Using fNIRS to Support User Interfaces

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As human-computer interaction (HCI) researchers, we strive to improve user experience and user performance when using interactive computer systems. Over the past fifty years, computers have gained power and efficiency, and can now process massive amounts of information at high speeds. Humans, on the other hand, have not witnessed such dramatic improvements. Thus, we develop interaction techniques to make humans more effective when they interact with computer systems. Early systems used punch cards, and later, command line interfaces. Today, the mouse and keyboard are ubiquitous input devices, while graphical displays on monitors are used for transmitting information from the system to the user. However, these techniques still are not able to capture the richness of the user's thoughts and intentions when interacting with a computer system.

To further increase the bandwidth from humans to computers, we are investigating methods for sensing signals that users naturally give off while using a computer system. We plan to use this data to augment the explicit input that the user provides through standard input devices. Using functional near-infrared spectroscopy (fNIRS), we can detect signals within the brain that indicate various cognitive states. fNIRS can open new doors for HCI research since it is safe, non-invasive, and portable, yet still provides cognitive state information. If used with care, this additional information can lead to interfaces that adapt appropriately to changes in the user's cognitive state. Our research aims to identify the best use of this cognitive state information in user interfaces.

We make use of the fNIRS signal as an additional input channel, providing hard-to-detect information such affective and cognitive states of the user. We are developing strategies for real-time utilization of this information to enhance the user experience. The systems will sense natural signals without requiring any additional effort from the user. Because the brain input is implicit (unlike a mouse or keyboard that the user explicitly uses for input), we do not want to surprise or confuse the user by making unexpected changes to the interface. In addition, the data is often noisy, and is constantly changing. Therefore, the adaptive interfaces should make subtle, helpful changes to the interface that ideally would not be too disruptive if the user's state was misinterpreted.

We have taken steps toward building an adaptive BCI using fNIRS. To classify cognitive states from fNIRS data alone, we developed noise reduction and machine learning classification algorithms. These have been developed to work in real time, as data is collected, in order to adapt the system in real time. In addition, we have conducted studies [1, 2] to determine the feasibility of recognizing various cognitive states with the fNIRS device. From these studies, we have shown the viability of distinguishing various cognitive workload levels, game difficulty levels, and specific cognitive resources (i.e. verbal working memory). We are particularly interested in high workload scenarios, where a person may be multitasking, and hope to build adaptive systems to better support the user.

Portable, non-invasive sensing devices such as fNIRS are becoming realistic tools for HCI researchers, giving us a better understanding of the user's cognitive and affective state. This knowledge can have a big impact on user interfaces, but it must be used appropriately. Since this input has unique characteristics that set it apart from most standard input techniques, we have been exploring the effective use of the device in human-computer interaction. This is an early step towards computers that can interpret the user's state and adapt accordingly.

1. Girouard, A., Solovey, E.T., Hirshfield, L.M., Chauncey, K., Sassaroli, A., Fantini, S. and Jacob, R.J.K., Distinguishing Difficulty Levels with Non-invasive Brain Activity Measurements. in *INTERACT 2009*, (Uppsala, Sweden), Springer.2009.

2. Hirshfield, L.M., Solovey, E.T., Girouard, A., Kebinger, J., Sassaroli, A., Tong, Y., Fantini, S. and Jacob, R.J.K., Brain Measurement for Usability Testing and Adaptive Interfaces: An Example of Uncovering Syntactic Workload with Functional Near Infrared Spectroscopy. in *Proc. of CHI'09 Conference on Human Factors in Computing Systems*, (2009).