Empathic Computer Architectures and Systems

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1 Introduction

Any computer system ultimately aims to satisfy the end user. However, computer design, evaluation, and optimization typically leave the user out-of-the-loop. Recent studies [1, 3, 5] indicate that there is significant optimization potential in considering the user when making system-level decisions. One of key challenges in user-aware research lies in understanding user satisfaction. While it is possible to explicitly ask the user for feedback, such interaction may be annoying. An effective implicit form of user feedback would be ideal. In this paper, we argue for incorporating such feedback into future architectures/systems and ask the question: ***Can we use human physiological traits to make informed user-aware (empathic) architectural and system-level decisions?***

As an example, imagine the following scenario for a laptop user. An eye tracker follows the user's line of vision. The OS scheduler increases the priority of the window which the user is focused on. During game play, the eye tracker recognizes user arousal through pupil dilation and notifies the game engine. To improve power consumption, several heuristics throttle CPU/memory/disk performance to minimize system performance to a level believed to satisfy the user. However, when biometric sensors indicate the user is annoyed, performance is increased, and the heuristics are updated accordingly.

2 Leveraging Physiological Traits

While the thought of empathic architectures and systems may seem farfetched, it is not as crazy as it might seem. For example, Mandryk [4] has demonstrated it is possible to continuously recover human emotional state during game play using physiological sensors. Computers would 1) need to be augmented with new input devices, 2) include hardware/software to process the input and determine the user's physiological state, and 3) make architectural and systems decisions to improve user satisfaction.

New input devices could include an eye-tracker, a photoplethysmograph (PPG) sensor for detecting heartbeat, a galvanic skin response (GSR)/electrodermal activity (EDA) sensor for measuring skin resistance, and a skin temperature (SKT) sensor [1]. Such devices can be added as separate new devices, or as an addition to existing input devices. As an example of the latter option, Whang [7] has embedded PPG, EDA and SKT sensors into a mouse.

For managing the user feedback, we propose a *User Management Unit (UMU)*, analogous to the memory management unit, to be incorporated in future architectures. UMU will process the physiological sensors and interact with the rest of the system. It will interrupt the processor if the user is annoyed and will also provide an API allowing the processor to query the state of the user.

Deriving user satisfaction and other empathic measures from the physiological data will involve close collaboration with the HCI and psychology communities. Additionally, it will be necessary to factor user satisfaction into its component parts; extracting the roles of architectures, systems, GUI and other sources on user satisfaction.

3 Using Humans-in-the-Loop

Putting humans-in-the-loop has shown promise in other areas. For example, distributed human computation via computer games [6] are being used to label images in a large scale. Emotional play technologies are being incorporated into computer games [4]. Most telling may be a patent very recently granted to Microsoft on a mobile platform incorporating biometric sensor feedback [2].

Why not have computers that are aware of their users? We believe it is time for computer architects and systems researchers to start putting humans-in-the-loop.

[1] One could argue that these devices are expensive biomedical devices. However, we point out that this is only an economies of scale issue. Nothing inherent to the devices is expensive, and if the devices can be useful to general purpose computers, the prices would decrease dramatically.

References

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