Building Implicit Interfaces for Wearable Computers with Physiological Inputs: Zero Shutter Camera and Phylter

Tomoki Shibata, Evan M. Peck, Daniel Afergan, Samuel W. Hincks, Beste F. Yuksel, Robert J.K. Jacob
Tufts University
Medford, MA, 02155, USA
{tshibata,epeck02,afergan,shincks,byukse01,jacob}@cs.tufts.edu

ABSTRACT
We propose implicit interfaces that use passive physiological input as additional communication channels between wearable devices and wearers. A defining characteristic of physiological input is that it is implicit and continuous, distinguishing it from conventional event-driven action on a keyboard, for example, which is explicit and discrete. By considering the fundamental differences between the two types of inputs, we introduce a core framework to support building implicit interface, such that the framework follows the three key principles: Subscription, Accumulation, and Interpretation of implicit inputs. Unlike a conventional event driven system, our framework subscribes to continuous streams of input data, accumulates the data in a buffer, and subsequently attempts to recognize patterns in the accumulated data – upon request from the application, rather than directly in response to the input events. Finally, in order to embody the impacts of implicit interfaces in the real world, we introduce two prototype applications for Google Glass, *Zero Shutter Camera* triggering a camera snapshot and *Phylter* filtering notifications the both leverage the wearer's physiological state information.

Author Keywords
implicit interface; wearable computing; Google Glass; brain-computer interface; BCI; fNIRS

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
With both the rise of wearable computing devices and physiological sensors, the integration of sensing technology into wearables is becoming increasingly common. However, despite the advertised potential, there are only a few existing applications to date that leverage this input to ease interaction. When compared to stationary computers, wearables tend to have advanced but limited communication channels to/from wearers. For example, Google Glass, a head mounted wearable device, offers two main interaction methods: touch gestures on the side bar and voice commands, but does not come with a conventional keyboard or mouse input. Behind the advent of wearable technology era, it is a challenge to design interfaces by taking advantages of having physiological inputs as additional communication channels.

To address this challenge, we build implicit interfaces which have the potential to augment conventional interaction styles. Implicit interfaces take the wearer's physiological signals as input and adapt to the wearer's present physiological state. In this way wearable computers can have the ability to *passively* act on the behalf of the user on a moment-to-moment basis by responding the wearer's physiological state, which is unlike the conventional Human-Computer Interaction in which explicit action initiates system response. Unlike explicit inputs, which are discrete commands by the user, such as typing on a keyboard, implicit physiological inputs are contiguous and may or may not require its immediate utilization. Because of the fundamental difference between the two types of inputs, a mechanism to accommodate implicit inputs is essential for implementing implicit interfaces.

This paper presents our core framework for building implicit interfaces, based on three principles: 1) *Subscribing or receiving passive sensor information*, 2) *Accumulating or holding implicit input*, and 3) *Interpreting the wearer's state*. The purpose of introducing this framework is to ease the implementation of implicit interface applications. We then present two prototype applications for Google Glass that make use of this framework - *Zero Shutter Camera* and *Phylter*, which both leverage the wearer's brain state information.

RELATED WORK
We have been studying Brain-Computer Interfaces (BCI) with using functional near-infrared spectroscopy (fNIRS), measuring hemodynamic changes happening in the prefrontal cortex. In a recent study, Afergan et al. showed a physiological interface making changes to a system when detecting periods of extended high or low workload can keep users engaged [1]. In this paper, we propose a method for abstracting the process to deal with passive physiological inputs, originally implicit brain input considered in our preliminary BCI study. We introduce three key principles for utilizing physiological input from any sensor in implicit user interfaces.

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CORE FRAMEWORK WITH THREE KEY PRINCIPLES

In this section, we consolidate a core framework aiming to accommodate implicit input. The core framework adhere to the three key principles:
1) Subscription: Ability to continuously receive information since implicit physiological input is a stream of information. (Client-Server architecture over a Bluetooth, IP-based or even wired connection would be applicable to achieve this.)
2) Accumulation: Ability to hold the received information for a certain duration in order to allow pattern recognition over recent past data.
3) Interpretation: Ability to recognize the wearer's present physiological state based on the accumulated information when the wearable computer asks. (Since there may be more than one implicit channel, this ability is also responsible to encompass all implicit input channels.)

In order to illustrate the impact of our core framework in implicit interactions between wearable and wearer, we next introduce the two prototypes built on its foundations: *Zero Shutter Camera* and *Phylter* for Google Glass.

Zero Shutter Camera

Zero Shutter Camera is a native Google Glass application that takes the prediction of the wearer's state as input and triggers a camera snapshot at special moments. *Zero Shutter Camera* determines when to take pictures by continuously monitoring the wearer's physiological state over a Bluetooth connection. Figure 1 represents the implicit interaction flow, invoked by the application passively responding to the wearer's current physiological state. To test the application, we used our real-time brain monitor [2] as input.

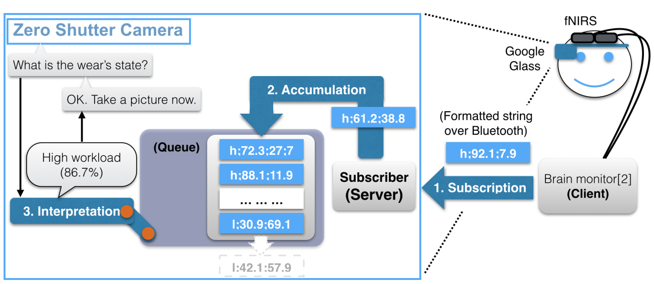

Figure 1. Zero Shutter Camera Framework. The introduced core framework 1) *subscribes* continuous state classification data as the formatted string, 2) *accumulates* at least 10 [sec] of the immediate data in the queue, and 3) *interprets*, when the application asks, by reporting the quantified confidence value [%] of the wearer being in a high or low workload state by averaging the accumulated data. Finally, if the application understands the wearer is in high workload state with a confidence value above a heuristic threshold, then takes a picture for the wearer.

We emphasize that the *Zero Shutter Camera* is *not* a direct control to push the shutter button by the brain. Instead, it passively takes pictures for the wearer based on the wearer's physiological state via an implicit communication channel. Because physiological state changes from moment to moment, not only can the *Zero Shutter Camera* be used in daily life as a life-log, it comes into its own in situations where the wearer is having situation disability - a circumstance where a non-disabled person is considered to be having temporal but critical disability due to the immediate context. For instance, the application would be most beneficial for police officers or medical doctors who are dealing with emergency situations where both hands are preoccupied.

Phylter

Without an intelligent protocol for timing and filtering content, notifications by wearable devices can easily distract wearers. Aiming to mitigate the issue, *Phylter* is an intermediate software between notification senders and Google Glass to schedule the delivery of notifications by using predictions of the wearer's state as input. We tested *Phylter* with our real-time brain monitor [2] as input. *Phylter* assesses the interruptibility of the user based on wearer's current brain state, ultimately deciding if she has the cognitive resources available to handle a notification of a known level of importance.

Phylter treats the implicit brain input in exactly the same way as *Zero Shutter Camera* by following the introduced core framework, except that implicit physiological information is conveyed over an IP-based connection. *Phylter*'s decision making logic is that whenever *Phylter* receives a notification from a notification sender, inspecting the wearer's current state. If the wearer has high cognitive workload with a heuristic threshold value, then *Phylter* blocks the notification; otherwise, delivers it to Google Glass.

Although we demonstrate two prototypes that take wearer's brain state as input, they can be easily modified to integrate other types of physiological input as long as they follow the introduced core framework.

CONCLUSION

Incorporating our three key principles (Subscription, Accumulation and Interpretation), we introduced the core framework to support implementing implicit interfaces for wearable computers. We presented two prototypes built on the foundation of the core framework for Google Glass, *Zero Shutter Camera* and *Phylter*, and illustrated their implicit interactions between wearable and wearer. We believe that the use of physiological input for implicit interfaces serves as an appropriate stepping-stone to an era in which wearable computers are not only worn by humans but actually become a part of the body.

NOTES

Zero Shutter Camera is made open source located at
`https://github.com/zshiba/zero-shutter-camera`.

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