensing area, the affordable hardware platform which cover all three [2] groups of the mobile crowd sensing process: environmental, infrastructure, and social sensing. Our platform will try to overcome the two primary technical obstacles in mobile phone centric MCS: the noisy data and lack of useful and effective feedback to the MCS users. Same barriers were also identified with authors in [6], where they as such prevent the new applications to "advance quickly, acting as a disruptive technology across many domains including social net-working, health, and energy."

Table 1. Overview of some MCS application providers

Device	Inertial	Compass	GPS	Microphone	Camera	Proximity	Light	Affordable
iPhone 6	✓	✓	✓	✓	✓	✓	✓	
Asus Zenfone 3	✓	✓	✓	✓	✓	✓	✓	
Nexus 6P	✓	✓	✓	✓	✓	✓	✓	
HTC 10	✓	✓	✓	✓	✓	✓	✓	
MPS device [7]	✓	✓		✓			✓	
Our MCS device	✓	✓ (1)	✓ (1)	✓			✓	✓

(1) External module

Lack of affordable, low cost, almost disposable device enabling MCS applications encouraged us to develop new type of wearable interface. Our main goal was to develop a device, which can cover all three groups of mobile crowd sensing. At the same time our goal was to keep the device cost at very affordable tag, which can also be of paramount importance.

2. CROWD SENSING DEVICE

Development of new MCS device started with design requirement specifications. The complete list of requirements is shown in Table 2.

Our main goal was to develop small and affordable system, which can be integrated into existing environment. To keep the device affordable we were not able to add sensors for all signals listed in Table 1, however the device has all interfaces which can provide communication with external modules when needed, e.g. GPS, Bluetooth or WiFi module.

Table 2. List of design requirements

Scope	Details
Displaying messages	Display short text messages on the device surface
Detect activity	Motion detected with accelerometer sensor and/or GPS
Environment sensing	Integrated microphone, illuminance sensor and thermometer
Communication	Standard interfaces provided on-board
Low power	Power consumption limited with careful component selection
Affordability	Keep total cost of the device as low as possible

2.1 Integration into sunglass

The device was designed to integrate into existing sunglasses which are widely available at very low cost. After some investigation we concluded the almost all low cost sunglasses have same lens shape (Fig. 1). This and the fact that such sunglasses can cost a bargain motivated us to use the shape of such lenses for our base modules.

Figure 1. Most common "wayfarer style" sunglasses.

Another reason to use sunglasses was the ability to integrate the wearable display, providing personal interaction from one MCS device to another user.

Since the printed circuit board is not transparent we were faced with one obstacle: how to prevent the MCS device users to become blind when wearing such eyewear. One option was to use transparent substrate. Electronics can be integrated onto the glass substrate. This would definitely void the affordability goal. Another option was to drill array of holes into the substrate. After some experimentation we discovered the perforated substrate in front of the eye doesn't interfere with normal vision. Based on experiments on subjects at different ages and gender we defined the perforation parameters which are most acceptable for all users (Fig. 2). After short introduction time the subject became comfortable with the eyewear.

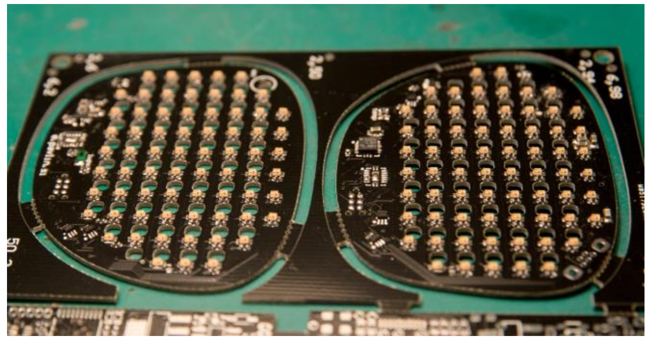

Figure 2. Perforated substrate of the MCS device used to replace the sunglasses lenses.

2.2 MCS Device

The device is divided into two modules: left and right "lens". Block diagram is shown in Fig. 3. Both modules communicate internally via I2C bus exchanging data from sensors and other peripheral devices.

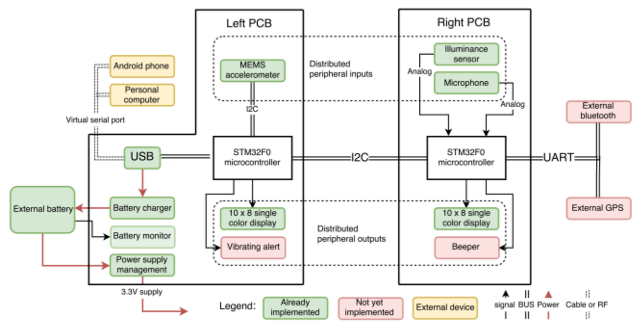

Figure 3. MCS device block diagram.

Lens from wayfarer style sunglasses were taken out of the frame and replaced by circuit boards with 69 LEDs on each. Every LED can be individually controlled much like pixels on 5×7 display. Both left and right circuit boards have a low power Cortex M0 micro-controller for driving the LEDs wired in a matrix. Among with the LEDs there are also other peripherals. The I2C bus enables both sides of the MCS device to communicate with each other. Programmable MEMS motion sensor (accelerometer) tracks head movements or other user motion activity. Tiny microphone detects environment sounds and provides MCS device to react on sound stimuli. Light sensor measures environment illumination. User can select modes of operation with one button. Device is powered by external lithium batteries residing on the frame. On-board LiPo/LiIon battery charger provides proper charging and is powered from micro USB connector, which also provides connectivity with personal computer or other mobile device applications. Finally, an extra ADC input is provided for experimenting with future sensors. External modules can be connected via USART interface such as Bluetooth or GPS.

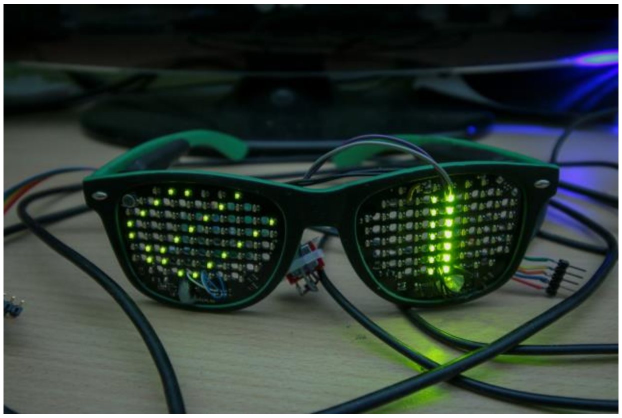

Figure 4. Working prototype of MCS device.

As expected few mistakes were made at designing the first prototype such as wrong component placement/connection and a faulty fabrication of the circuit board. After minor workarounds the MCS device became functional as expected albeit the initial design and fabrication mistakes. The first prototype looks very promising. A second version has already been designed.

2.3 MCS Device technology challenges

The perforated substrate leaves not much room for the components between the holes. The LED matrix which is placed on tiny bridges required smallest vias, tracks and tracks spacing. This can be derived from the mass market mobile phone production at very low expense. There are technologies providing micro vias and ultra-low design sizes, which could enable even larger holes in the substrate perforation. Unfortunately this would result in higher production costs. During first tests we found out there is no big issue with that and we could produce the MCS device with existing technology and geometry.

3. CONCLUSION

The field of mobile crowd sensing has recently evolved from the availability of vast sensing opportunities in modern mobile devices. Despite availability the existing commercial mobile devices lack of features in some aspects.

The paper presents the device to provide base for growing ubiquity of personal connected devices creating the opportunity for a range of applications which may fit into sensed signals and generated visual effects. The sensing requirements set by future applications will probably evolve over time very dynamically. The future expansion will depend on the evolving interest in different types of data gathered by presented MCS device based on different contextual factors. Hopefully the device will provide new approaches to modeling and programming multi-modal sensing applications with enhanced modularity and high affordability.

The presented MCS device is in no way limited only to the mobile crowd sensing, but can also provide some useful ways of use in everyday life at many levels. Display capability of the eyewear can e.g. provide new opportunity for disabled persons. One possibility is to provide personal contact with deaf(-mute) person when another person can’t understand the sign language. The eye contact is more personal than e.g. writing or sketching on the paper or typing on the mobile phone screen. The experience could be completely different when “conversation” is held by maintaining eye contact.

Our hope is to spread the device to targeted crowds and use it as a tool for real world crowd sensing studies in this new and promising area.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] Ma, H., Zhao, D., & Yuan, P. (2014). Opportunities in mobile crowd sensing. *IEEE Communications Magazine*, *52*(8), 29-35.

[2] Ganti, R. K., Ye, F., & Lei, H. (2011). Mobile crowdsensing: current state and future challenges. *IEEE Communications Magazine*, *49*(11), 32-39.

[3] Cardone, G., Foschini, L., Bellavista, P., Corradi, A., Borcea, C., Talasila, M., & Curtmola, R. (2013). Fostering participaction in smart cities: a geo-social crowdsensing platform. *IEEE Communications Magazine*, *51*(6), 112-119.

[4] Ludwig, T., Reuter, C., Siebigteroth, T., & Pipek, V. (2015, April). Crowdmonitor: mobile crowd sensing for assessing physical and digital activities of citizens during emergencies. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 4083-4092). ACM.

[5] Nugroho, L. E., Lazuardi, L., & Non-alinsavath, K. (2015, October). Ontology-based context aware for ubiquitous home care for elderly people. In *2015 2nd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)* (pp. 454-459). IEEE.

[6] Lane, N. D., Miluzzo, E., Lu, H., Peebles, D., Choudhury, T., & Campbell, A. T. (2010). A survey of mobile phone sensing. *IEEE Communications magazine*, *48*(9), 140-150.

[7] Choudhury, T., Borriello, G., Consolvo, S., Haehnel, D., Harrison, B., Hemingway, B., ... & LeGrand, L. (2008). The mobile sensing platform: An embedded activity recognition system. *IEEE Pervasive Computing*, *7*(2), 32-41.