WISEglass – Multi-purpose context-aware smart eyeglasses

Florian Wahl, Martin Freund, Oliver Amft
ACTLab, Chair of Sensor Technology, University of Passau, http://actlab.uni-passau.de
{wahl, freund, amft}@fim.uni-passau.de

ABSTRACT

We extend regular eyeglasses with multi-modal sensing and processing functions for context awareness. Our aim was to leverage eyeglasses as a platform to acquire and process context information according to the wearer's needs. The eyeglasses provide inertial motion, environmental light, and pulse sensors, data processing and wireless functionality, besides a rechargeable battery. We implemented prototypes of the smart eyeglasses and evaluated recognition performance in a study of daily activities with nine participants. The accuracy of recognising nine activity clusters from the smart eyeglasses motion sensors was 77% on average, confirming the benefit of smart eyeglasses for context-aware applications.

Author Keywords

mobile sensing, smart glasses, activity recognition, eyewear

ACM Classification Keywords

I.5.m. Pattern Recognition: Miscellaneous

INTRODUCTION

Over recent years context awareness has opened a vast spectrum of applications that benefit from momentary information on user activity, environment, physiology and similar. Wearable devices are often key to provide context information as sensors could be placed comfortably at body locations, including wrist, leg, chest, or the ear. As wearable computing targets seamlessly integrated technology and wearer-augmenting functionality in daily life, it seems natural to consider regularly worn accessories as basis for context-aware applications. In particular, regular eyeglasses have a unique opportunity to carry sensors and extract context information at the head, while being worn by millions of people [1].

Functionality of smartglasses often centred around displaying information in front of the wearer's eyes, e.g. for augmented or virtual reality applications [4, 6]. GoogleGlass established microinteractions as feature of smartglasses and focused on interaction and displaying information using glass-attachable electronics. We believe that instead of displays and direct interaction, smart eyeglasses can serve in context-aware applications, where the focus is on sensing and processing [1].

Moreover, smart eyeglasses should closely match regular eyeglasses in form factor and handling.

In this paper, we present our smart eyeglasses architecture that integrates multi-modal sensing and processing functions in a regular eyeglasses design. With the smart eyeglasses design, sensor data could be continuously processed. We present here a processing framework to continuously recognise activities using Gaussian Mixture Models (GMMs). We evaluate our eyeglasses prototypes in a study of everyday life activities. We grouped the performed activities into nine activity clusters and show the recognition performance in a leave-one-participant-out validation.

Integrating smart eyeglasses as multi-purpose sensing device distinguishes our approach from earlier work that primarily considered conveying visual information to the wearer. Being a new approach towards smart eyeglasses, the sensors and electronics used for our first prototypes are not yet fully integrated. In this work, we establish that smart eyeglasses could substantially enrich context awareness and thus assist their wearer. In the future, further integration will make smart eyeglasses unobtrusive and robust for everyday life.

RELATED WORK

Aziz et al. [3] presented e-AR, an ear-worn sensor for monitoring patients after abdominal surgery. In a study with 20 users they investigated motion patterns in data obtained from two dual-axis accelerometers. They used a pulse oximeter clipped to the users earlobe to monitor heart rate and oxygen saturation. The authors of [2] compared seven different on-body motion sensor locations while grouping the activities by physical intensity level. At the head, e-AR was used. The authors found that the ear location delivers good results for 4 out of 5 activity levels. Ishimaru et al. [5] used EOG and acceleration signals to classify reading, typing, eating, and talking activities, recorded from 2 users at an average of 70% accuracy using user independent models. Our WISEglass architecture provides accelerometer, gyroscope, magnetometer, RGB light sensor, and pulse sensor at the head and integrated into eyeglasses.

WISEGLASS CONCEPT AND ARCHITECTURE

WISEglass retrofits regular eyeglasses with a multi-modal sensor system for context-aware applications. WISEglass could be used as an everyday accessory, just as regular eyeglasses are used today, or as a special-application device, e.g. as safety or sports glasses are used for special purposes. For our design investigations, we specifically chose standard off-the-shelf eyeglasses and avoided designing the device from scratch to ensure that the typical eyeglasses form factor will be maintained. Our prototype of WISEglass is depicted in Figure 1. Processor, flash memory, communications interfaces, power controller, as well as inertial sensors were integrated onto a baseboard, the central computing unit of WISEglass. In our first prototypes, battery and baseboard were bound together using shrink tubing. However we consider that the units could be embedded in opposite ends of the eyeglasses frame in future versions. With the light sensor, we investigated the possibility of embedding components into the bridge of the eyeglasses. The pulse sensor was mounted with a cable tie to enable users to customise the sensor wearing position. In further versions, the pulse sensor could be embedded directly into the temple, thus avoiding manual adjustments.

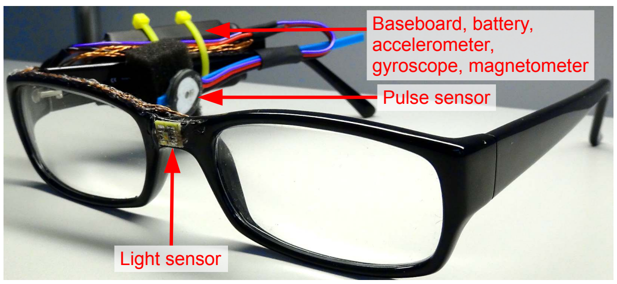

Figure 1. WISEglass prototype. Baseboard, battery, accelerometer, gyroscope, and magnetometer are mounted on the outside of the eyeglasses' temple. The pulse sensor is mounted on the inside of a temple. The light sensor is integrated into the bridge.

The WISEglass electronics were implemented using a set of off-the-shelf components. We used the MPU-9250 from InvenSense that provides 3-axis accelerometer, 3-axis gyroscope, and 3-axis magnetometer, and a digital motion processor in a single package. Light intensity is measured with a TCS3472 from AMS that provides red, green, blue, and clear light spectra separately. The light sensor was mounted on the bridge of the eyeglasses, closest possible to the wearer's eyes. To obtain heart rate, we used a pulse sensor that is based on the reflexive photoplethysmography (PPG) principle. Placement of the pulse sensor was experimentally determined. We found the temple to be a good location as it eliminated the need for an ear clip.

DATA COLLECTION AND EVALUATION

To evaluate our approach we conducted a study with 9 participants (3 female, 6 male between 20 and 27 years old). All participants either did not require prescription glasses or wore contact lenses. Participants performed 20 different typical activities of daily living across one day. Subsequent to the recordings, activities were grouped into nine activity clusters: Eating, walking, brushing teeth, walking stairs, jogging, cycling, reading, screen work, and cleaning. All sensors were sampled at 50 Hz yielding a total of 66 hours of data.

A sliding window of $n = 1500$ sa (30 s) with $s = 50$ sa (1 s) steps was used to extract a set of 25 time domain features over each of the three accelerometer axes, the L2 norm of all accelerometer axes, and the gyroscope axes. Feature vectors were standardised and normalised before further processing. We applied principle component analysis to reduce the number of features. To ensure generality and stability of our results we used Leave-One-Participant-Out (LOPO) cross-validation. For the motion-based activity classification, a GMM classifier with diagonal covariance matrices and three components for each class was deployed. To detect unlabelled data without making assumptions on the data in the null class, we implemented classifier reject.

RESULTS

Motion-based activity recognition yielded an average accuracy between 70% and 84% per participant, with a mean of 77%. Per-class performances between 80% and 90% were achieved, except for cycling which was around 50%. As cycling was performed at low intensity on a gym device, head motions showed similar footprints as other activities involved in the confusions, including eating, walking, brushing teeth, and cleaning.

CONCLUSION

WISEglass is the first multi-modal sensor system retrofitted to off-the-shelf eyeglasses. The platform offers motion, light, and pulse sensors, can store data, or stream it wirelessly to another device. The motion-based activity recognition showed an average accuracy of 77 % for distinguishing 9 activity clusters using LOPO cross-validation. We conclude that WISEglass will be suitable for a wide range of applications requiring context awareness.

Acknowledgements

This research is supported by the Dutch Technology Foundation STW grant numbers 12184.

REFERENCES

1. Amft, O., Wahl, F., Ishimaru, S., and Kunze, K. Making regular eyeglasses smart. *IEEE Pervasive Computing* (In press).
2. Atallah, L., Lo, B., King, R., and Yang, G.-Z. Sensor placement for activity detection using wearable accelerometers. In *Body Sensor Networks (BSN), 2010 International Conference on*, IEEE (2010), 24–29.
3. Aziz, O., et al. Pervasive body sensor network: an approach to monitoring the post-operative surgical patient. In *Wearable and Implantable Body Sensor Networks, 2006. BSN 2006. International Workshop on*, IEEE (2006), 4–pp.
4. Azuma, R. T., et al. A survey of augmented reality. *Presence 6*, 4 (1997), 355–385.
5. Ishimaru, S., et al. Smarter eyewear: using commercial eog glasses for activity recognition. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*, ACM (2014), 239–242.
6. Zhou, F., Duh, H. B.-L., and Billinghurst, M. Trends in augmented reality tracking, interaction and display: A review of ten years of ismar. In *ISMAR 2008: Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality* (2008), 193–202.