ABSTRACT
Arm fatigue, or gorilla-arm, was the primary reason for the initial failure of mid-air or touchscreen computer interaction systems [1]. Gestural interfacing is now being adopted widely in gaming, medical applications as well as education, but only through careful research and development of such systems to eliminate or significantly reduce fatigue and optimize the interaction.

Although the most common mid-air interactions focus on arm and hand gestures, such as the LeapMotion and also a Nintendo Wii remote, several other techniques exist or are in development to bring the whole body of the user into the interface. The concept of gorilla-arm also extends to whole body interactions, and in a sense is much more important. Mobility is an additional aspect of a whole body interaction (WBI) system which is to be addressed.

On-body visualizations, EM noise sensing, grounded interfaces, and intra-operative machine interfacing through inertial sensors are all systems currently in their research and development stage, and in-depth studies looking at the development principles of such systems have also been conducted. One such study identifies key design qualities of a WBI system which is to be addressed.

ON-BODY VISUALIZATIONS
The advent of nano-projectors and powerful processing capabilities of mobile devices has allowed for the development of mobile on-body visualization methods. With existing technology, information may either be displayed on or gathered from a user’s body, however very few products attempt to do both. This unique combination differentiates on-body interaction from gesturing. Prototypes such as SixthSense, SkinPut and OmniTouch are among the major tools in this field.

The prototype, Armura [3], developed by the authors of this paper, is made specifically to demonstrate its ability to detect, track and recognize the gestural shape of the hands and arms, in real-time. For this, a ceiling mounted camera and projector has been used, however as the previous paragraph suggests, wearable products are also possible. Figure 1 shows how Armura could be used for navigation. Although this only shows output onto the body, the positions of fingers could be used as inputs to the system.

INTRODUCTION
Popularized by the Nintendo Wii and Microsoft Kinect, whole body interaction systems are being introduced into many different applications. However current technology introduces some rather significant limitations to the possible applications, two of them being fatigue and lack of mobility. With both Wii and Kinect, the user is confined to the detectable area in front of the sensor, and both inherently have issues with user fatigue.

Gorilla-arm is still an issue with some current technology, and to an extent, the progress of WBI systems is dependent on its elimination. Early failures of mid-air or touchscreen systems was attributed to gorilla-arm, which can be extended to whole body fatigue for a WBI system. Some of the following studies are designed such that body fatigue is inherently reduced.

The progress of WBI is equally as dependent on how mobile the systems are. For instance, as more and more systems become computerized (eg. ovens) [2], an immobile and bulky kinect sensor isn’t practical, and just as impractical is putting a sensor on each and every machine. Thus, the development of mobile WBI systems is also a key aspect which is addressed in the following sections.

Furthermore, current tools already allow a user to customize the interaction they have with a machine. As more variable systems are developed, a framework or blueprint on which a user should base their interaction is also required. Thus, two recent studies which address this are also presented in the following analysis.
focus on arms and hands, there are no restrictions or implications of using an off-body system to project whole body controls on the user’s body.

MOBILE GESTURE RECOGNITION
The need to instrument the environment and/or user with expensive electronics and sensors has been a major hurdle for whole body gesture recognition systems. Apart from cost, another problem is that they are very localized, for example, users are limited to the field-of-view of an Xbox Kinect sensor. On-body systems such as bio-acoustic sensors, electronic muscle recording, capacitive touch sensors as well as inertial sensors allow greater freedom as the requirement for localization is eliminated; however, these systems are limited by the sensors used and their placing on a user, and inherently support limited range of body gestures recognition.

Humantenna is the on-body, whole-body gesture recognition system developed by Cohn et al. [4]. In a very novel approach, Humantenna turns the user into an antenna using existing EM noise from the surroundings, and tracks how the signal changes as the body moves. Using EM noise signal observation also allows the computer to determine location, provided the EM noise in the area is characteristic.

Figure 2 shows a user playing Tetris using Humantenna—notice the lack of sensors and additional hardware.

![Figure 2. Playing Tetris using Humantenna and whole body gesture recognition [4]](image)

This technique requires no additional hardware to the environment, and very simple and minimal instrumentation to the user making it much cheaper than current tools. This is perhaps the most promising new technology, as it allows for real-time, truly mobile, whole-body gesture recognition.

INTRA-OPERATIVE MACHINE INTERFACING
Computerization and sterility are both equally as important to a medical procedure, however both are very difficult to deal with at the same time for a surgeon, and typically computer control is offloaded to an assistant [5]. Verbal communication is prone to misdirection and this frequently results in time lost during a surgical procedure. Thus, intra-operative gesture-based interaction systems are welcome technology. Due to the nature of the application the sensing method must be non-invasive and independent of environmental conditions, which immediately eliminate vision based systems, whose performance depends on conditions such illumination.

A robust software architecture coupled with multiple small wireless inertial sensors attached to the surgeon’s arms underneath the coat. A wireless receiver on the computer collates sensor data and processes the gesture recognition. Typical vision based gestural interfaces either provide discrete or continuous control to operators. Using on-body inertial sensors allows for precise measurements and position tracking of the subject, making accurate continuous control plausible. This is incredibly useful for surgeons allowing them to operate cameras with precision, for example. Figure 3 shows the sensors used and where they may be attached. Two on each arm allows for plenty of unique gestures.

![Figure 3. Multiple inertial sensors can be used for on-body gesture recognition [5]](image)

Although such sensing may be considered somewhat intrusive due to the attachment of hardware onto the user, it has its own benefits such as allowing for precise continuous control of a system through gestures. There are obvious gorilla-arm implications with this as well, however they are somewhat lessened, as there are no external sensing parameters to conform to—gestures designed can help to eliminate gorilla-arm.

GROUNDING INTERFACES
Although they are becoming increasingly uncommon, grounded interfaces provide certain interaction simplicities not possible with mobile methods. For example, the propagation of force applied by the user can be a control variable, and a grounded interface allows the device to take advantage of the reactive support provided by the grounding [6].

Jang, Yang and Kim characterize a good virtual reality system and its interface as one that provides a sense of presence and an immersive interaction for the user. Setting these as requirements, there is no better way to satisfy them than interacting with the user’s entire body. As full body sensing is complex and expensive, and still a point of research, simply inducing the use of the whole body still achieves the objective.

This is the basis of the G-Bar (Grounded Bar) interface developed by the authors. Using a grounded interface, they demonstrate a WBI system without complex sensing techniques or equipment. The G-Bar is a two-handed force input device.
Although simply two-handed, the application of force onto the G-Bar causes an indirect contribution to be made by the legs and body of the user. The accurate measuring capability of the sensors and precise force control through the whole body allows for a more natural and dynamic interaction.

For validation, a virtual 3D maze was prepared. Test subjects were faced with navigating through the maze, first with a generic keyboard, and secondly with the G-Bar. Results (eg. number of wall collisions) show the whole body interface to be more appropriate, although subjects were more familiar with a keyboard. On the other hand, subjective results dictate the keyboard was still easier to use, even though the G-Bar was much more immersive and gave better results.

WHOLE BODY INTERACTION SYSTEM DESIGN

Critical Design Qualities

As whole body interaction technology gains traction and public acceptance, more and more unique techniques continuously emerge. The Nintendo Wii and Microsoft Kinect are two such systems commercially available for the public. For example, the sporting games mimic the use and motion of artefacts such as a skateboard or golf club. Accurate replication of the skilled user’s interactions with these artefacts allows for a more intuitive, realistic and accepted experience.

For accurate replication of a user’s interaction with an artefact and the environment, key generic design qualities are to be identified. Tholander and Johansson studied various aspects of a user as they executed tasks with non-digital artefacts such as a golf club and skateboard, and by comparing to the analysis of users executing tasks with a Bodybug (a digital artefact), they identified 8 critical design qualities [7].

A few of the qualities identified are unexpected results. A counterintuitive interaction model is one of them. This forces the user to learn a completely new way to interact and the additional challenge allows for a long term understanding.

A second key quality is a one size fits all design in regards to motion as opposed to the artefact. An increasing complexity of interaction may allow for more advanced control of the task, without the need for upgrading the artefact. This allows the user to grow and master the technique over time. Such a concept is common with Nintendo Wii controllers, for example.

The dominance of a visual response of the Bodybug caused test subjects to state that it feel like one is in one’s own sphere; ie. being unaware of what is going on around them. This resulted in them being close to bumping objects on multiple occasions. The elimination of this issue defines another key quality: the harmonization of various perceptual modalities in the interaction. This forces the user to be fully attentive to the task at hand as well as fully aware of their environment.

Possibly the most important design quality is the concept that an interaction must connect to the physical space allowing for full engagement in the activity. For example, a skateboarder connects to the environment through the skateboard touching the ground, and through their eyes and ears reading the incline or texture of the ground. The effective use of various perceptual modalities, as expressed in the previous paragraph, also reinforces this quality.

A Blueprint for WBI Software

Since first initiated in the mid-1990s, WPI performance systems for artistic purposes have been a point of interest for multiple parties, but sparingly accepted or used by choreographers, because of their technical complexity and demanding infrastructure [8]. Current systems are predominantly optical and reliable results are often exclusive to dedicated motion capture labs such as the Motion-e, because of the technical requirements of realizing such systems. A forever growing interest in the field as well as advancements in wireless inertial measurement systems has prompted the research and development of complementary software.

EnActor, developed by Lympouridis, is a modular tool which serves as a blueprint for the design and development of WBI systems. In-depth studies of performers, choreographers and musicians were conducted using Orient, a wireless inertial motion capture system. Essentially, EnActor provides a platform for developing software which allows the developer to overlap virtual reality and performance arts such as dance and music, where the results of the aforementioned studies have dictated the platform’s specifications.

From previous studies, Lympouridis separates a WBI system into three categories methodical, empirical and dialectic. Methodical and empirical are both based on written rules, in which the performer is to learn how to use the software. Dialectic is the most complex of the three, based almost entirely on artificial intelligence and self-learning. Due to its simplicity, EnActor currently only allows for the development of methodical and empirical systems.

The design of Enactor consists of multiple interconnected modules. A hit detection mechanism caters for triggering the initiation or termination of sounds for musical applications. A motion analysis module interprets user motion and distributes information to other modules. A body control panel allows custom allocation of core-engines to different parts of the body. A core-engine handles hit detection and velocity analysis. Additional modules such as posture recognition, gesture recognition and spatial orientation all contribute in making EnActor incredibly versatile, allowing a user to customize how their body communicates with a computer.

EnActor allows for a more personal whole body interaction experience, allowing the user to customize how the computer interprets the inputs. It is primarily based on inertial measurement systems such as the Orient, but can easily be extended to other motion sensing systems.

CONCLUSIONS

- Mobility of the sensing technique and user fatigue are both important for successful WBI systems.

- Humantenna provides the most mobility and least fatigue out of all researched techniques.
• Grounded interfaces allow for force application, and provide whole body interaction simply by inducing the use of the rest of the body.

• The design of WBI systems requires careful thought. Design qualities and blueprints have been developed to simplify it and allow for customization.

FUTURE WORK
Currently, there exists a proportional relationship between the quality of sensing or gesture recognition, and the number of sensors used, and thus the price. For on-body motion systems, more 'nodes' means exponentially more unique gestures which can be detected. However, this also results in a much more complex interaction. Thus, a balance must be found between the two to gain full acceptance from the public. Smarter controllers may allow for an increase in 'resolution' without the need for additional/advanced hardware. These may, for example, have contextual control, where one gesture has multiple meanings, depending on the state of the controller, or depending on which activity is being executed. There is always scope for WBI systems in gaming, however developments in the sensing technology ought to bring them into the home and workplace for daily use in the future.

REFERENCES


