



Haptic Rendering

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www.cs.ucl.ac.uk/teaching/VE

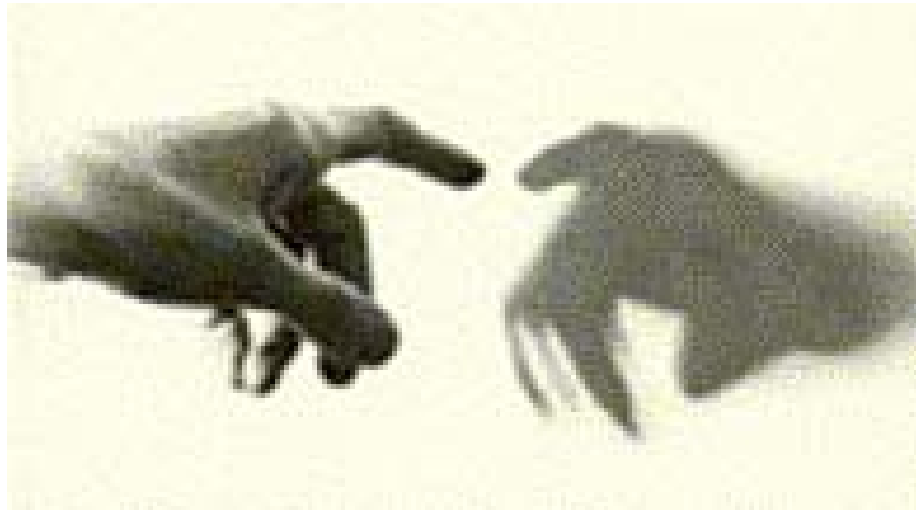
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Outline

- Intro to Haptic and Haptic Rendering
- Examples of Haptic Devices
- Example of Haptic Applications
- Human Haptic
- Basic of the Haptic Control
- Haptic Rendering
- Math
- Conclusions

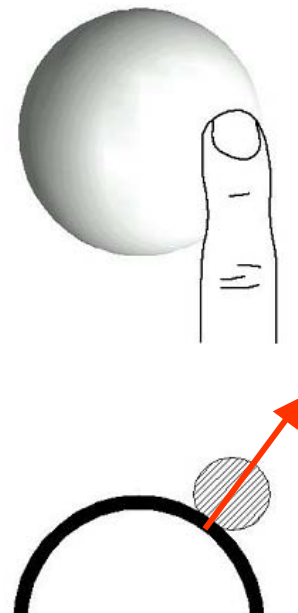
Haptic ...

...means “Use the sense of touch to interact with Virtual Environments”



Haptic Interface ...

... is a robotic device that gives the user a **FORCE FEEDBACK** from the Virtual Environment



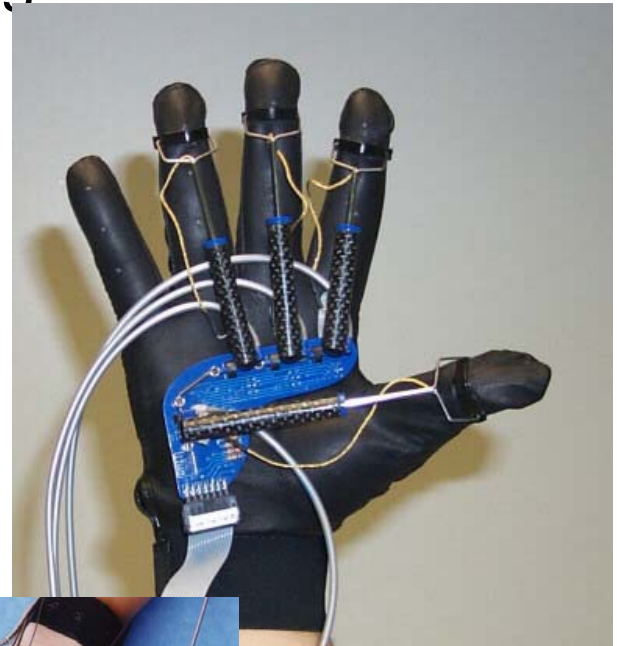
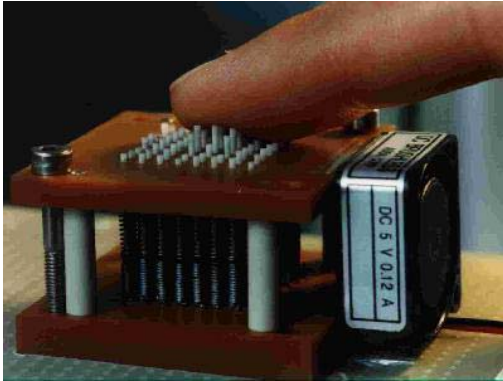
Haptic Rendering ...

*“... is the process of **computing and generating forces** in response to user interactions with virtual objects.”*

(Salisbury, 1995)

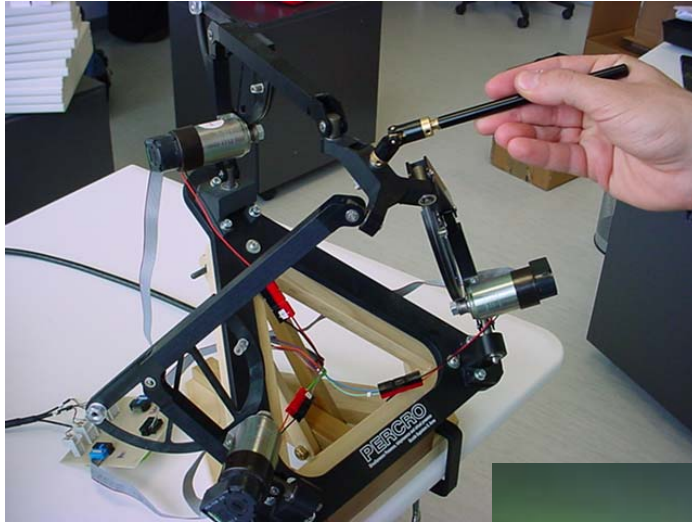
Haptic Interfaces

Touching and Grabbing



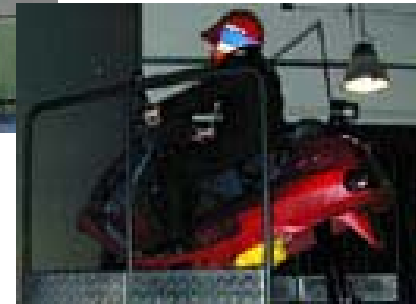
Haptic Interfaces

Touching and Manipulating



Haptic Interfaces

Complex Systems



What a HI is for ?

- Natural Interaction

It provides a natural interaction with the environment

- Augmented Experience

It adds another possibility in the interfacing with the environment

- Touch

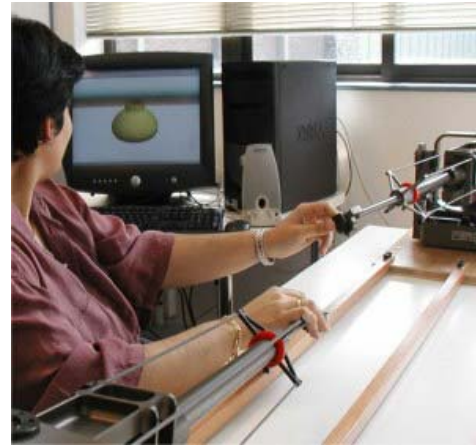
It adds another human sense at the system

Haptic Applications

Medicine

Medicine

- Surgical simulators
- Minimally invasive surgery
- Telemedicine
- Disabled

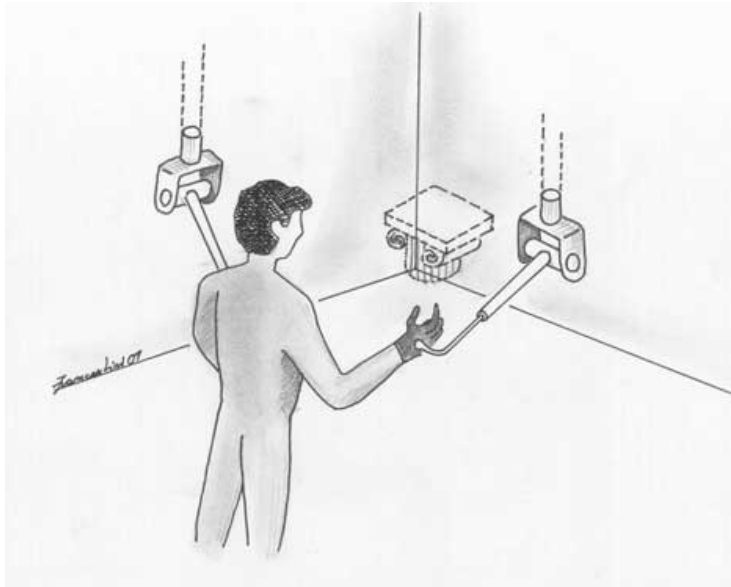


Haptic Applications

Arts

Arts

- Virtual painting and sculpting
- Virtual Museums



Haptic Applications

Education & Entertainment

Education & Entertainment

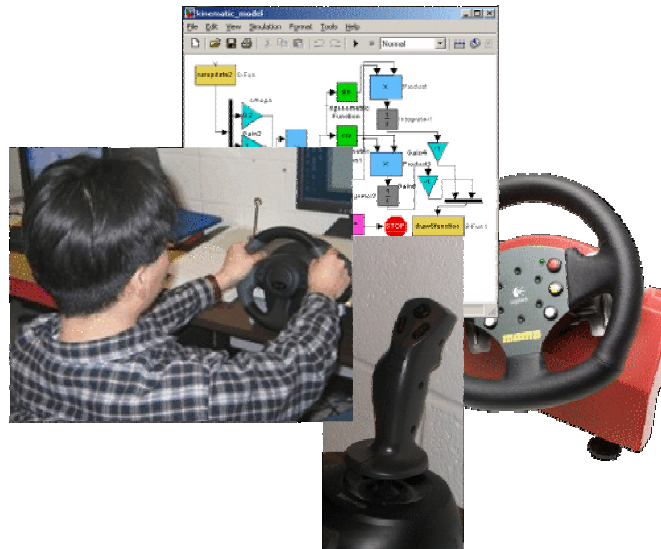
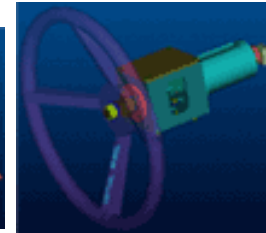
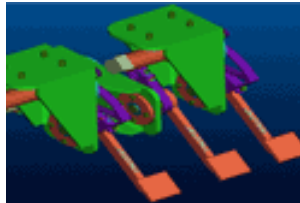
- Studying complex data sets
- Video Games and Simulators



Industry

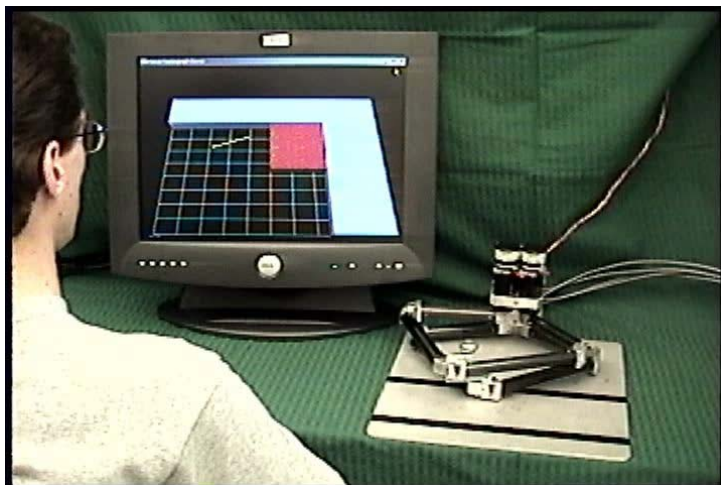
Industry

- CAD systems
- Virtual prototyping
- Simulations



Movies

General



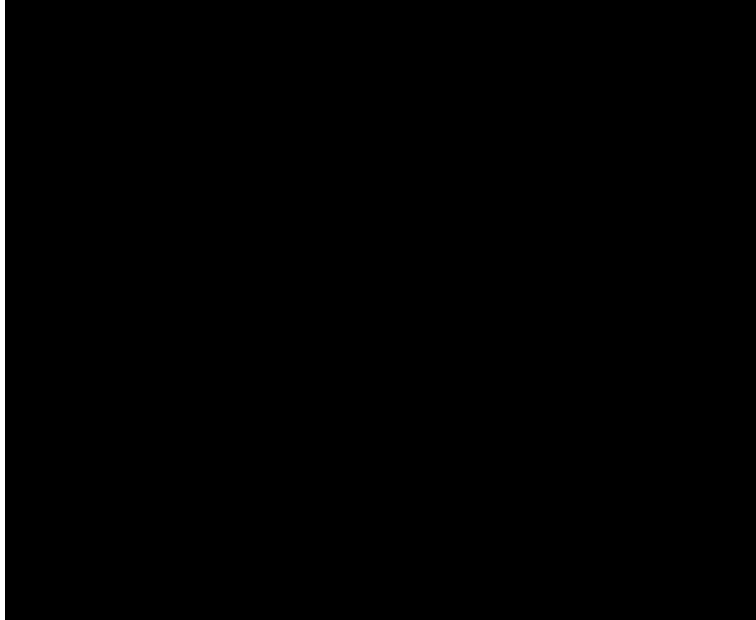
Movies

Surgery



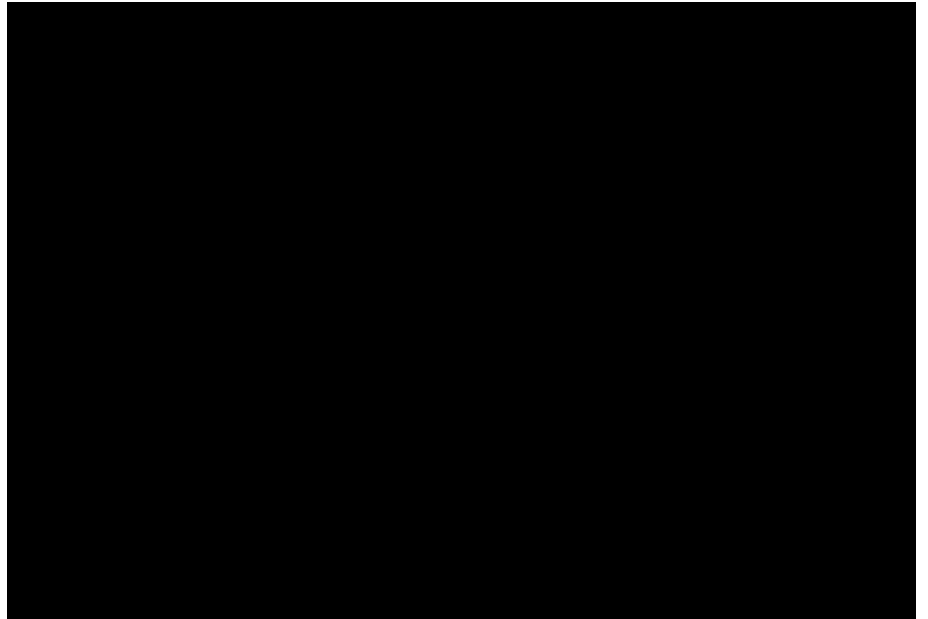
Movies

Entertainment



Painting

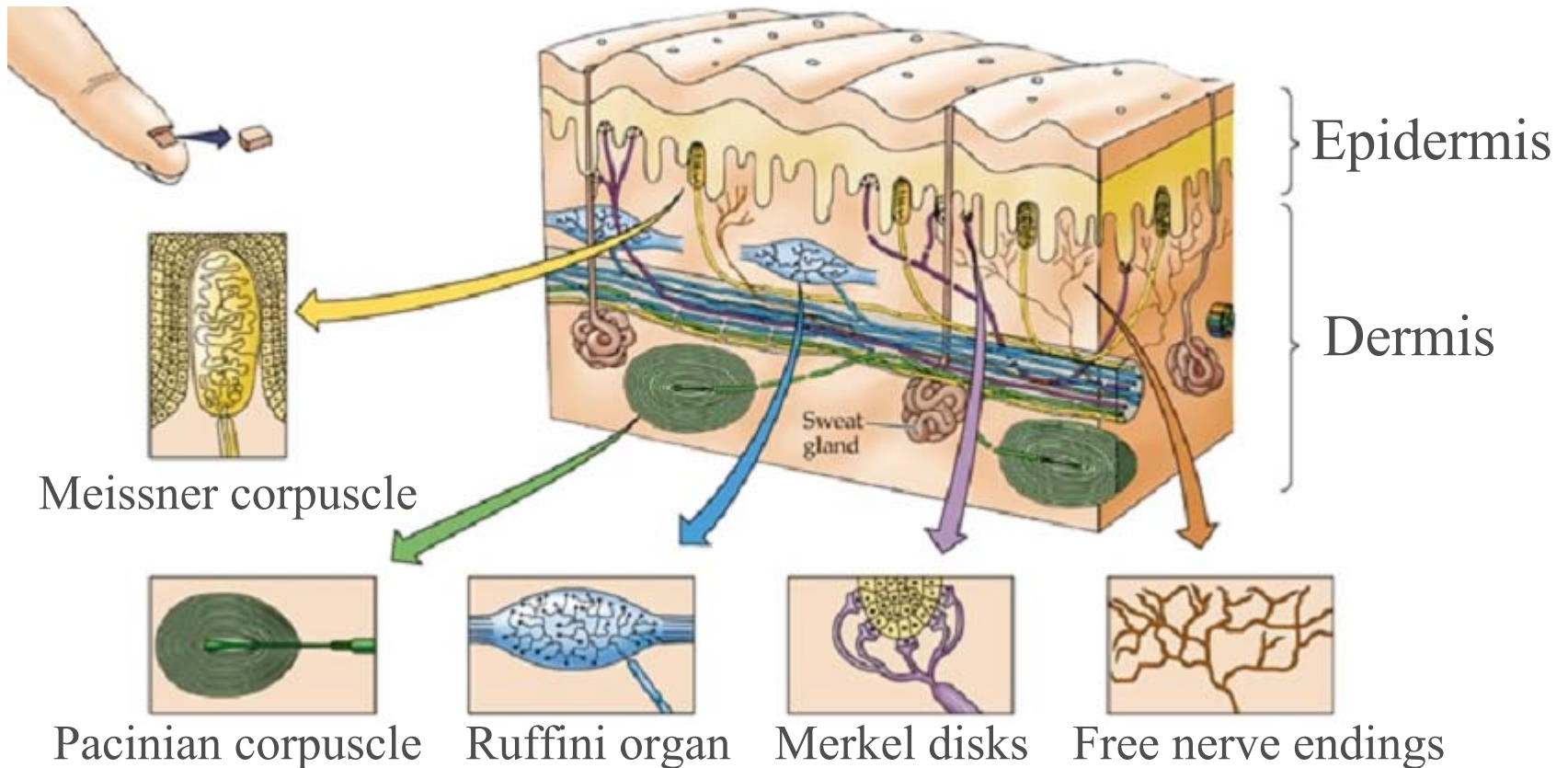
Sculpturing



Haptic
Battle

Human Haptic

Skin



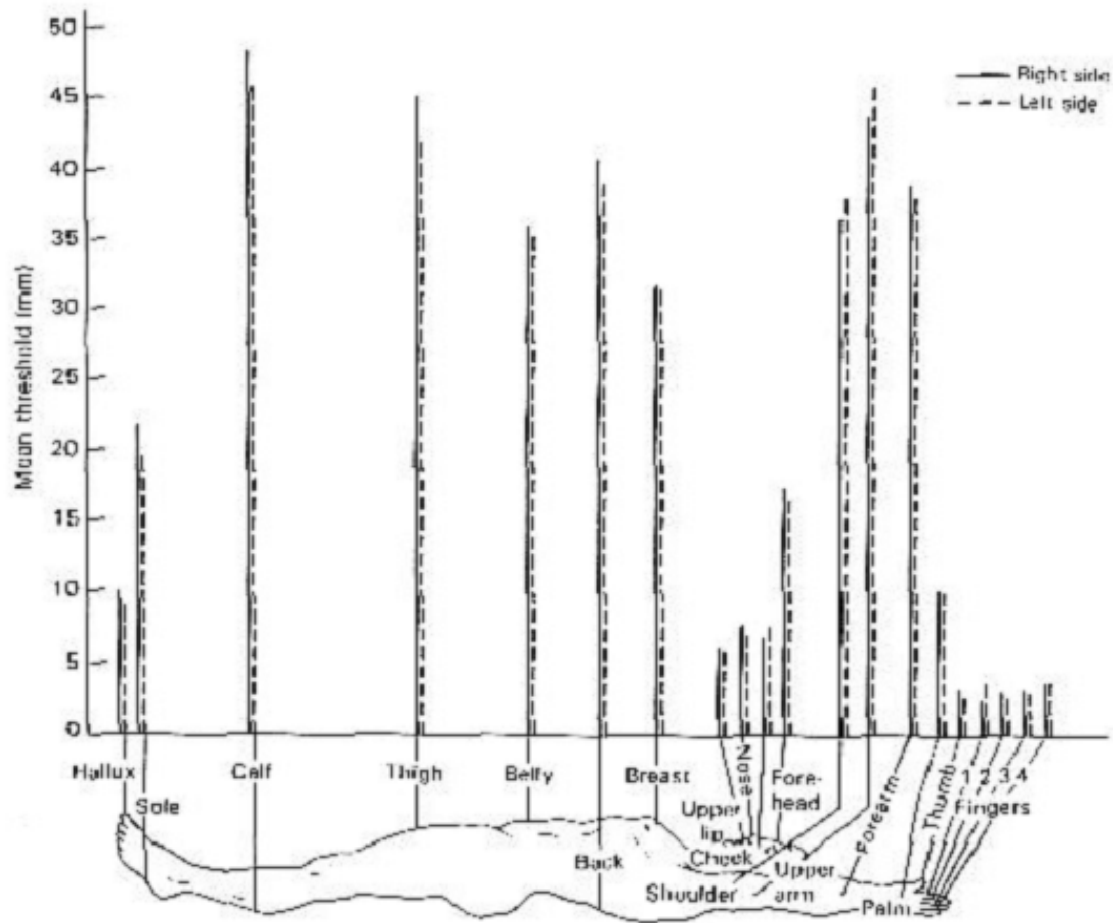
Human Haptic

Receptors

Receptors	Frequency Range	Perception	RF Size
Merkel	0.3-3 Hz	Pressure	Small
Meissner	3-40 Hz	Flutter	Small
Ruffini	15-400 Hz	Stretching	Large
Pacinian	10-500 Hz	Vibration	Large

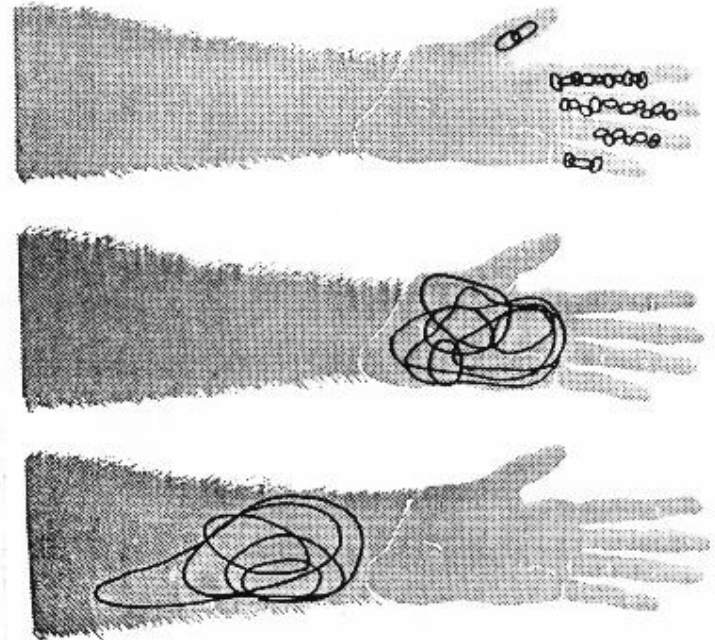
Human Haptic

Spatial Resolving Capacity - Two-points threshold



Human Haptic

Homunculus



Human Haptic

Complementary Channels

➤ TACTILE / CUTANEOUS

- Skin contact with an object
- Slipping, fine textures, small shapes and softness
- Spatial and temporal distribution of forces

➤ KINESTETIC

- Perception of one's own body position and motion
- Large shapes, coarse properties of the objects
- Receptors located within the body's muscles and tendons

Human Haptic

Resolution

Kinesthetic Resolution

- 2 degrees for fingers and wrist
- 1 degree for shoulder

Force exerted by a finger

- 50 to 100 N (Newton) maximum
- 5-15 N during exploration and manipulation

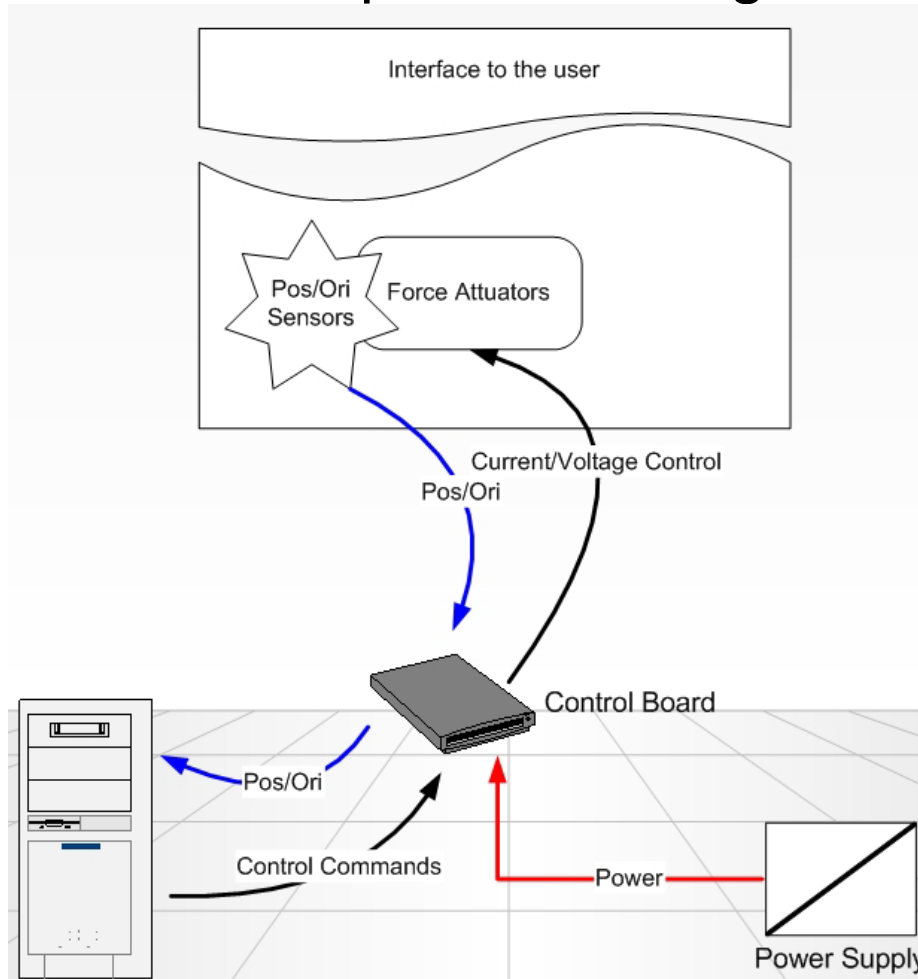
Human Haptic

Property of Objects

- Geometric (size, shape ...)
- Material texture (roughness, stickiness ...)
 hardness (compliant)
 apparent temperature
- Weight (total mass, inertia ...)

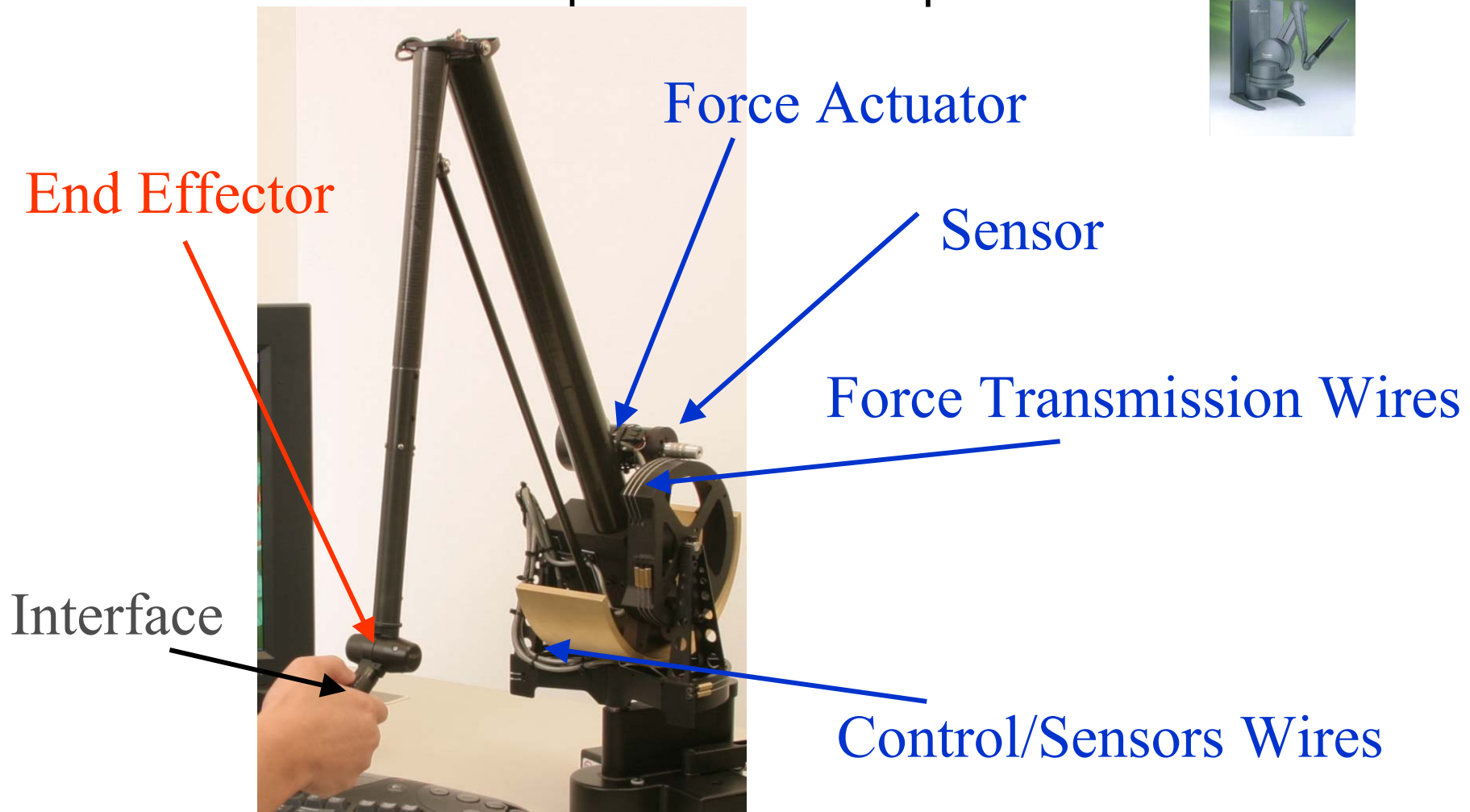
Haptic Interfaces

Components - diagram

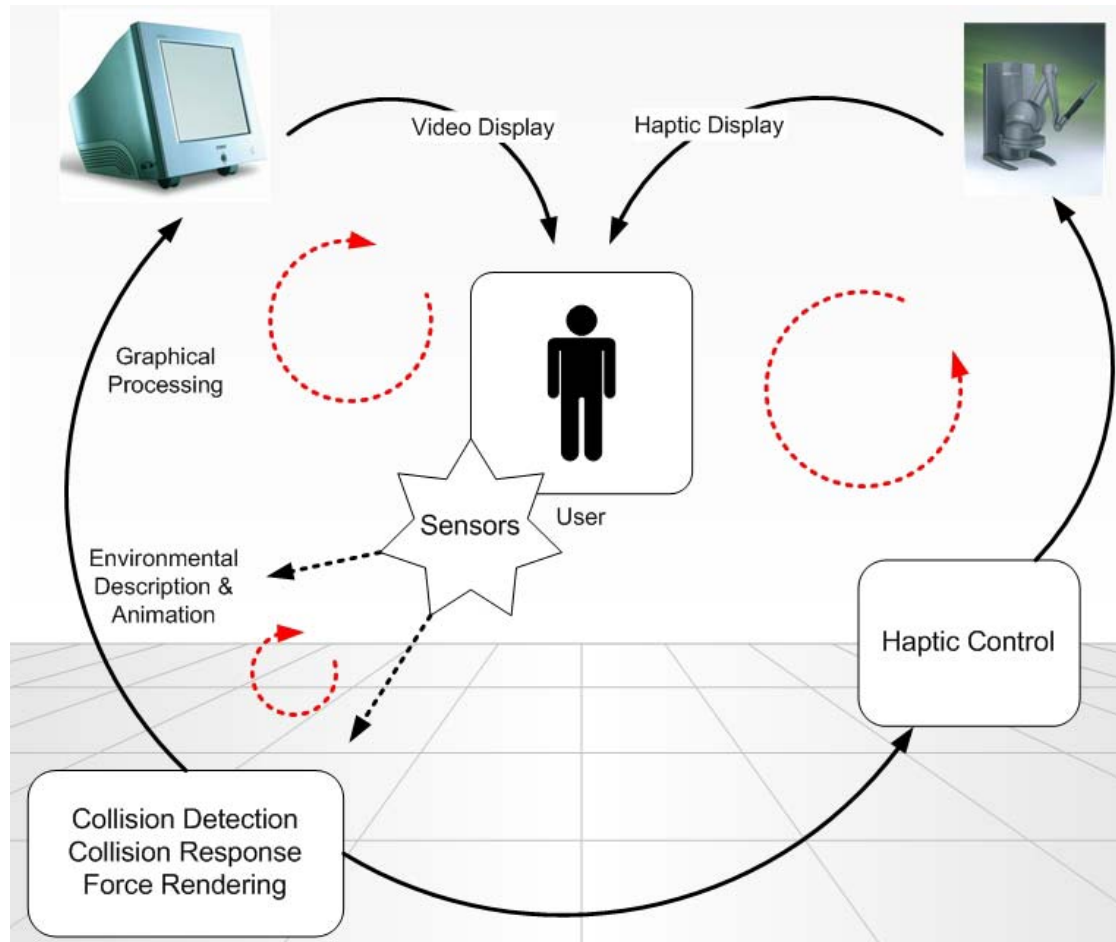


Haptic Interfaces

Components - example



Haptic Control Loops

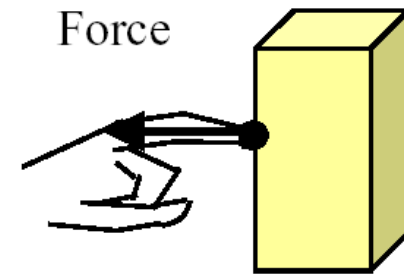


Haptic Rendering

Interactions

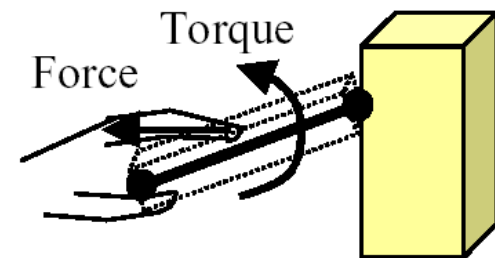
➤ Point Based

- Only the end-effector of the device interacts with the virtual surface
- Detection of the position of the end-effector



➤ Ray Based

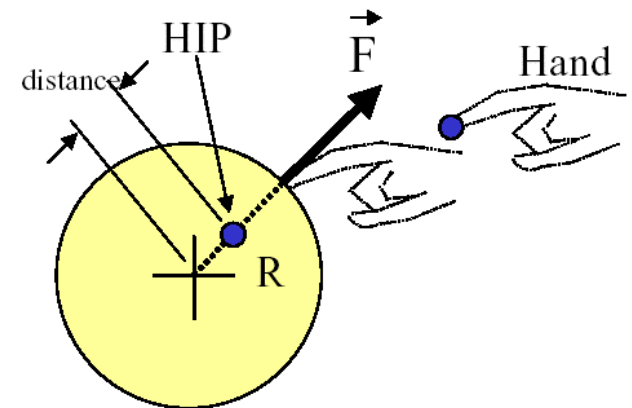
- Torque interactions
- Touch multiple objects simultaneously
- Probe as a linear segment with orientation



Collision Detection

General

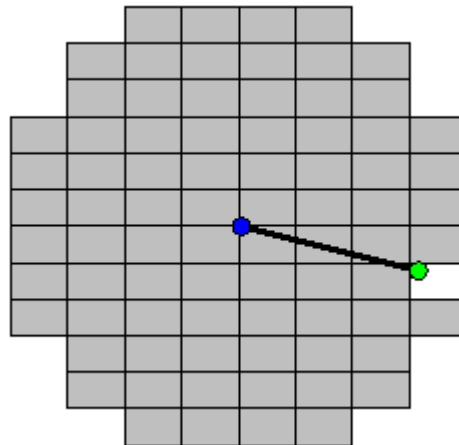
- Detection of the collision between the probe and the virtual object
- Updating rate at least 1 KHz
- Methods:
 - Spatial decomposition
 - Bounding Volume hierarchy
 - Multiresolution
 -



Collision Detection

Penalty Methods

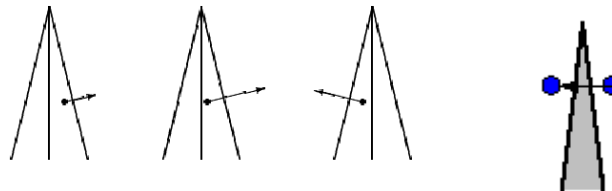
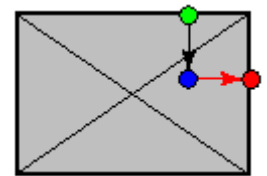
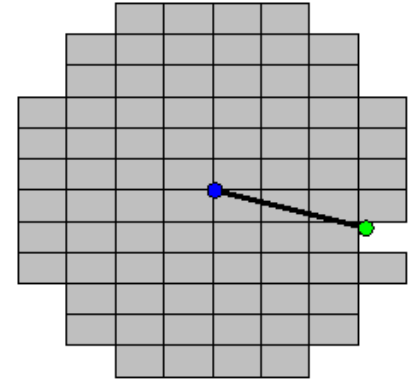
- Determine the feedback force using the penetration depth
- Work well for simple objects
- Subdivide the internal volume and associate each sub-volume with a surface



Collision Detection

Penalty Methods - problems

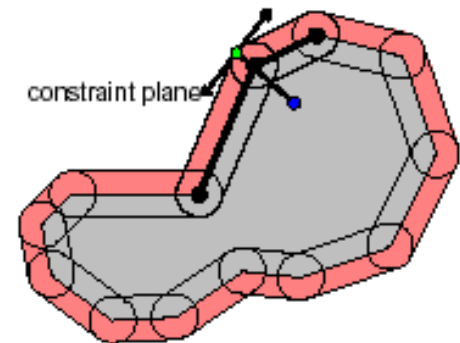
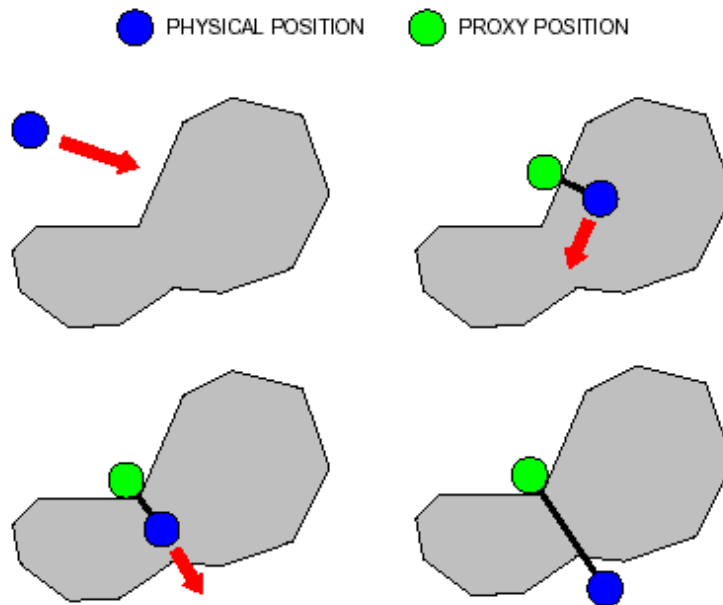
- Lack of locality: difficulty to determine which exterior surface should be associated with a given internal volume
- Force discontinuity: a probe can be attracted by another surface
- Pop-thru: thin objects may have insufficient internal volume to generate constrain and let the probe go through



Collision Detection

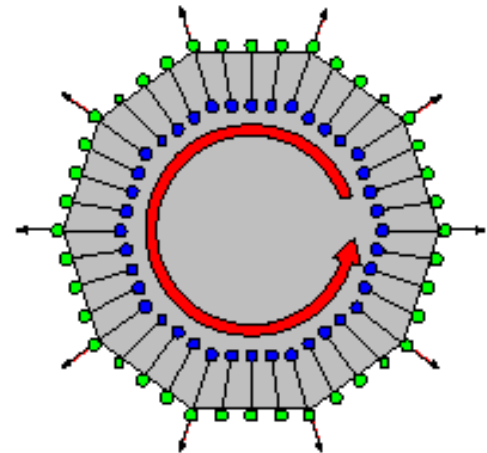
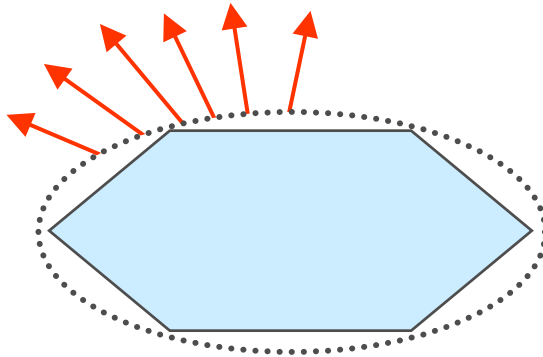
Constrain Methods

Constrain Methods – they constrain the virtual proxy to remain on the virtual surface



Force Shading

- ✓ Analogous to the Phong shading for graphics
- ✓ Try to represent the surface smooth and continuous



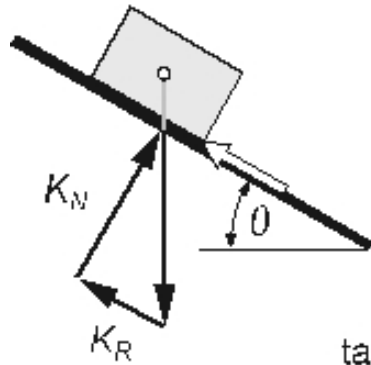
Surface Friction

what

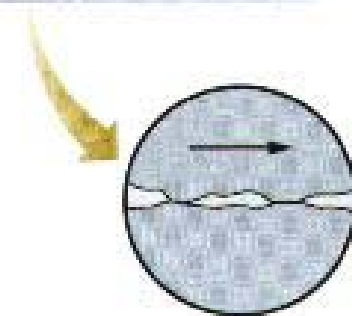


Surface Friction

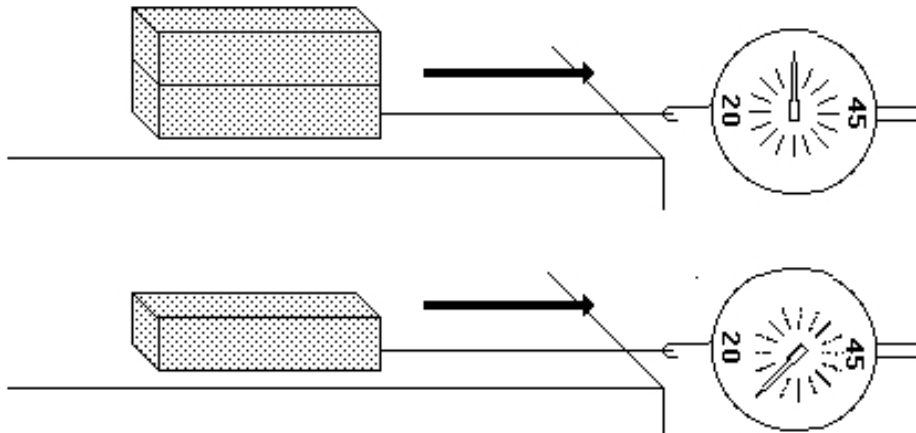
how



$$\tan \theta = \frac{K_R}{K_N} = \mu$$



- Double the mass by stacking identical blocks



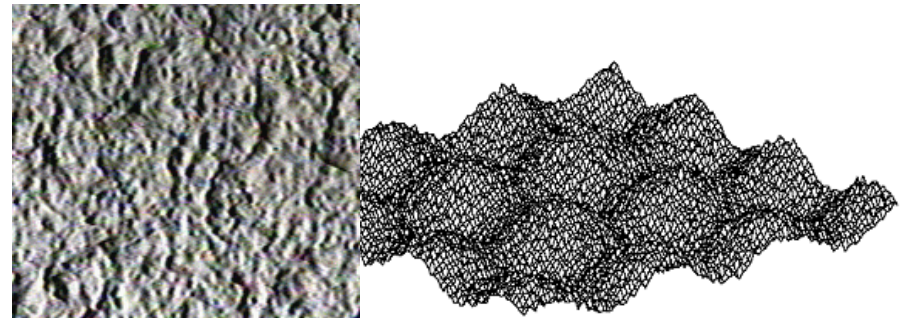
Surface Friction

when/why

- It happens when the user touch the virtual surface with the probe and move it along the surface
- It's a lateral force opposite the motion
- It's a function of the *FRICTION COEFFICIENT* and the normal force in the contact point
- There are *STATIC* and *DYNAMIC FRICTIONS* (Coulomb)

Haptic Textures

- Flat surface
- Modification of the force feedback based on the position
- Direction and magnitude of the force from different methods:
 - ✓ 2D image data (grey scale / colour scale)
 - ✓ Mathematical functions
 - ✓ Haptic recording
 - ✓

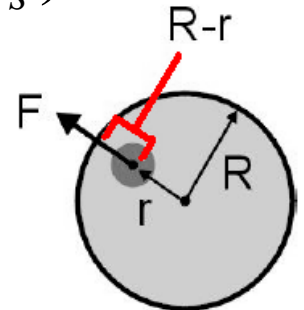
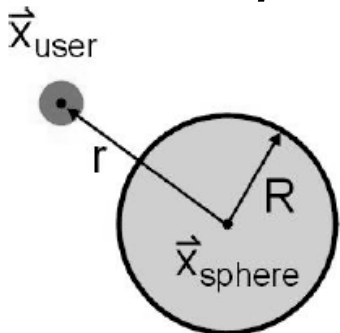


A little bit of Math ...

Simple Force

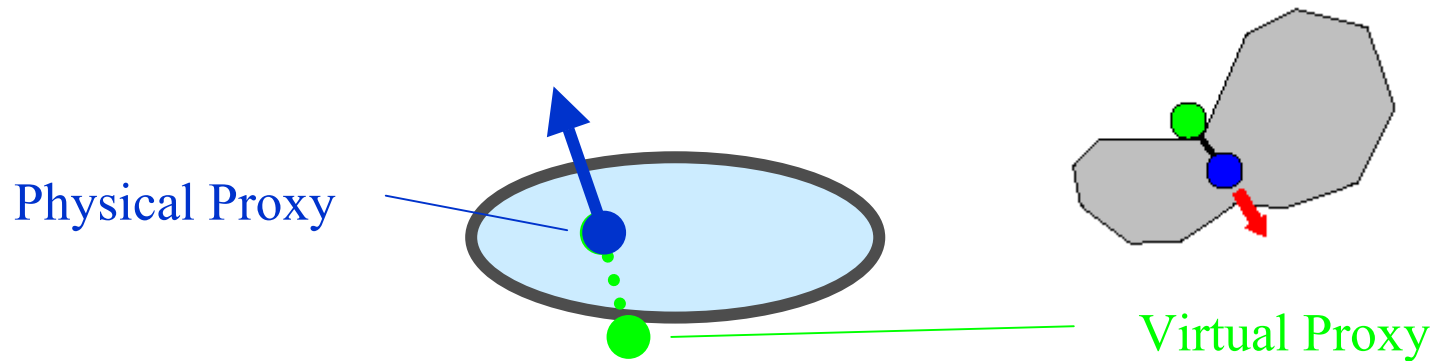
$$Force = \begin{cases} 0 & \text{for } r < R \text{ (no contact)} \\ k(r - R)\hat{r} + B\hat{v} & \text{for contact/inside (plus surface viscosity)} \end{cases}$$

$$r = \sqrt{(x_p - x_s)^2 + (y_p - y_s)^2 + (z_p - z_s)^2}$$



A little bit of Math ...

Constrain Method – Force Model



- Minimize the absolute distance between the virtual (**P**) and the physical proxy (**X**)

$$\|\hat{X} - \hat{P}\|$$

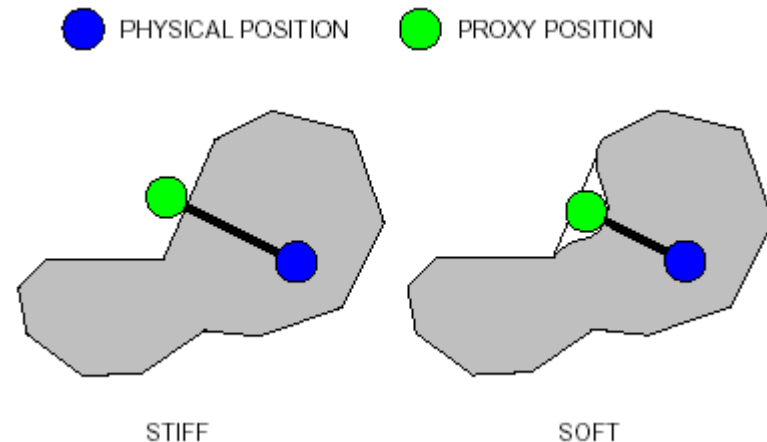
A little bit of Math ...

Friction

$$f_t - \mu_d f_n = m\ddot{x} + b\dot{x}$$

This sets the
limit of the
proxy's
movement

- f_t tangential component of the force
- f_n normal component of the force
- m mass of the object (approaching to zero)
- b viscous term
- μ_d coeff. Of the Coulomb friction



Summary

- Haptic adds another sense to the Virtual Reality
- Human Feeling has too many variables
- Hardware is various
- Software control has a lot of math
- Haptic is complex !!!