Augmenting Visual Feedback Using Sensory Substitution[1]

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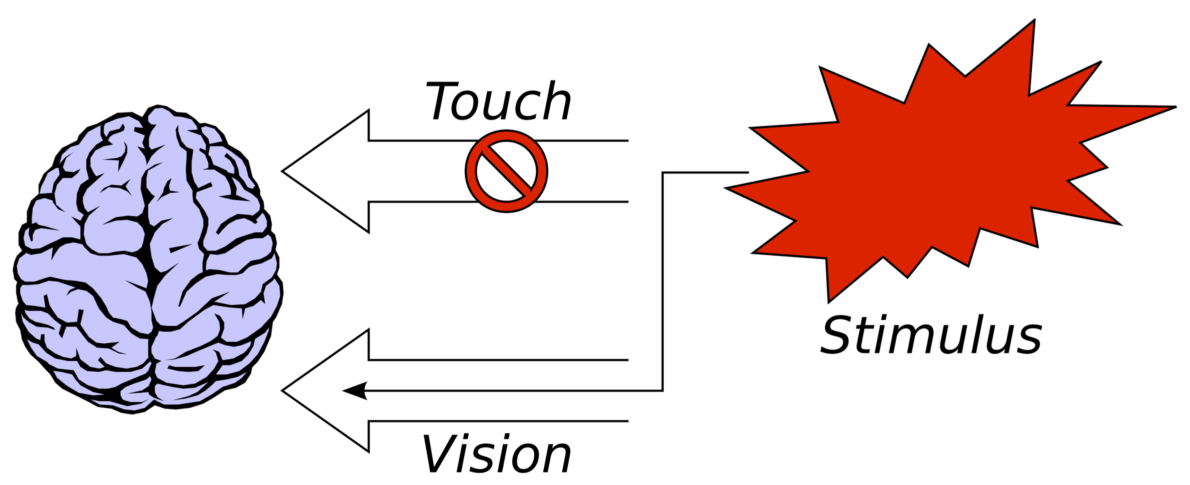
Abstract

Direct interaction in virtual environments can be realized using relatively simple hardware, such as standard webcams and monitors. The result is a large gap between the stimuli existing in real-world interactions and those provided in the virtual environment. Conceivably these missing stimuli might be supplied through a visual modality, using sensory substitution. This work suggests a display technique that attempts to employ sensory substitution to usefully and non-detrimentally display proximity, tactile, and force information.

Visual & Somatosensory Stimuli

Real-world stimuli missing in virtual worlds make users less effective and efficient. We can use vision to display some of the missing information.

Sensory Substitution



Current Techniques for Visual Substitution

Virtual Contact	Virtual Distances	Virtual Forces
blinking objects, colour changes, disks	opacity changes, colour changes	bar diagrams, cones, arrows, springs

Pseudo-haptic feedback changes the control / display ratio for the probe:

Natural proprioceptive feedback + Virtual image
→ Perception of force

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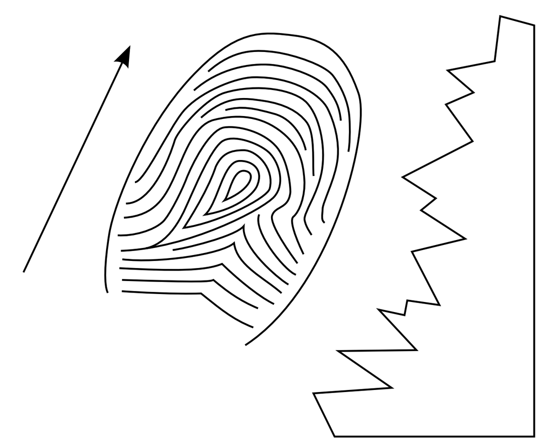
Tactile Texture Perception

Large Features ($> 1mm$)

- Detection depends on geometry alone
- Can use pseudo-haptics to display large features



Small Features ($< 0.1mm$)

- Detection of textures with small features requires vibration
- Vibration depends on fingerprints, surface texture elements, velocity
- Fingerprints filter vibration for detection around $250Hz$, to which we are most sensitive.
- Physical texture element geometry *statically* affects perception.
- Velocity *dynamically* affects perception.

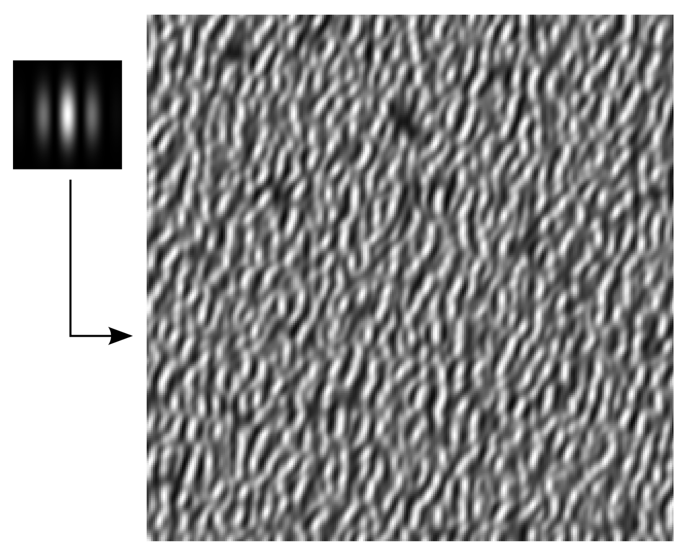
Rendering

Goal: The feedback mechanism

- should be capable of displaying multiple dimensions of information,
- should not be distracting, and
- should not obscure the primary visuals.

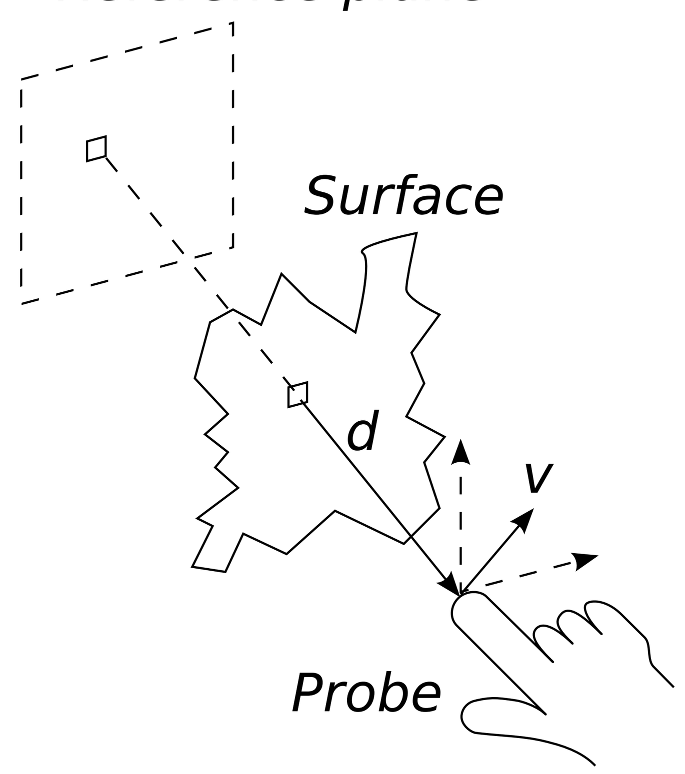
Procedural Texture Generation with Gabor Kernels
We do not draw the probe. Instead, a "pseudo-shadow" maps the static tactile texture properties to ranges of values for Gabor kernel functions:

$$\left.\begin{array}{r}\text{Element width}\\ \text{Element height}\\ \text{Element spacing}\\ \text{Anisotropy, Direction}\end{array}\right\} \rightarrow \left\{\begin{array}{l}\text{Wavelengths}\\ \text{Amplitudes}\\ \text{Densities}\\ \text{Orientations}\end{array}\right.$$

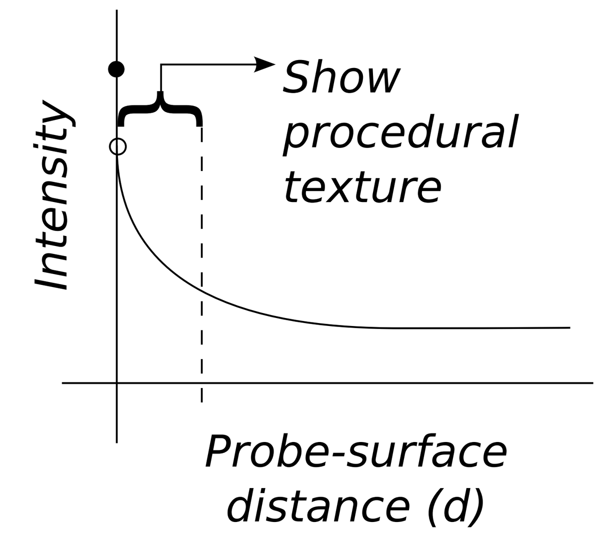


Rendering Steps

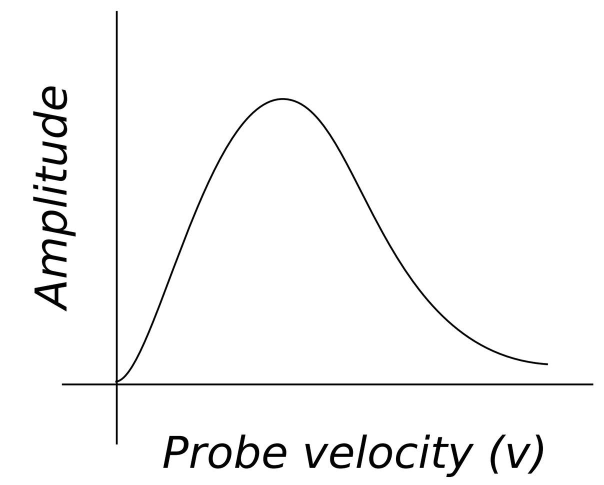
1. Make an orthogonal depth-map of the probe from the reference plane.
2. For each surface fragment,
   (a) find the surface depth relative to the reference plane;
   (b) look up the probe depth in the depth map;
   (c) modulate shadow intensity with probe-surface distance;
   (d) modulate texture amplitude with probe velocity; and
   (e) apply a pseudo-haptic "force" if the probe penetrates the surface.



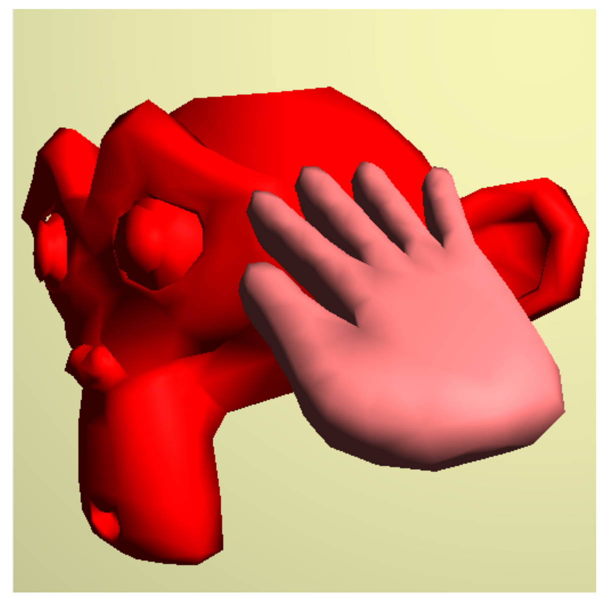
Probe-surface distance (d) and velocity (v)



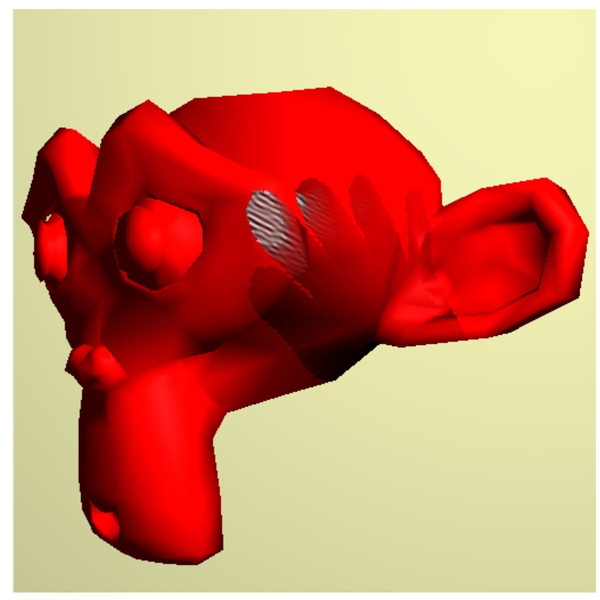
Shadow modulation



Texture modulation



No extra feedback



Pseudo-shadow

Conclusions

This work has addressed the task of augmenting visual feedback in interactive virtual environments for displaying non-visual (in the real world) information.

- Our goal is a technique with the capability to display multiple dimensions of content, while being as non-distracting as possible, and not reducing the information content of the primary visuals.
- We define a set of tactile texture properties, together with distance and force, to display. A pseudo-shadow displays this information by modulating a virtual procedural texture using the probe velocity and probe-surface distance.