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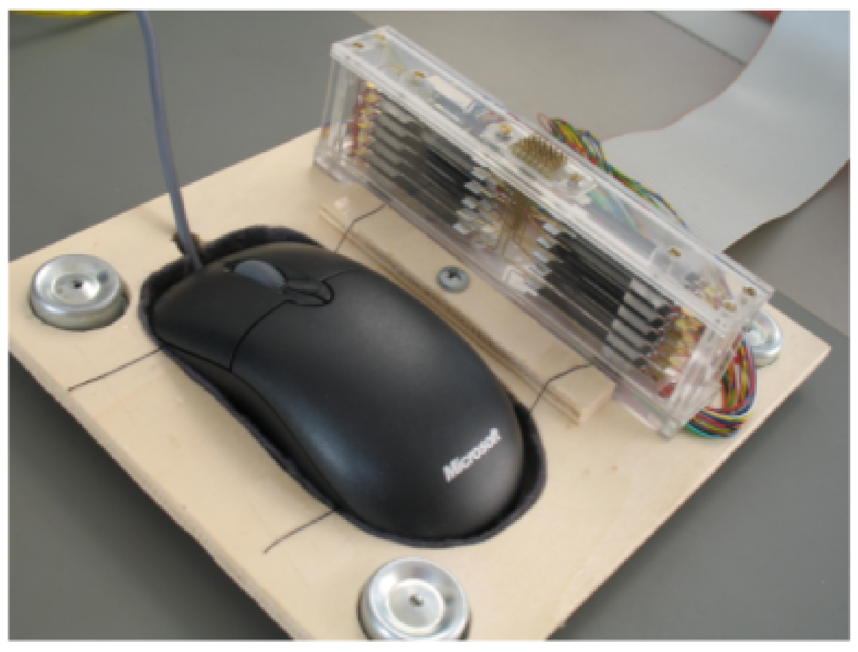
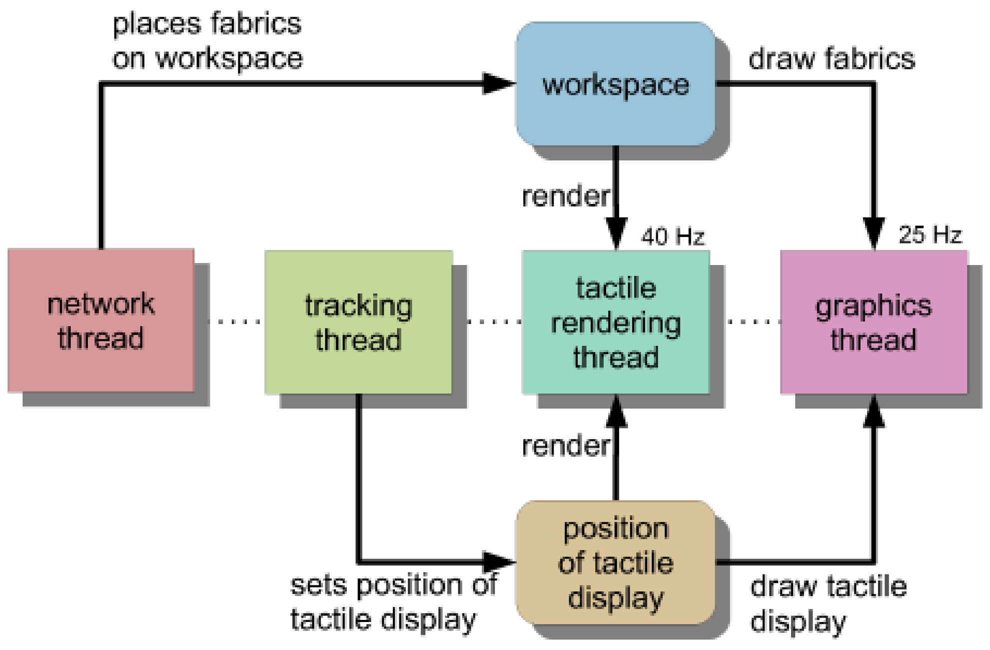
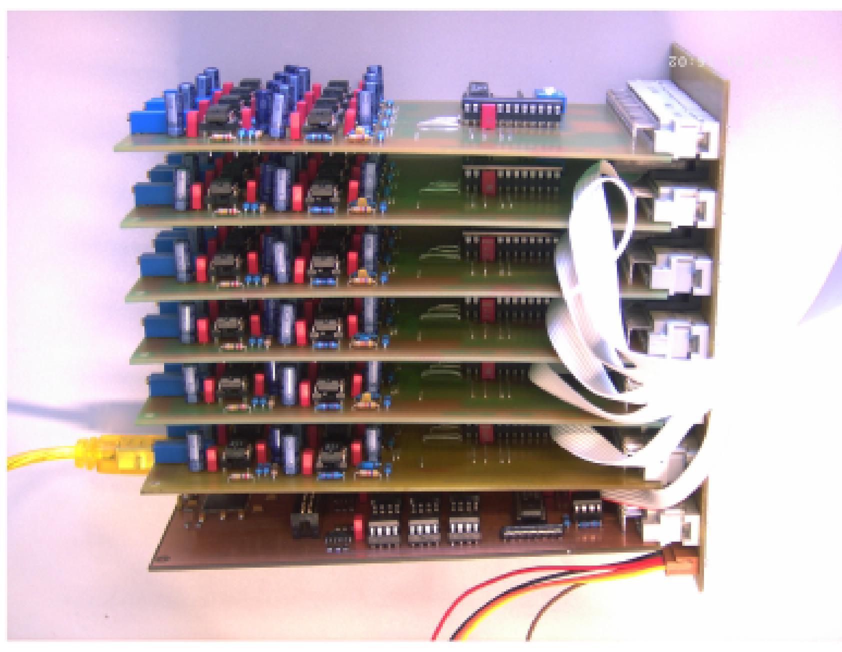
Tactile Simulation of Textiles in a Virtual Reality System

Generation of stimuli with a vibrotactile approach.







Most haptic devices focus on the transmission of forces as this is the most straightforward approach to simulate the haptic presence of an object. These forces are usually exerted on the fingertip via a simple thimble, disregarding the actual force distribution on the contact area between fingertip and object. This is comparable to the haptic interaction with real objects using a real thimble. Assessing small surface features or surface roughness is very hard or even impossible in this way. Using a tactile display is a possibility to overcome this shortcoming.

Human Perception

Perception is the process of attaining awareness or understanding of sensory information. Together with our motor skills it is nothing less than our gate to the reality outside our psyche. As the scope of this thesis is the simulation of a certain facet of reality, namely the tactile properties of textiles, a good insight into human perception is a necessary prerequisite.
Tactile perception is the sensation of pressure, vibration and temperature via receptors of the skin. Together with proprioception, which delivers information on the position of the joints and the tension inside of the muscles and the tendons, it belongs to the haptic perception.

Afferent	Receptor type	Adaptation	Receptive field	Function
SA1	Merkel discs	slow	small	form and texture
SA2	Ruffini's corpuscles	slow	large	hand conformation and forces acting on the hand
RA	Meissner corpuscles	rapid	small	minute, low-frequency skin motion and feedback required for grip control
PC	Pacinian corpuscles	rapid	large	detection of distant events by vibrations

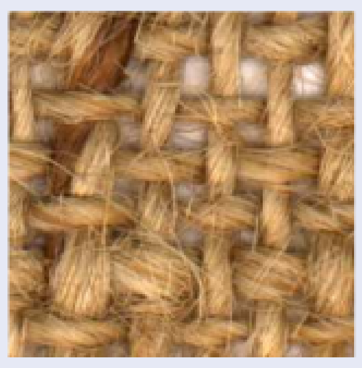
The glabrous skin of the human hand is innervated by four types of mechanoreceptive afferents, which are responsible for the perception of pressure and vibration. They can be categorised by receptor type, rate of adaptation, size of the receptive field, and by their function. In this context adaptation is the change over time in responsiveness of a sensory system to a constant stimulus. The receptive field of an afferent is the area of the skin where stimuli have an effect on its firing rate.

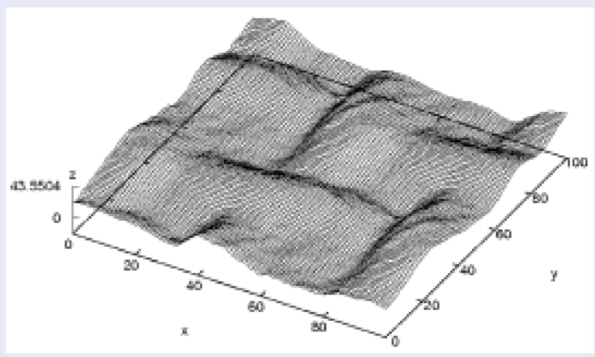
Tactile Displays

In this project a tactile display developed at the Biomedical Physics Group of the University of Exeter was employed. It consists of an array of 24 pins that are driven by vibrating piezoelectric bimorphs. These pins are intended to produce virtual touch sensations by creating an appropriate spatiotemporal variation of mechanical disturbance over the skin of the fingertip. The principal topic of the project is the search for such a spatiotemporal variation that resembles the touch sensation of a finger moving over the surface of a real textile.

Virtual Surfaces

Using fabrics for the evaluation is handy, because there exists a large variety of fabrics with different surface properties. It is possible to test the simulation system with samples having rather extreme properties, e.g. extremely rough or extremely smooth. Nevertheless it is also possible to test the system with samples that are not very different in order to investigate the ability of the system to simulate only very little differences. However, fabrics are just a test case, the systems could be generalised to a larger class of surfaces later. A set of altogether 54 different fabric samples has been kindly provided by the Smart Wear Lab at the Tampere University of Technology. Different methods for the generation of virtual representations from real fabrics were investigated.



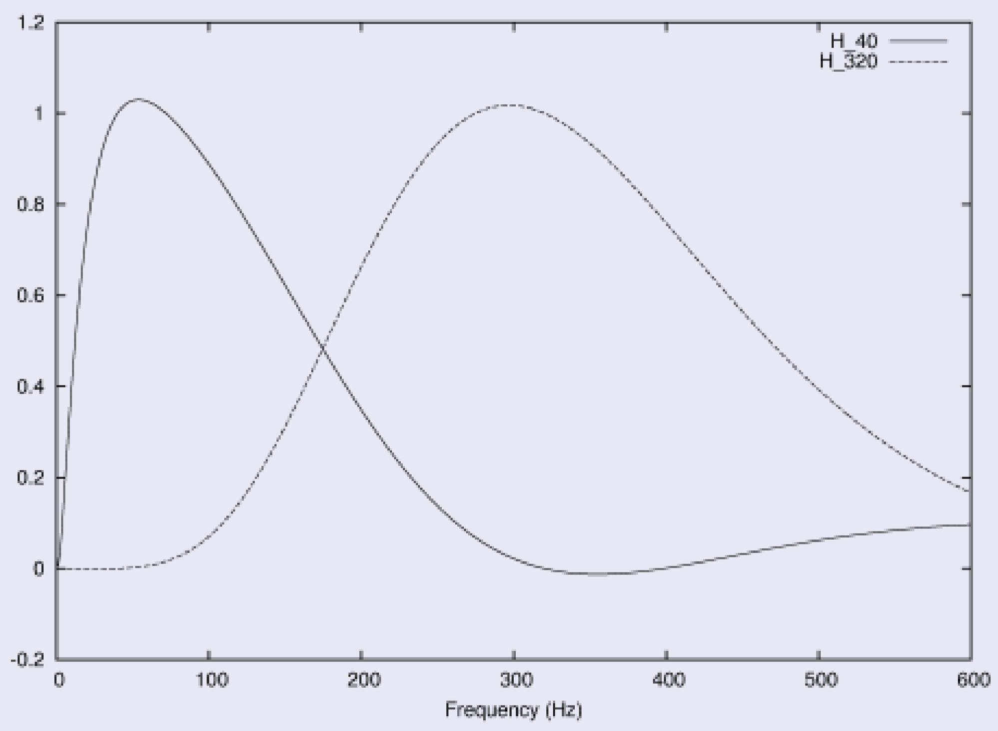


Tactile Rendering

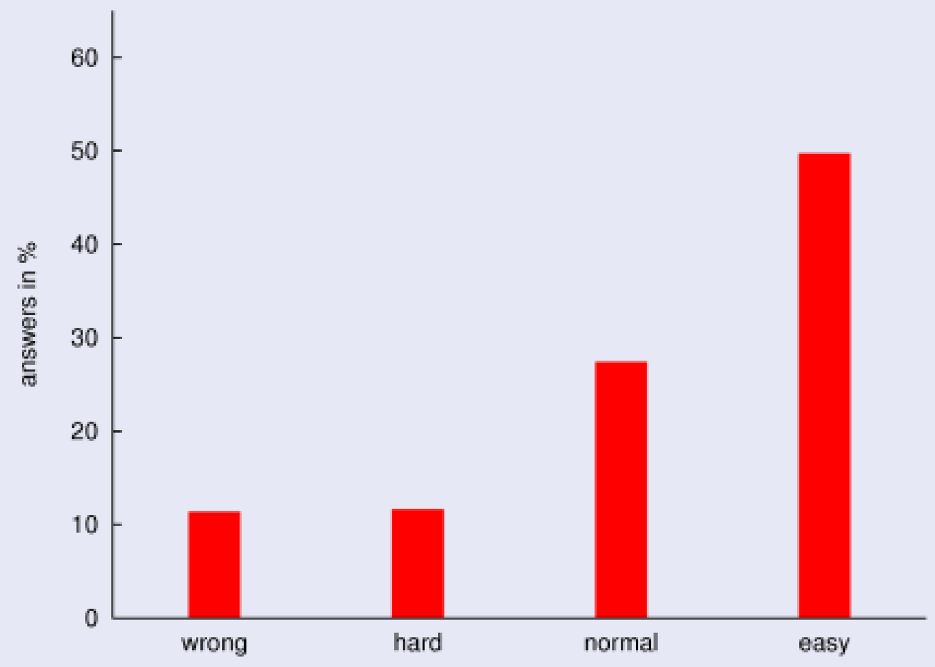
In the colour model of computer graphics a colour consisting of a whole spectrum of light is substituted with the combination of only three colours creating the same sensory impression. This model works because the human eye only provides three channels for the perception of colour. Virtually all computer screens and televisions are based on this principle. The success of this model suggests that a similar model for tactile perception might also be successful. The tactile simulation system follows such a suggestion. Like the colour model two different tactile channels of the human skin are stimulated with sinewaves at two different frequencies. For the stimulation of the two types of mechanoreceptors a superposition of sinewaves at 40 and 320 Hz was chosen.
Computation of vibrations:

$$\text{Amplitude } a_{40} = \int H_{40}(\omega) \cdot F(\omega) d\omega$$

$$\text{Amplitude } a_{320} = \int H_{320}(\omega) \cdot F(\omega) d\omega$$



For the evaluation of the system a set of seven relatively similar fabrics was chosen. In an odd-man-out forced-choice procedure eight subjects had to discriminate the fabrics. They also had to judge if the decision was "easy", "normal", or "hard".



References

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