McGee, M.R. and Gray, P.D. and Brewster, S.A. (2001) Haptic perception of virtual roughness. In, *Conference on Human Factors in Computing Systems, 31 March - 5 April 2001*, pages pp. 155-156, Seattle, Washington, USA.

http://eprints.gla.ac.uk/3221/

Haptic Perception of Virtual Roughness

Marilyn Rose McGee, Philip Gray, Stephen Brewster

Glasgow Interactive Systems Group
Department of Computing Science
University of Glasgow, Glasgow, G12 8QQ, UK

Tel: (0141) 330 3541
Email: {mcgeemr, pdg, stephen}@dcs.gla.ac.uk
Web: http://www.dcs.gla.ac.uk/~mcgeemr

ABSTRACT

The texture of a virtual surface can both increase the sense of realism of an object as well as convey information about object identity, type, location, function, and so on. It is crucial therefore that interface designers know the range of textural information available through the haptic modality in virtual environments. The current study involves participants making roughness judgments on pairs of haptic textures experienced through a force-feedback device. The effect of texture frequency on roughness perception is analysed. The potential range and resolution of textural information available through force-feedback interaction are discussed.

Keywords

Haptics, force-feedback, texture perception.

INTRODUCTION

Despite the increasing prevalence of haptics in today's computing environments, the effective representation of haptic information is still a relatively new design problem for human computer interaction research. Force feedback interfaces in particular pose a variety of design questions. For example, what can and cannot be communicated convincingly via such devices?

The perception of surface texture is a specific design issue in haptic environments. In human sensing and manipulation of everyday objects, the perception of surface texture is fundamental to accurate identification of an object (Katz, 1989). In a virtual world also, haptic texture information can both increase the sense of realism of an object as well as convey information about what the object is, where it is, and what it is for (Jansson *et al*, 1998).

There has been considerable previous work investigating the perception of real surface textures (e.g. Lederman *et al.*, 1974; Katz, 1989). The physical properties of textures are complex and difficult to reproduce for virtual textures. Little is known about the perceptual response to virtual surfaces. Representing textures with force feedback devices in particular has proved problematic.

Force-feedback devices convey texture by actuating kinesthetic forces on the users' finger, hand, or body. This often relies on much larger forces than those typically experienced on the skin during real texture perception (Katz, 1989). We have found in our previous work that such gross textures can perturb the users' movements so much that the ability to stay on the textured surface is adversely affected (Oakley *et al* 2000).

Force feedback devices are nonetheless becoming increasingly realistic interaction tools in a variety of applications where texture perception may be of importance. It is crucial therefore that designers know the range of textural information available through the haptic modality in virtual environments. The current study investigates the effects of frequency of texture on the relative perceived roughness of a set of force feedback generated textures.

CURRENT EXPERIMENT

The current study involved participants making a series of roughness judgments on a set of force feedback generated textures explored via the PHANToM force feedback device. The user can rate one of the textures as roughest or both the textures as the same roughness. In this way, the proportion of times each texture is rated as rougher than each of the other textures can be determined.

Hypothesis (A): The frequency of the texture will have an effect on the proportion of times that texture is rated as rougher than each of the others.

Hypothesis (B): The frequency of the texture plotted against perceived roughness score will not produce a monotonic mapping from frequency of texture to perceived roughness. This will further reflect the complex nature of the concept of roughness.

The PHANToM 1.0 force feedback device (by SensAble Technologies) was used to create the haptic virtual surfaces.

Optical sensors detect changes in the device's configuration and mechanical actuators apply forces back to the user. Users interact with the device by holding a pen-like stylus attached to a passive gimbal on the device. By scraping this stylus/probe back and forth across the textured area the appropriate forces can be calculated from the positional information of the tip of the probe and the stored algorithmic models of the textured surface with which the user is interacting.

Six haptic textures were generated as (a series of) sinusoidal ridges on a rectangular patch on the back wall of the workspace. The resulting profile depended on the amplitude and frequency of the ridges. The textures had fixed amplitude of 0.5mm and one of 6 frequencies (cycles per fixed length of surface) - 10, 15, 20, 25, 30, or 35.

12 participants compared each texture to itself and to each of the others twice (in a random order) resulting in 42 trials that lasted an average of 35 minutes. Participants made their response by clicking the stylus switch on the probe of the PHANToM to select the button that reflects their roughness judgment for each trial.

RESULTS AND DISCUSSION

The results highlight the complex nature of the concept of roughness as well as providing some guidelines as to how to present perceptually distinct virtual roughness through force feedback interaction.

Effects of Frequency on Perceived Roughness

The number of times each (frequency of) texture was judged as roughest was measured as an overall roughness score (Table 1).

Frequency of texture	10	15	20	25	30	35
Perceived roughness score	24	18	38	35	61	69

Table 1. Effect of frequency on perceived roughness.

With the exception of a trough at frequency of 15 increasing frequency (for this range) leads to increased perceived roughness. It is likely however that the range used is only a sample from a probable quadratic function of perceived roughness (see Lederman et. al., 1974). In fact, it is likely that as the frequency of the texture goes below 10, the surface becomes a series of distinct bumps or waves rather than a unified texture. On the other side of the range, frequencies somewhere beyond 35 will become almost smooth again as the force profile becomes essentially flat.

Same-Same Judgments

Textures with equal frequency were not reliably judged as the same roughness (accuracy: 50%-87.5%, mean: 64%). Lower frequencies were more subject to variations in perceptual differences. This is perhaps due to the interaction between probe size and texture-profile size; lower frequencies being more easily affected by differences in hand force and exploration speed.

Same-Different Judgments

A frequency separation of 5 was not sufficient to significantly separate the perceived level of roughness. For larger frequency differences, participants found it easy to decide whether the textures felt the same or different but much more difficult to decide which was roughest. This might be caused by the range of stimuli generating two distinct notions of roughness. Frequencies of 10 and 15 were perceived as "bumpy" or "corrugated roughness" whereas frequencies from 20-35 were perceived as "sharp" or "sandpaper roughness".

CONCLUSIONS AND FUTURE WORK

The results of the study further illustrate the complex nature of the concept of roughness as well as providing some guidelines as to how to present perceptually distinct virtual roughness through force feedback interaction. The addition of audio information to such force feedback textures might increase the range and/or resolution of textures available to the designer through such devices alone. Work currently underway is investigating the effects of multimodally presented textures on the perception of virtual roughness.

ACKNOWLEDGMENTS

This research is supported under EPSRC project GR/L79212 and EPSRC studentship 98700418. Thanks also go to the SHEFC REVELATION Project, SensAble Technologies and Virtual Presence Ltd.

REFERENCES

1. Jansson, G., Fanger, J., Konig, H, Billberger, K. (1998), Visually Impaired Person's use of the PHANToM for Information about texture and 3D form of Virtual Objects, *Proceedings of the Third PHANToM Users Group Workshop*, Cambridge, MA: Massachusetts Institute of Technology.
2. Katz, D. (1989) *The World of Touch*, (Translated by Krueger, L.E.), Erlbaum, Hillsdale, NJ. Original work published in 1925.
3. Lederman, S.J. (1974). Tactile roughness of grooved surfaces: the touching process and effects of macro- and microsurface structure, *Perception and Psychophysics*, 16, 2, pp. 385-395.
4. Oakley, I., McGee, M.R., Brewster, S. & Gray, P. (2000) Putting the Feel in 'Look and Feel', *In Proceedings of ACM CHI 2000*, The Hague, ACM Press, Addison-Wesley, pp.415-422.
5. West, A.M. & Cutkosky, M.R. (1997), Detection of Real and Virtual Fine Surface Features with a Haptic Interface and Stylus, Proceedings of the ASME Dynamic Systems and Control Division, 61, pp. 159-166.