Future Challenges to Actuate Wearable Computers

Stewart Von Itzstein and Ross T. Smith
Wearable Computer Lab – University of South Australia
stewart@vonitzstein.com ross@r-smith.net

Abstract

This workshop paper discusses how actuated materials and substances can provide compelling functionality for future wearable computer systems. We present a number of current opportunities and describe the future challenges of integrating advanced actuators into wearables

1. Introduction

Wearable computers are a compelling technology that allow computational tasks to be performed out of sight and near the user. To be useful they employ methods of input and output (sensors and actuators). These sensors include temperature, motion or more complicated GPS inputs. Actuators allow computers to manipulate the real world based on the interpretation of the sensors. For example, arrays of belt worn vibration actuators were combined with a GPS to support navigation tasks [1]. Although this type of functionality is very useful and powerful we believe the use of actuators on wearable computers is only in its infancy and there is a great opportunity to advance them further. We have been pondering on the question "Why are more interesting and capable actuators not around?" The aim of this paper is to discuss the potential uses of advanced actuators and to examine the challenges of building more capable and advanced actuators for wearable computing.

2. Opportunity for Actuated Wearables

Wearable computers are increasing in popularity as they can be programmed to respond to a stimulus and react in automatic ways. For example, there are a number of projects utilizing clothing based computing [2, 3] where devices exchange information with other users in close proximity and interact using customized input devices. Consider using a wearable computer with a virtual keyboard to input data; because the projection does not provide suitable haptic feedback, you have to look at the keyboard to keep your hands on target. This is not a problem with a real keyboard because the feel of the object allows the user to take their eyes off the keyboard by using the bumps on the home keys. Now there are great opportunities for wearable computer systems to leverage and innovate actuation technologies to extend their functionality. For example, if an actuator was embedded into gloves that made the fingers slightly straighten on command, you could simulate the hills and valleys of the keyboard and allow the user to take their eyes from the virtual keyboard. This type of simulated haptic feedback has the potential to increase user performance and the immersive nature of current wearable systems.

3. Advancing Sensors and Actuators

Recently, there has been an increased interest in widening the number of sensors that are used in computers. Nintendo's Wii Remote with its fairly accurate and cheap position sensing (followed by Microsoft Kinect and Sony Move) has shown that there is an interest in adding new sensors to devices. Apple has also contributed to pseudo-wearable computers with addition of gyros, magnetometers and additional sensors in their mobile devices. These have allowed new methods of interaction. Over the last five years more and more sensors are being added to consumer devices based on the success of the first generation mentioned above.

With the flood of new sensors being added to consumer computing devices, one wonders why actuators have not taken off to the same extent? One reason is that sensors are much easier than actuators to design, manufacture and embed. As sensors measure a physical effect they tend to be smaller compact and do not require the same complexity of an actuator used for a physical effect. However, recently there have been a number of advances that show promising results for the actuation methods that change the viscosity of fluids and potentially fabrics. For example[4], demonstrated that electro-metallic materials could change their viscosity allowing for the creation of a surface that can change its shape[5] to imply the physical shapes on the surface have a physical presence. This allows better affordance to the user than that of a non physical interface such as the virtual light projected keyboard mentioned in section 2 above

4 Wearable Actuator Challenges

Bringing these new forms of actuators to wearable computers requires we overcome a number of challenges. There are a number of parameters we believe will influence future actuation devices.

Power Usage

With current battery technologies, mobile devices carefully consider power consumption aspects to maximize the battery life. Actuators for mobile devices are limited by the amount of energy required to drive them. A typical motion sensor can use as little as 25 μA whilst a typical vibration motor will consume 74 mA (3000 times more current). Another example is the use of magneto/electro-rheological fluids for haptic feedback. Magneto/electro-rheological fluids employ Ferro fluid and magnets provide computer controlled physical shape of the Ferro fluid. The amount of power to maintain a shape either by using an electric charge to align the material in the Ferro fluid or a magnetic field to align the material is currently prohibitive. New lower power approaches are needed to make these haptic devices viable. Similarly, most common actuators that provide linear movement also have prohibitive power requirements.

Size and Weight

Actuators often need to work against human muscles in order to provide haptic feedback. This requires not only the current required to drive the device but also the physical size to be able to generate the force. Smaller actuators just do not provide the torque to provide a sufficient force to the users to have a gratifying haptic effect.

Mechanical Complexity

Actuators tend to be mechanical in nature as they are attempting to impact on the real world. This requires construction of physical devices that can pull, push, move, glow, change, heat or cool. These effects are not cheap in size or power usage and tend to be complicated, as the device needs to enact some physical principle in order to achieve the desired result. In particular, actuators that move and change usually require mechanical crafting. This crafting needs to be small enough as to not get in the way, but strong enough to not be easily broken or confounded in operation. For instance, to move the actuator you may use a magnetic field to turn a shaft, cogs to gear, or sliders to relocate the force. These effects are rarely cheap to produce, especially at the scale of a wearable computer where there is a stringent power budget.

5. Future of Wearable Actuators

A compelling example can be taken by looking at science fiction movies for inspiration. For instance the recent Batman movies make extensive use of worn actuators such as a cloth that can form rigid structures when electric current is applied. This leads to many possibilities on shape changing effects, such as the cape that turns into wings from the movie above.

Recently, interest has developed using actuation on armor for soldiers. These actuation-based devices divide into two basic approaches, the first being a passive approach that relies on physical properties to distribute energy such as shear thickening fluids. These fluids use a property that makes the material harden in proportion to the energy applied. These do not require energy or control however, the second approach uses a more active approach. An example for the second approach is the electro-rheological approach that activates the armor when the soldier is under attack. Whilst initial versions of this material used significant amounts of power to produce weaker structures each generation is improving significantly. Currently the best power efficiency is about 16A per square meter[6]. Unfortunately that is still high for wearable devices but is not unreachable with battery technology improvements.

Looking further into the future the Hollodeck is a great example of how the ultimate actuators might be employed to provide full computer control of matter. This vision was described in detail by Sutherland [7] where he said “The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal”. Although this level of computer controlled matter will require significant technological advances, there are many smaller steps we can take to work towards this goal. The Holy Grail for actuated devices is a device that can form any shape on demand. This would allow the user to build tools on demand on their body. This would require a device that can move or create molecules that could be moved into place to “replicate” the required device. We are not close to that as yet but there are still significant scientific challenges that must be addressed before this vision can become reality; the use of actuators and the materials such as magneto/electro-rheological fluids look promising for future approaches.

6. References

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