Haptic transmission over IP networks: image perception in response to increasing latency

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Abstract

Computer haptics is increasingly becoming available for use within human machine dialogues as display capabilities improve and their cost falls. The next obvious development is for haptics to be included within multimodal applications running over networks using Internet protocols (IP). Clearly, in order to engineer networks to carry haptic information in an efficient and cost-effective manner, it is necessary to quantify how the characteristics of the transmission path impact on the user perceptions of haptic image quality.

This paper will report the results of experimentation with our haptic network simulation into the impact network latency on the user perception for quality of transmission of a haptic image. And, it will briefly discuss the implications this research may have for the transmission of haptics over IP networks and QoS measurement.

1. Introduction

Quality of service (QoS) models and assessment methods exist for visual and auditory transmission. These will need to be combined with haptics, and other new types of sensory information emerging onto public networks, to provide QoS tools for assessing the capability of networks to carry multimodal information.

For the transmission of visual and auditory information a key constraint that impacts on image quality is the bandwidth available for the transmission. However, for an experimental haptic transmission system we developed – this linked two Phantom display units via an IP network to enable two way communication between them – we found bandwidth to be a minor issue. The major factor that governed the image quality in our haptic transmission was the latency of the network over which it was running.

Latency is the time taken within a network for the round trip of a packet of information to a destination and back to the source. With our simple haptic transmission system we saw instability and communication break down when network latency increased. To investigate this further, and to enable us to develop strategies to control or manage the impact of latency on haptic IP transmission, we built a simple haptic network simulator that allowed us to control the latency within a simulated haptic transmission path.

One end of our network simulation was a virtual Phantom haptic display which could have a virtual object placed in front of it. A real Phantom was then used to feel the remote virtual object through the simulated network by communicating with the virtual Phantom. The latency of the network between the real and virtual Phantoms was varied to investigate the impact on the user perception of the transmission quality.

The latency range used in the experiment was 0 to 40 milliseconds in 10 millisecond steps. This roughly covered the range found when we used the “Ping” network tool to check the Internet latency from our laboratory to a small selection of UK Universities where computer haptics research is currently taking place. Since we may need to engage in haptic communication over these network routes in future studies they were used to set the latency range for our experiment.

2. Methodology and procedure

An experimental control program was written in LabView and C++ to control the presentation of an image presented to a participant with a Phantom haptic display. The image simulated an object that had been sent from a remote Phantom over an Internet link with a controlled level of latency and a little simple damping. Each participant carried out a simple object discrimination task.

For a level of latency a participant was asked to determine if the image being presented by a Phantom was a cube or sphere. After each object presentation the subject adjusted an on screen cursor with a mouse to provide an image quality judgement on a rating scale.

The rating scale was one developed for use in transmission performance testing (ITU 1998) and has been used for on-screen presentation in audiovisual quality assessments (Hands 2001). The participants were also asked to indicate whether the image quality was acceptable before going on to the next object presentation.

Each subject received 5 levels of latency (0, 10, 20, 30 and 40 milliseconds) for both a sphere and cube recognition task and repeated 5 times. The presentation order of the treatment combinations was randomised.

There were 16 participants who were BT employees working in the Adstral Park site near Ipswich.

3. Results

The experimental control program recorded measurements of the user interaction with the virtual objects. This enabled both objective measures of the participants performance to be taken as well as the quality of service ratings that the participant provided.

Statistical testing of the rating scale score with a 2 way repeated measures ANOVA indicated that there was a significant difference in user perception of image quality as a result of increasing latency $F(4, 60) = 34.9$, $p<0.0001$ There was also a difference between the object shape $F(1, 15) = 26.909$, $p=0.0001$, and a significant interaction between shape and latency $F(4, 60) = 14.908$, $p<0.0001$

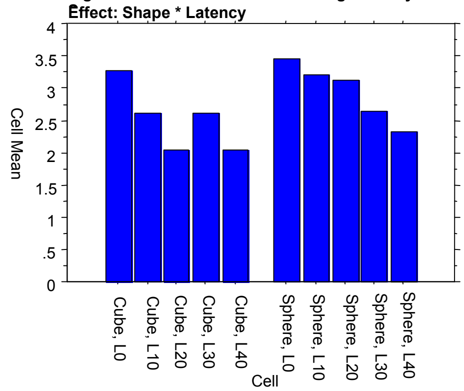
The average acceptability score was also tested with a 2 way repeated ANOVA. Again latency was statistically significant ($F(4, 60) = 21.164$, $p<0.0001$), but there was not a significant result for object shape or the interaction.

Testing the participant's recognition times did not provide any statistically significant results. Neither was their any statistically significant differences in the accuracy with which participants were able to identify whether an object was a sphere or a cube.

4. Discussion

As latency increased in this experiment the users perception of the quality of the haptic image was reduced. This was not a simple linear relationship with increasing latency. The reduction in perceived quality interacted with the type of object being displayed. For the sphere degradation was not as large as for the cube as the latency increased see fig 1.

Fig. 1 Interaction Bar Plot for Average Quality of Service
Effect: Shape * Latency



Clearly, this type of quality measurement is going to be task dependent. Any task used will need to be representative of the eventual use of the transmission path.

Traditionally in communications networks the major concern has been with the bandwidth limitations. With increasing use of new forms of sensory information being used over networks it will be necessary for network providers to offer a quality of service that is both economic and effective for the consumer. If latency cannot be avoided then it will be necessary to develop methods for transmitting haptics that are robust with respect to latency (Wilson et al 1999).

5. Conclusions

A better understanding of human communication with computer haptic simulations, and interactions with other sensory modalities, will indicate where it may be possible to make engineering trade offs to manage down or remove the impact of latency on the customers perceptions. There is much work that needs to be done to enable robust reliable real time haptic communication to take place over public IP networks with a reasonable quality of performance when latency is present.

6. References

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7. Acknowledgements

The authors wish to acknowledge the significant contribution made to this experiment by John Miles, who provided technical support and to Dave Knight for the assistance he provided to John during the data preparation and analysis.