Object appreciation through haptic interaction

Matthew Butler and Peter Neave
Berwick School of Information Technology
Monash University

Much research and development has gone into creating a viable means to interact with virtual objects. Haptic devices, such as the Phantom Omni by Sensable Technologies, provide a means of using computer graphics and force feedback to create a multimodal sensory experience. We use touch to conceptualize objects and obtain a greater understanding of them, however objects such as artworks are usually prohibited from being interacted with in this way. Some artworks, like Michelangelo's David, have been replicated in 3D. These virtual artworks can be sent all over the world and users can interact with them by means of a haptic device. This paper compares the different characteristics of existing haptic-enabled museums and further questions the worth of using haptics as a means to communicate tactile information to museum visitors. A system has been developed to allow users the ability to interact with a replica of Michelangelo's *David*. Response has been analysed, showing that the possible benefits of virtual museums include the opportunity for greater engagement with artworks by visitors, new means of educating, and storing existing historic artwork for future generations.

Keywords: haptics, virtual museums

Introduction

Haptics is a term used to define the sense of touch. The study of haptics within the Information Technology community has recently been excited by the commercial availability of haptics devices and the ease of developing with them. There are many types of haptic devices available on the market, each allowing various degrees of freedom and each allowing force feedback to be produced. Such features contribute to allow the user to feel a 3D representation of an object. Combined with the use of visual and audio technology, virtual environments can gain more believability and immerse users through the deception of their senses into a virtual reality. We need touch to understand objects in three-dimensional space, and to fully appreciate an object we are required to handle it. The psychologist David Katz (1989) stated that no other sense is more able to convince us of the reality of an object than does our sense of touch. Combined with our other senses, we are able to understand the objects in a way that we would not have been able to understand by sight alone.

A number of researchers call for haptic technology to be used for cultural applications (Brogni et al. 1999; Brewster 2001; Barbagli et al. 2002; Bergamasco et al. 2002; Dettori et al. 2002). There are many advantages with using haptics in a museum environment, such as interaction with rare or fragile art pieces. Visitors are not required to physically be at the particular art gallery in order to experience the artwork. A larger collection of artwork can be made available than just the number of artefacts on display. Sight is no longer the only necessary sensory means to appreciate the artwork, we can use touch through haptic devices and this also gives those that cannot see the opportunity to enjoy the artwork (Brewster 2001).

Although the application of haptics to a museum context may seem obvious, given the effort required to create accurate 3D representations of artworks, along with integration of haptic technology, is the process of significant benefit and worth? This paper will investigate the effectiveness of haptics to promote museum and art pieces, particularly sculpture and evaluate if they allow the user to focus on particular details that they may overlook otherwise. Literature is discussed in the area of Haptics and Haptic devices. An implementation of a haptic device in the museum context is then presented, along with a discussion of findings based on user testing of the artefact. The research considers if using a haptic device allows the ability to educate, understand and appreciate sculptures more thoroughly, conducted through interactions with a virtual sculpture using a haptic device and a replica present.

Haptics

Haywood et al. (2004) define haptics as the capability to sense a natural or synthetic environment through touch. The tactile system encompasses a substantial part of the peripheral and central nervous systems (Hayward et al. 2004). When we touch we use cutaneous (skin) sensations and kinesthesis (movement) sensations. The term somesthesis is the ability to touch. It encompasses both cutaneous and kinesthesis sensations. However, it is more common for researchers to use the term haptics to describe the sense of touch (Robles-De-La-Torre 2006).

Katz and Krueger (1989) suggest that we mentally store tactual images of the objects that we touch. We can call upon a tactual image of the object, usually accompanied by a visual image. These memories can be of a surface touched in the past, such as glass, sandpaper, velvet, wool or wood. He relates an experience where he touched an object that looked like a marble surface. To his surprise, the surface did not present the cold smoothness or the inelastic hardness that is normally characteristic of marble. His visual senses had identified the object and his mind had retrieved past experiences from his touch memory. He was in fact touching a piece of wood that had been painted to imitate marble. His surprise 'indicates that the specific memory touch of marble had been evoked or at least put in a high state of readiness' (Katz and Krueger 1989, p. 63). As Katz moved his fingers over the surface, the stimuli he felt did not match the mental model he had developed from past experience. Through touch, he was able to identify that the material he was interacting with was not the same as it was visually designed to resemble and thus was able to learn more about it.

Due to its physical nature, haptics has been difficult to generate mechanically. The simplest way to imitate haptics is to produce the forces that we would feel if we were to interact with another object. As we press our fingertips against an object, we experience the object pressing itself against our fingertips. With this notion in mind, haptic devices utilise this principle by providing opposing force to the user's exploratory movement.

Haptic devices are examples of how computers can act as chameleons. The defining deferential of these devices, compared to other devices which are only able to 'read' the users movement, is that they are able to provide feedback in the form of force. This controlling of the device provides resistance to the user's movement and through this they are able to touch a virtual object. Asano et al. (2005) refer to it as a position input and force output device. This bidirectionality is, according to Hayward et al. (2004), the most distinguishing feature of haptic devices. They also comment that it is less complex to read the movement from the user than it is to produce the necessary experiences to guide our senses into recognising a virtual object.

With a large selection of haptic devices available, Dettori et al. (2002) mention that part of the problem that developers face is matching the most appropriate device to the need of the project. Currently, haptics are widely used in computer game design. Usually hand held controllers vibrate when the users avatar interacts with another object, say a wall for example. Grow et al. (2007) discuss the use of haptics as a means to educate. They propose the use of haptics to present the quantity of force of a ball on another planet, for example. They also briefly mention the use of haptics in museums. Hayward et al. (2004) agree with Grow et al. (2007) in that haptics could be utilized to illustrate physical phenomena, maths and anatomy. They also note that haptics have already been utilized in driving, flying, surgery and other professional simulations.

We can use haptics within two types of context; a purely virtual environment or a mixed environment. With a virtual environment there are practically no limitations to what can be interacted with. The cause of limitations with interacting in a virtual world stems from the limitations of the haptic device (Dettori et al. 2002). With a mixed reality, a 3D visualisation of a pre-existing object is developed and interacted with through haptics. This type of reality has application for objects that are usually difficult to touch. Dettori et al. (2002) have suggested this use of haptics for educational purposes. Haptics can support the development of mixed realities. As the virtual side of mixed realities become increasingly more sophisticated and immersive, we can use haptic technology to increase the ability to conceptualize 3D shapes (Dettori et al. 2002). It would make it easier to learn about objects that we could not interact with otherwise.

Haptics in the museum and educational context

Bergamasco et al. (2002) discuss two models for virtual representation of artwork, introduced in the previous section. The first type is a mixed reality approach, where the museum visitor uses a haptic device in proximity to the real life statue inside a museum. The second is a purely virtual approach, where the user views a virtual representation within a virtual environment. With the first model the visual stimuli will be provided by the real sculpture and a virtual representation on a computer screen. The computer screen provides orientation for the user and allows them to determine which part of the sculpture they are interacting with. Although not physically present, other art pieces that are associated with the viewed art piece could be displayed virtually. This method could immerse the visitor deeper into the culture of the art piece (Bergamasco et al. 2002). The second model will present the historic artefact in context and recreate the environment in which it was found or associated with. Bergamasco et al. (2002) lean more towards the first model because they suggest that it would be more immersive and realistic to the user.

Existing haptic-enabled museums

There is a collection of museums who have already embraced haptic technology. 'The Museum of Pure Form' (Frisoli 2007; Tecchia et al. 2007) is an interactive museum that allows interaction with virtual artwork. It does so by the use of haptics combined with stereoscopic 3D projections. The user wears polarized glasses and uses the haptic device while they are taken on a tour of a virtual museum. More than 1600 users across Europe have attended the museum to date. Also, more will be able to explore the virtual museum as a web ready haptic museum, developed for the Museum of Pure Form website (Friosoli 2007).

The University of Southern California has a virtual museum called 'The Interactive Art Museum'. Its main purpose is to give the ability to touch what was classically known as untouchable artwork. The university believe that the 'hands-off' policy can be annulled by using haptic devices. (Brewster 2001; Barbagli et al. 2002). It is the only museum of its kind found in literature that utilizes haptics and virtual art pieces. Its initial exhibition was a collection of 150 teapots from different parts of the world. This virtual exhibit was within a non-museum environment, but museums could implement a mixed reality to complement their existing collection of artwork.

Brewster (2001) explains how the Glasgow University used a haptic-enabled mouse to interact with objects in a museum exhibit. The mouse allowed two degrees of freedom and visitors were able to feel 2D information. Interviews and surveys were conducted with mainly sighted visitors. The results showed that the exhibition was easy to use, interesting and it engaged children. Part of the exhibit modelled hieroglyphics that were located near the haptic enabled museum. Children who used the device were observed going back and forth from the hieroglyphics and the haptic exhibit. They felt a strong desire to know what the hieroglyphics felt like and they verified this knowledge by seeing the actual artefact. Although deemed a success, the research did not adequately show the benefits of having the real object adjacent to the virtual object.

There have been surveys conducted on distributed haptic museums (Asano et al. 2005), yet little literature considers the public perception of mixed reality haptic-enabled museums. Research needs to be conducted to establish how society accepts haptic devices as a means to gain a more comprehensive appreciation of artwork. It needs to gauge to what extent synthesised tactile information adds to the experience of viewing a sculpture.

Benefits

There are many reasons to implement a mixed reality haptic-enabled museum. One benefit of virtual sculptures is that the history of the created artwork can be stored. If the artist wishes to change their mind with regard to an aspect of the art piece, they are free to do so. They can undo removing sections or change the colour of sections of the virtual object. The artist is allowed the freedom to trial ideas and explore through the artistic process. As an educational tool, art teachers could view the various stages and comment to the student how they could improve their technique (Creighton and Ho-Stuart 2004), or even guide the student over the internet through guided haptic interaction.

Another benefit of using digitised 3D models is that duplication and transfer of 3D data is relatively easy. This allows the possibility of distributed haptic-enabled museums. Asano et al. (2005) propose a haptic-enabled museum. This system allows users to interact with museum exhibition pieces via the internet. They created four exhibits and visited five museums within Japan. They surveyed visitors with regard to the distributed haptic-enabled museum. The system was quite popular. Although it was portable, the system was best seen as being located within a museum environment.

According to Barbegli et al. (2002) the digitizing of objects has been very successful but they feel that haptics should be utilised more with digital art pieces. They propose the use of haptics within the virtual museum context as a means to preserve culturally historical artwork. Through natural decay and exposure to the elements it is unlikely that an art piece is going to last forever. There is also the problem of transportation that may cause damage and so generally most art pieces are not transported far from their origin. This limits the number of people who can enjoy the art piece to those who are able to travel to where the art piece is located. By using the digital copy of the artwork more people are able to view the art piece via the internet. It is also argued that the originals are not so important but that in fact the knowledge gained from them is the most important and that replicas can achieve this (Asano et al. 2005).

Bergamasco et al. (2002) comment that not only could the present state of the artwork be displayed, but also the history of the artwork. If the art piece has been damaged from exposure or broken into sections, then those states could be presented also. Using the statues history to give an account of its progression up to the point that the viewer interacts with it would be very educational.

Methodology, artefact development and evaluation

Methodology

To establish the effectiveness of Haptics as a means of presenting a multi-modal experience, data must be collected about the user's response to the new technology. Although haptic devices have been in existence for a considerable amount of time, public exposure to haptic devices has been very limited, with its implementation being mainly restricted to research environments. With this in mind, the most effective method of collecting data about the user's experience with haptic devices and artworks was for them to view a sculpture and use a haptic device simultaneously.

A mixed qualitative and quantitative method was used to establish the effectiveness of haptics. The reason for a mixed approach is that there are some elements that can be measured, such as the time taken to view a sculpture, and other elements that require the user to describe how they felt about a situation. Since it is impossible to accurately ascertain the exact amount of time spent by participants in a museum or art gallery setting in their previous visits, the participants would need to gauge how much time they felt they spent viewing sculptures in a gallery. The types of questions asked of the participant were mainly qualitative in nature – asking the opinions of the user after they have used the device. A survey was used to gather the sample populations' response and translate that into statistics that can be analysed.

The choice of sample population for the preliminary study was restricted to people located within the Berwick Campus of Monash University. Ideal participants would be those found within a museum or art gallery setting, however for preliminary evaluation, the cross section of participants found in the university setting was sufficient.

The purpose of the research was not to compare virtual representations to the physical counterpart. The limits of computers and hardware cannot completely synthesise an experience that would be as complete as being able to touch and view the physical sculpture. The purpose was to establish if haptics can improve the experience the user would have with sight alone. Similar research was conducted by Asano et al (2005). They surveyed visitors regarding how they enjoyed a virtual haptic-enabled museum. Their focus was on the effectiveness of using haptics in a distributed virtual museum. They did not have a physical sculpture for the user to reference while using a haptic device.

Development

3D model and user interface
In order to conduct the research, an object needed to be presented next to a virtually interactive version of the same object. To gain a fuller understanding of the type of interactions available the object needed to have both smooth and rough surfaces. Alternatively, more than one object could be presented to demonstrate each type. For example, it was considered if abstract sculptures would be the ideal example for smooth sculptures. However, it would become problematic to accurately recreate the sculpture in 3D without adequate resources and accessibility to appropriate sculptures.

Levoy et al. (2000) of Stanford University documented the process of laser scanning the world famous *David* and other sculptures by Michelangelo. As part of their research project the *Digital Michelangelo Project*, they placed the sculptures on a website (http://graphics.stanford.edu/projects/mich/) for other researchers to be able to access. Permission was obtained to download the 3D meshes as well as to use these 3D models for the purpose of haptic interaction. Most of the models were presented in a large Stanford University propriety 3D format. However, the sculpture of David was also presented as a simplified mesh OBJ file – which had been simplified to about half a million triangles.

A replica bust of Michelangelo's *David* was also obtained. Although it was not a replica of the full model, the bust provided certain characteristics that could be advantageous towards the research. It provided both smooth and rough surface properties. The cheeks, chin, forehead and, to a certain extent, the nose were smooth. Elements such as the eyes and hair also provided a complex and rough surface the user could potentially interact with. The main advantage of using the David was that most people would be familiar with the sculpture. It is also an example of a heritage piece that is highly valued and cannot be touched.

In order to make the 3D model match the physical representation as much as possible, it needed to be altered slightly. The model was of a complete sculpture of the David, so most of the body below the neck was removed. By doing so, the contours of the neck left a gap that needed to be filled by extruding the edges down towards a bevelled base made out of a cube. The lower half of the 3D model was altered to make it resemble the physical sculpture used.

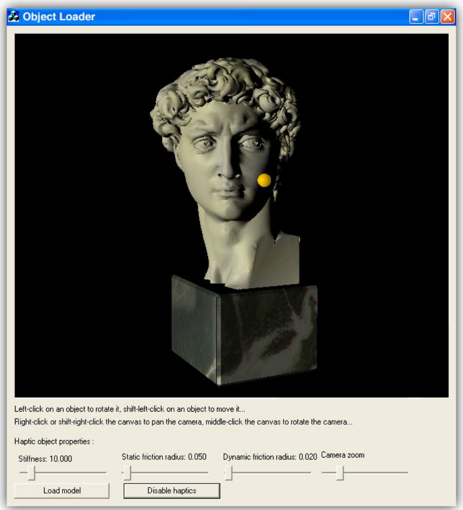

Figure 1: Screen shot of application and 3D model including probe near left cheek of statue

To display the model and allow 3D interaction, the open source Chai3D Toolkit (http://chai3d.org) was utilised – particularly the example Object Loader. This program allowed for any OBJ file to be loaded with textures and interacted with. There were many options available on the interface. It was felt that this would be too distracting to the user, so many of the options were removed to allow the user to focus on the 3D model.

Haptic Device

There is an array of programmable haptic devices that are commercially available. Each one approaches the complex problem of haptic representation in a different manner to the other. The haptic device that was used for the study was the *Phantom Omni* by Sensable Technologies. The type of haptic feedback it utilises is described as point interaction, where the user handles a stylus and explores as you would if you were using a pen to touch an object. By moving the stylus one can feel objects by the direction and magnitude of the opposing force synthesised by the device and thus we are able to touch a virtual representation of the object. There are some who see this as a limitation (Brewster 2001) and it should be noted that this is only one implementation of a haptic device.

The Phantom Omni, as shown in Figure 2, allows for six degrees of freedom and can track the position and orientation of a stylus within an area 16 cm wide, 13 cm high and 13 cm deep (Dettori et al. 2002). The stylus can also be replaced with a thimble-like attachment, allowing for the user to interact as if they were running their finger over the object. The user sees a 3D representation of the environment on the screen as they interact with it. This allows for virtually any object or scenario to be presented to the user and for the user to interact with that which has been presented to them. It was selected due to accessibility however it is also very well accepted and supported by the research community. The main limitations of the device were the user was restricted to the range of movement of the device and the device provided feedback for only one point of contact. However, it provided sufficient force feedback to allow the user to develop an understanding of the virtual model through proprioception.

Figure 2: Phantom Omni by Sensable Technologies (2006)

Figure 3: Physical and virtual sculpture with haptic device

Evaluation

A survey was developed to cover relevant aspects of the research context, especially to find out user reaction to the device. Questions were centred on areas such as:

- did they enjoy the device?
- did they spend more time viewing the sculpture because the device was accessible?
- would they attend museums more regularly if they could use a haptic device?

These questions sought to establish the benefit or lack thereof of using haptics as a means of focusing the user to pay more attention to the sculpture.

Analysis

A total of fifty people participated (n = 50) in the study. All participants were recruited on university grounds and therefore had an affiliation with the university. The sample population were mostly young, with most between the age of 18-24 (82%) and 25-34 (12%). Five people did not complete the whole survey, and as some questions were being compared, the number of usable responses was 45 (n = 45).

For haptics to be deemed successful as a means of educating, the following criteria were established:

- The user must spend more time viewing the sculpture with the haptic device present. This indicates that the user is more interested in the sculpture.
- The users must visit locations where sculptures are presented more frequently because they can use haptic devices to touch the sculptures.
- The users must not focus on the haptic device more than the artwork. The haptic device should be as transparent to users as possible and it should be easy to use.

There were three questions that concerned how much time people spent viewing sculpture and how much time they spent viewing the sculpture while using haptics. All questions were based on their experience and opinion, as no devices were used to monitor the amount of time the user spent while using the haptic device. It can be assumed that the amount of time spend viewing a sculpture directly correlates to the users interest in the sculpture. By asking the participants to state how much time they spent with or without haptic devices present establishes the successfulness of haptics as a means of sustaining the user's interest in the sculpture.

Results and discussion

Overall, haptics for the use of cultural heritage and to enable virtual interaction with sculptures was successful. Most of the participants were infrequent museum or art gallery visitors. 22% had never attended an art gallery or museum and 64% visited approximately up to once a year. Just over half (52%) of participants said that they had a desire to be able to touch the sculptures. Surprisingly, just over half (52%) had knowledge of haptic devices. The possible reason for this may be because they filled in the survey after using the device as this result was expected to be lower.

Most participants found the Phantom Omni enjoyable (84%). This high percentage could be attributed to the 'wow' factor of new technology and a lack of comparison to other haptic devices. 67% felt that they devoted more time towards the haptic device, while only 24% felt they viewed the device and sculpture for equal amounts of time. Given more time and exposure with haptic devices, it can be expected that users will learn to focus more on the sculpture and the experience rather than the haptic device itself.

Participants were asked to rate how much time they felt that they spent viewing sculptures with and without haptics. By comparing the two time amounts given, 72% of participants said that they would spend the same amount (18%) or more (54%) time viewing the sculpture because of the haptic device. To verify this comparison, another question asked the participants to evaluate if they felt that they would spend more time viewing the sculpture if a haptic device was present. 77% said that they felt that they would spend more time viewing the sculpture because of the haptics. 75% said they would, generally in other situations, spend more time viewing the sculptures if there was a haptic device present. Figure 4 shows the trend line representing the amount of time spent while viewing sculptures without haptics is skewed towards shorter amounts. By contrast, the trend line representing the amount of time spent viewing sculptures while a haptic device is used shows that the amount of time increases, indicating that more time is spent viewing the sculpture while using the haptic device.

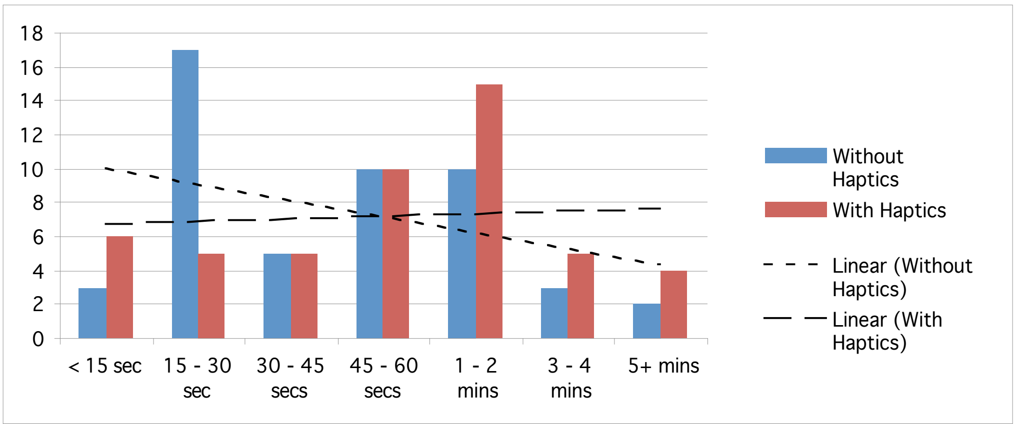

Figure 4: Comparison between time spent while viewing sculptures with and without haptics

Despite there being problems with the geometry that could cause the participant to fall into the model, most (67%) stated that the model was not too complex to appreciate. However, comments about particular parts of the geometry that were complex included areas such as the hair and eyes, which contained a substantial amount of detail and complexity. This could be attributed to the fact that many did not realise they could rotate the model and were unable to focus on the particular part they were interacting with, so as to fully use both visual and touch senses. Some participants commented that they thought that they would have been able to gain a better appreciation with a haptic device that provided multiple points of interactions, such as a glove-style haptic device. This can be confirmed by research performed by Asano et al. (2005) they found that a glove-style haptic device was the preferred device compared to a pen-style haptic device.

When asked how they felt about the level of accessibility of haptic device within museum settings, many (81%) specified that they thought that it should be made available for certain art pieces. Particularly special art pieces or those that are fragile would be good candidates to be touched virtually. Most participants agreed that by making haptics selected accessible that it would provide a unique method of highlighting key art pieces.

Most sculptures are presented in such as way that would allow visitors to be able to walk about to view the sculpture from different angles. To allow for this same amount of freedom, the haptic device would have to be able to be moved freely. 51% agreed that they felt anchored to the one vantage point, while 44% gave a neutral response. This could indicate that while most felt anchored that this feeling was not significant enough to be concerned with. However, most agreed that if they were allowed to move freely around the sculpture they would, with 67% of the sample population agreeing that it would be important to be able to move around the sculpture while being able to use the haptic device. An exoskeleton style haptic device, as currently being developed by Bergamasco et al. (2002), would be useful in allowing the user to walk around freely while viewing the model.

Finally, regarding if people felt they learnt from using the device, the results were not compelling enough to draw a solid conclusion. 42% agreed, 33% gave a neutral response and 24% disagreed. However, overall the sample population were not as certain if they learn more about the sculpture through using the haptic device. Once again, the new experience of the haptic may have been an influencing factor. Those that felt that they learnt from the experience wrote comments about how they were able to focus on a particular region and notice subtle interesting features that would not have been able to recognise without the use of haptics. Also, others commented on how they were able to gauge the shape of the sculpture as a whole.

Conclusions and further research

From the results, it could be recommended that haptics be actively used to promote interaction with virtual and physically-based art, especially haptic devices designed to be worn as a glove or exoskeleton with multiple contact points. However, it should not be overused and cause potential haptic museum visitors to be come disinterested in the experience. There needs to be a balance, so visitors can appreciate the benefits of haptics more.

Computers can be used to artificially stimulate our senses to provide a virtual experience. They can influence our emotions, promote new ideas and entertain us. They are designed to provide visual, audio and haptic information. By using the senses individually and combined, we can build a multi-modal understanding of the world around us. We compare the experience with the mental model we have developed from previous experiences. It promotes us to view objects we take for granted in a new light.

With the use of computer graphics, 3D models can be used to visualise artwork nearby or the other side of the world. Artwork can then become immortalised in cyberspace, allowing it to be accessed over great distances. However, the benefits of using haptics to gain a better understanding by presenting the 3D model next to the real sculpture should also be noted. It promotes active exploration of the details of the sculpture. The user, simply by engaging with the device, spends more time viewing the sculpture and will consequently learn more about the detail of the sculpture. It engages the user and focuses their attention.

Through this research it has been established that haptics may be a successful way of engaging users to spend more time viewing sculptures. The sense of touch is important in the development of the mental model of an object and this should be catered for by utilising haptics. Although there may be some focus towards the technology initially, hopefully continual use will cause the user to focus on the sculpture instead. The research conducted in this paper focused on the implementation of the Phantom Omni Haptic device and only one sculpture. To test the use of haptics further, research must be conducted that can counter the 'wow' factor. A possible way of doing this is to have a collection of different sculptures and allow the user to experience each one. As the user progresses to the final sculpture they will have become more accustomed to the technology and will start evaluating the system as a whole rather than focusing on the haptic device singularly.

Future research will ultimately entail using the device in a museum or art gallery setting. Although virtual galleries have been presented within this context already, sufficient research does not exist to establish the effectiveness and acceptance of haptics to complement a physical statue. The focus of the research will be directed to moderate to frequent visitors. Other devices might be made available to determine which is most suitable for haptic interaction.

References

Asano, T., Ishibashi, Y., Minezawa, S. & Fujimoto, M. (2005). Surveys of exhibition planners and visitors about a distributed haptic museum. *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology*. Valencia, Spain, ACM Press.

Bergamasco, M. Frisoli, A. & Barbagli, F. (2002). Haptics technologies and cultural heritage applications. *Proceedings Of Computer Animation 2002 (CA 2002).* Geneva, Switzerland, IEEE Comput. Soc.

Basdogan, C. & M. A. Srinivasan (2002). *Haptic Rendering in Virtual Environments. Handbook of Virtual Environments*, K. Stanney. London, Lawrence Earlbaum, Inc.: 117-134.

Bergamasco M., Brogni A., Frisoli A., Salvini F., & Vignoni M. (2002). Tactual Exploration in Cultural Heritage. *Computer-aided Egyptology Round Table (IE2002).*

Brewster, S. A. (2001). The Impact of Haptic 'Touching' Technology on Cultural Applications. *Proceedings of EVA2001*, Vasari UK, s28 1-14.

Brogni, B.A., Avizzano, C.A., Evangelista, C., & Bergamasco, M. (1999). Technological approach for cultural heritage: Augmented reality, *8th IEEE International Workshop on Robot and Human Interaction. (RO-MAN '99),* IEEE

Creighton, I. & C. Ho-Stuart (2004). A sense of touch in online sculpting. *Proceedings of the 2nd international conference on Computer graphics and interactive techniques in Australasia and South East Asia*, ACM.

Dettori, A. Avizzano, C.A., Marcheschi, S., Angerilli, M., Bergamasco, M. Loscos, C., & Guerraz, A. (2002). Art Touch with CREATE haptic interface, *ICAR 2003,The 11th International Conference on Advanced Robotics*, University of Coimbra, Portugal, June 30 - July 3, 2003.

Frisoli, A. (2007). *The Museum of Pure Form*. from http://www.pureform.org/

Grow, D. I., L. N. Verner, & Okamura, A. M., (2007). Educational Haptics. *AAAI 2007 Spring Symposia - Robots and Robot Venues*, Resources for AI Education.

Hayward V., Astley O.R., Cruz-Hernandez M., Grant D., and Robles-De-La-Torre G. (2004). Haptic interfaces and devices. *Sensor Review* 24 (1), 16-29.

Katz, D. & L. E. Krueger (1989). *The world of touch*. Hillsdale, N.J., L. Erlbaum Associates.

Kim, J., Kim, H., Tay, B. K., Muniyandi, M., Srinivasan, M. A., Jordan, J., Mortensen, J., Oliveira, M. & Slater, M. (2004). Transatlantic touch: A study of haptic collaboration over long distance. *Presence,* 13(3), 328-337.

Levoy, M., Pulli, K., Curless, B., Rusinkiewicz, S., Koller, D., Pereira, L., Ginzton, M., Anderson, S., Davis, J., Ginsberg, J., Shade, J., & Fulk, D. (2000). The digital Michelangelo project: 3D scanning of large statues, *Proceedings of the 27th annual conference on Computer graphics and interactive techniques*, ACM Press/Addison-Wesley Publishing Co. New York, NY, USA.

Robles-De-La-Torre, G. (2006). The importance of the sense of touch in virtual and real environments. *Haptic User Interfaces for Multimedia Systems* IEEE.

Tecchia, F., Ruffaldi, E., Carrozzino, M., Bergamasco, M., & Frisoli, A. (2007). Multimodal interaction for the web. *Museums and the Web 2007: Proceedings, Toronto, Archives & Museum Informatics*. http://www.archimuse.com/mw2007/papers/tecchia/tecchia.html

Authors: Mr Matthew Butler, Berwick School of Information Technology, Monash University
PO Box 1071, Narre Warren, VIC, 3806
Australia. Email: matthew.butler@infotech.monash.edu.au
Mr Peter Neave, Berwick School of Information Technology, Monash University
PO Box 1071, Narre Warren, VIC, 3806

Australia. Email: peterneave@gmail.com

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