Computer Haptics and Applications

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Resources:

Introduction:

Basdogan C. and Srinivasan, M.A., "Haptic Rendering in Virtual Environments", pp. 117-134, Handbook of Virtual Reality (*available at http://network.ku.edu.tr/~cbasdogan*)

Historical Perspective:

Proceedings of Phantom Users Group Workshops (available as MIT AI/RLE Tech. Reports)

Conferences:

- IEEE Haptics Symposium (part of IEEE VR)
(used to be a part of ASME Dynamic Systems and Control)
- EuroHaptics
- Siggraph
- IEEE Int. Conf. on Robotics and Automation

Journals:

Haptics-e Journal (free access), Presence: Virtual Environments and Teleoperators, IEEE Robotics and Automation, International Journal of Robotics, ASME Dynamic Systems and Control

Outline

Part I. Fundamentals

"what is computer haptics?"

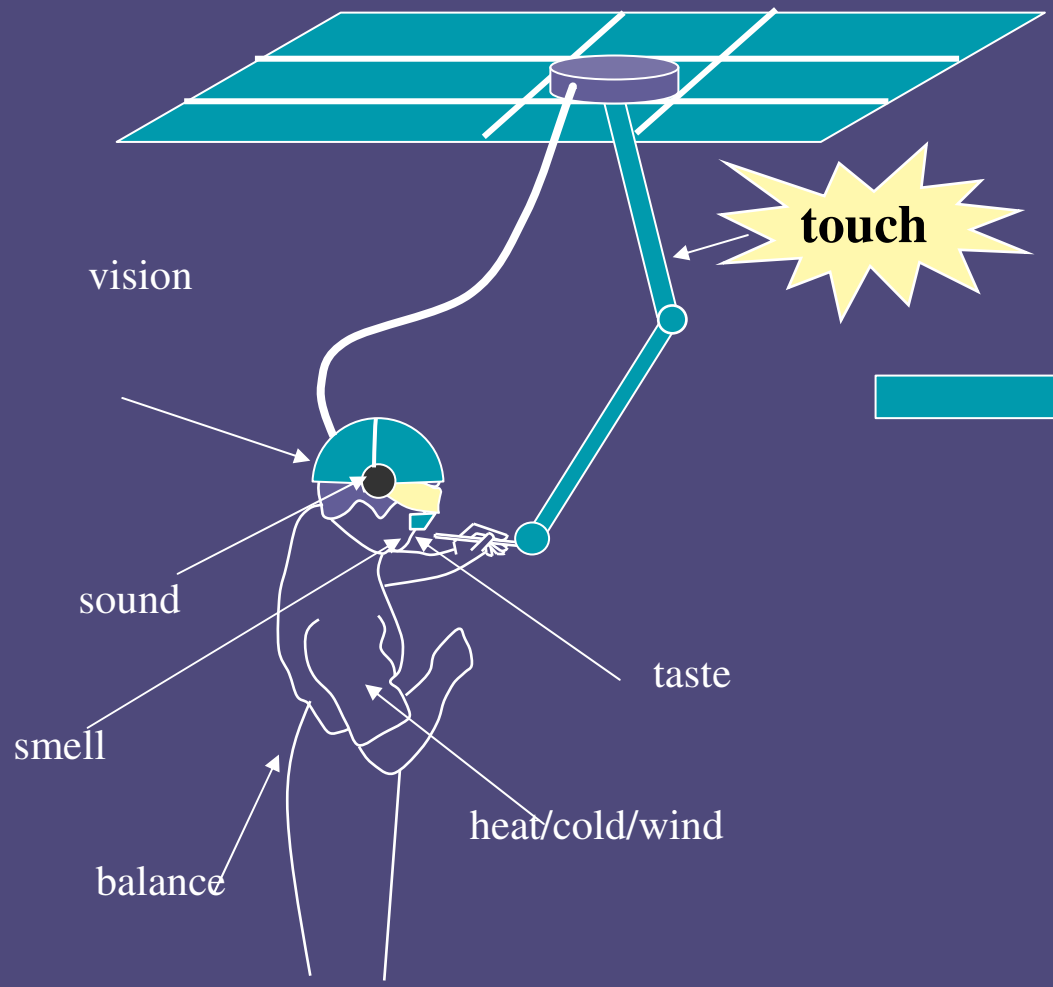
Part II. Applications/Experimental Studies

"where to use it?"

a. Surgical simulation
b. Shared Virtual Environments
c. Human Perception and Cognition
d. Haptic Visualization: Tangible Models of Martian Rocks

Multi-Modal Virtual Environments:

a synthetic environment that is designed to simulate our sensory communication with outside world.



Applications:

- Education
- Art & Entertainment
- Medicine
- Space Technology
- CAD / CAM
- …

The Power of Touch:

A little evidence can tell the whole story!

Haptic (adj.):

related to the sense of touch.

Computer Graphics:

display of synthetically generated 2D/3D visual stimuli to the user

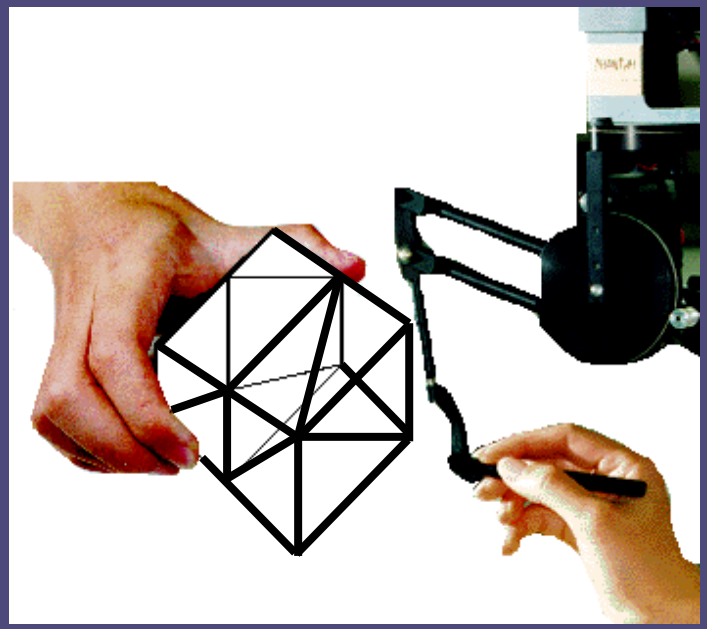
Computer Haptics:

display of synthetically generated 2D/3D haptic stimuli to the user

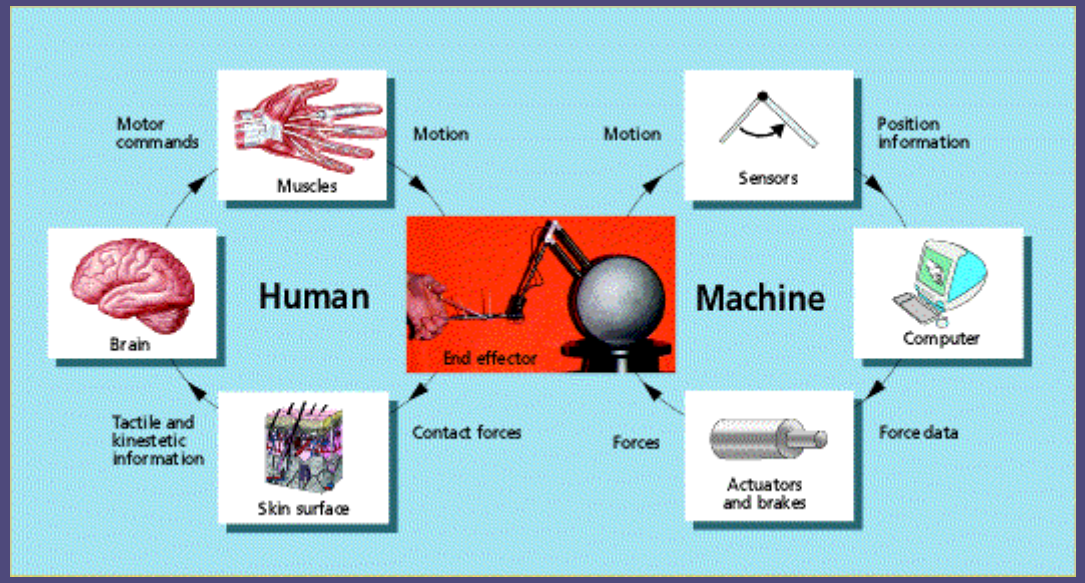
***Haptic Interface*: device for touch interactions in real and virtual worlds**

Human vs Machine Haptics:

Human Haptics



Machine Haptics



Human Haptics Game:

1. What is the smallest separation distance between two points that can be discriminated by a human finger?

   (a) 5 mm (b) 1.5 mm (c) 0.1 mm

2. On a smooth surface, what is the height of a smallest size dot that can be detected by a human finger?

   (a) 1 mm (b) 0.1 mm (c) 2 micron

3. What is the maximum force that you can exert with your pointer finger?

   (a) 10 N (b) 50 N (c) 120 N

4. If you pinch a person, approximately how much force do you apply on him/her?

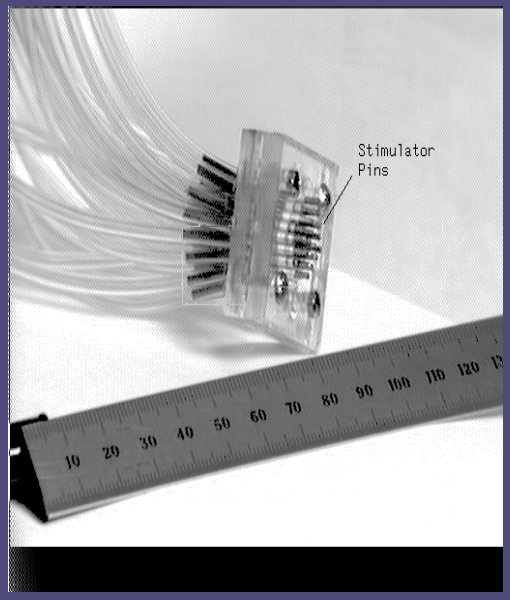
   (a) 70-100 N (b) 30-50 N (c) 5-20 N

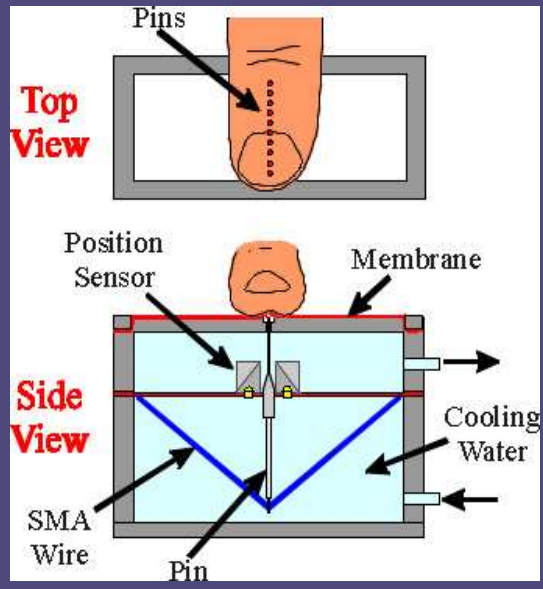
Machine Haptics:

Types of Haptic Devices

Net Force Displays

Tactile Displays





Types of Haptic Devices

Passive

keyboard, trackball, mice, etc.

Active

Types of Haptic Devices

Grounded

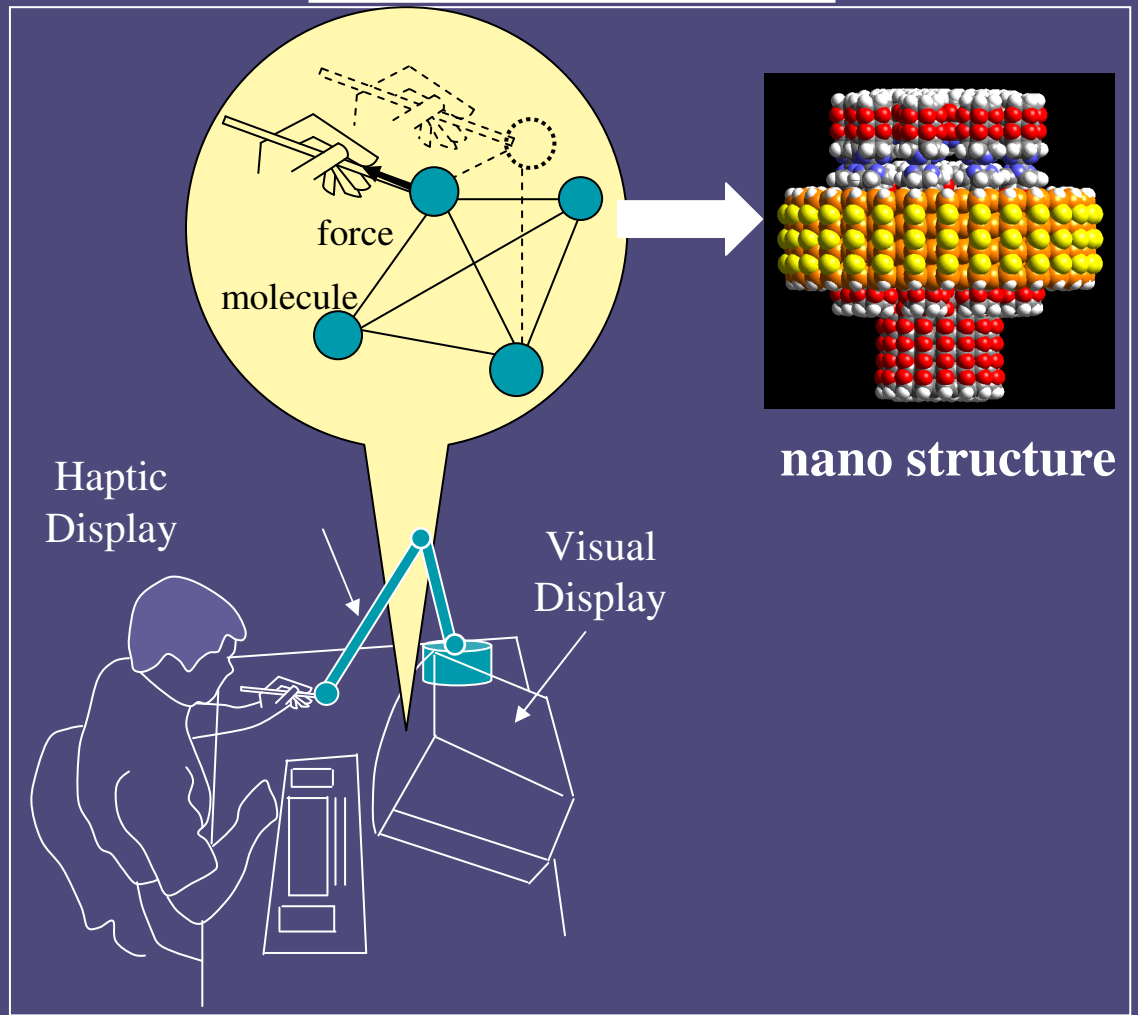
combined

Ungrounded

Applications

Haptic Feedback for Medical Simulation and Training

Haptic Feedback for Molecular Simulation



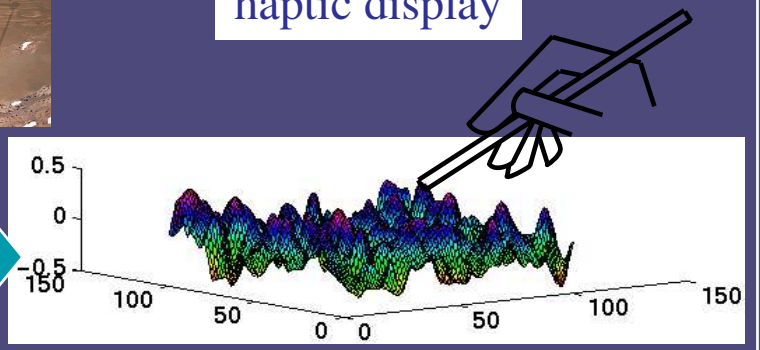
Applications

Haptic Feedback for Collaborative Engineering Design

Haptic Visualization

collected data

haptic display

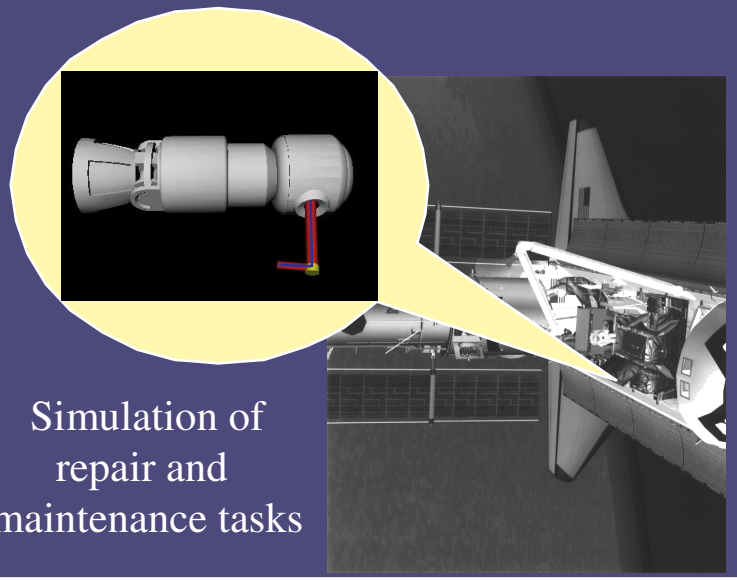


tangible data

Tangible Interfaces

- buttons
- dials
- slider bars
- folders
- layers
- force fields

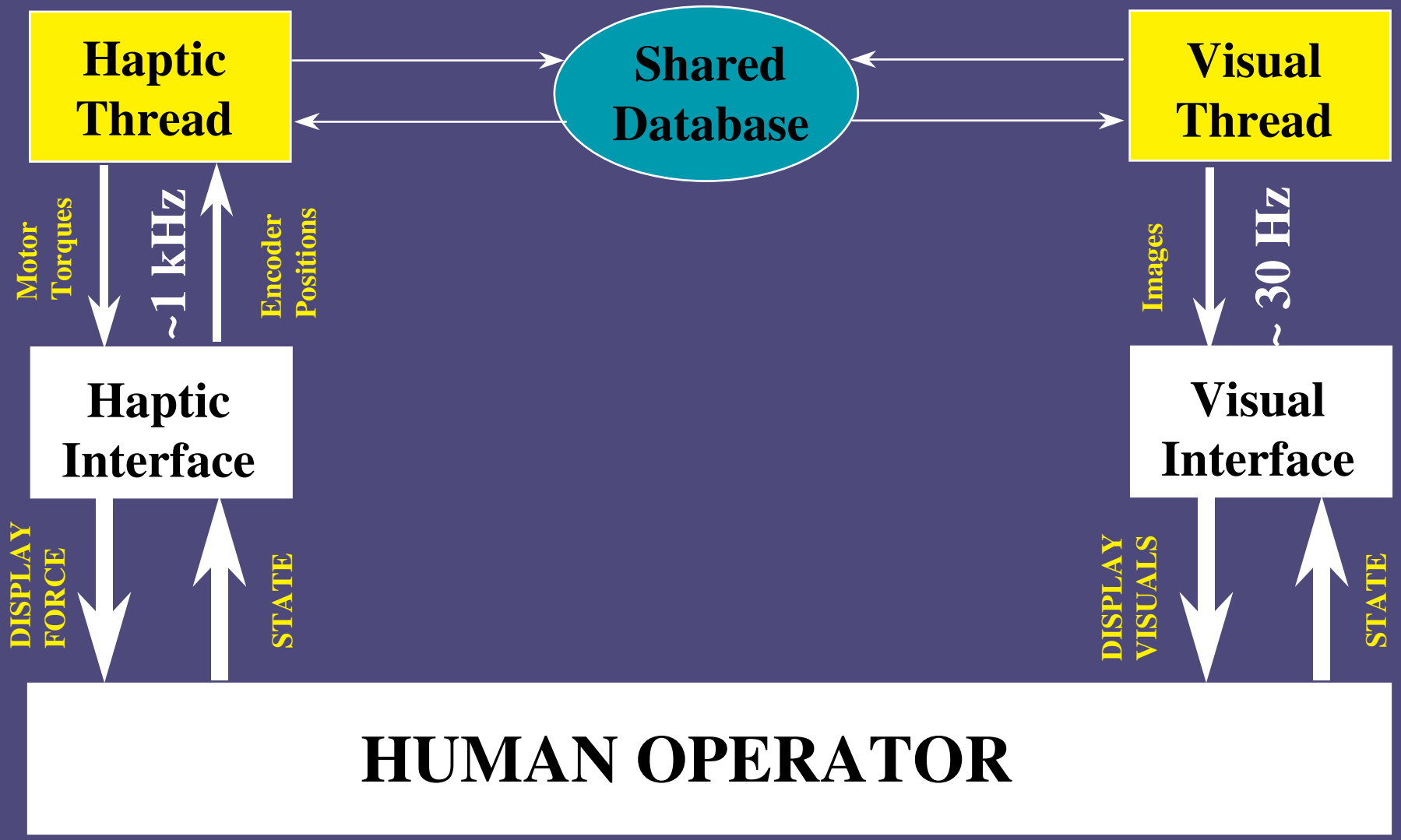
Haptic User Interface (HUI)



Simulation of repair and maintenance tasks

Haptic Feedback for Crew Training

Integration of Vision and Touch

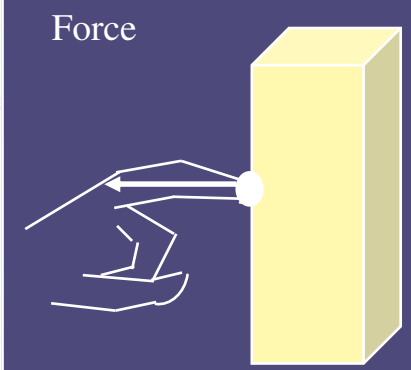


Haptic Rendering with a Force Display

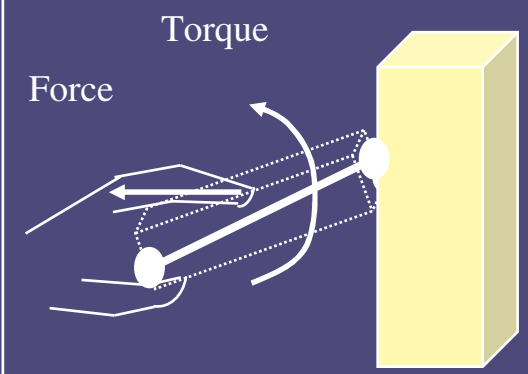
Types of Haptic Interactions with 3D Objects:

a

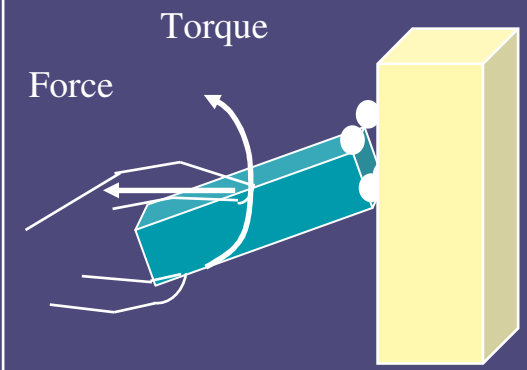
b



c



d



Point-Object **Line Segment-Object** **Object-Object**

more computation

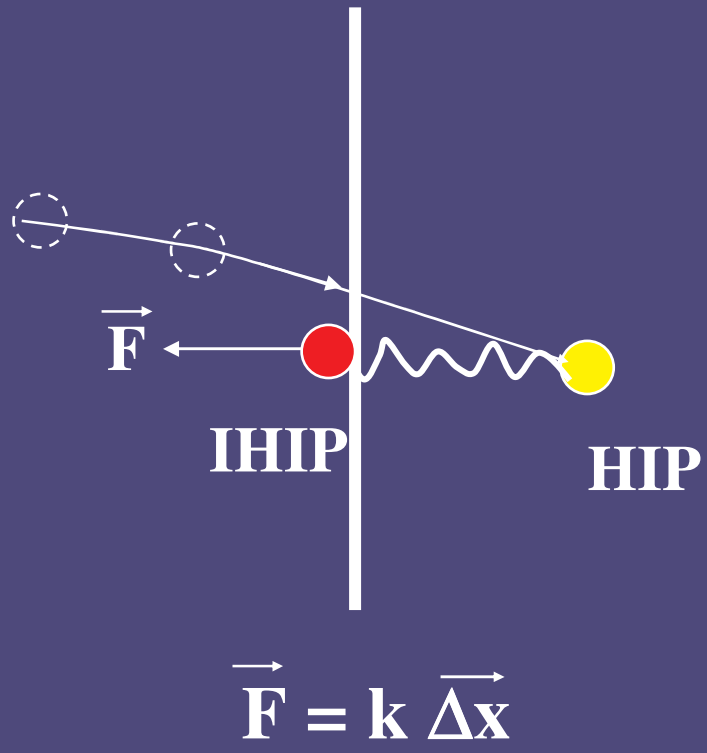
Point-Based Haptic Interaction

get_position (Vector &position);

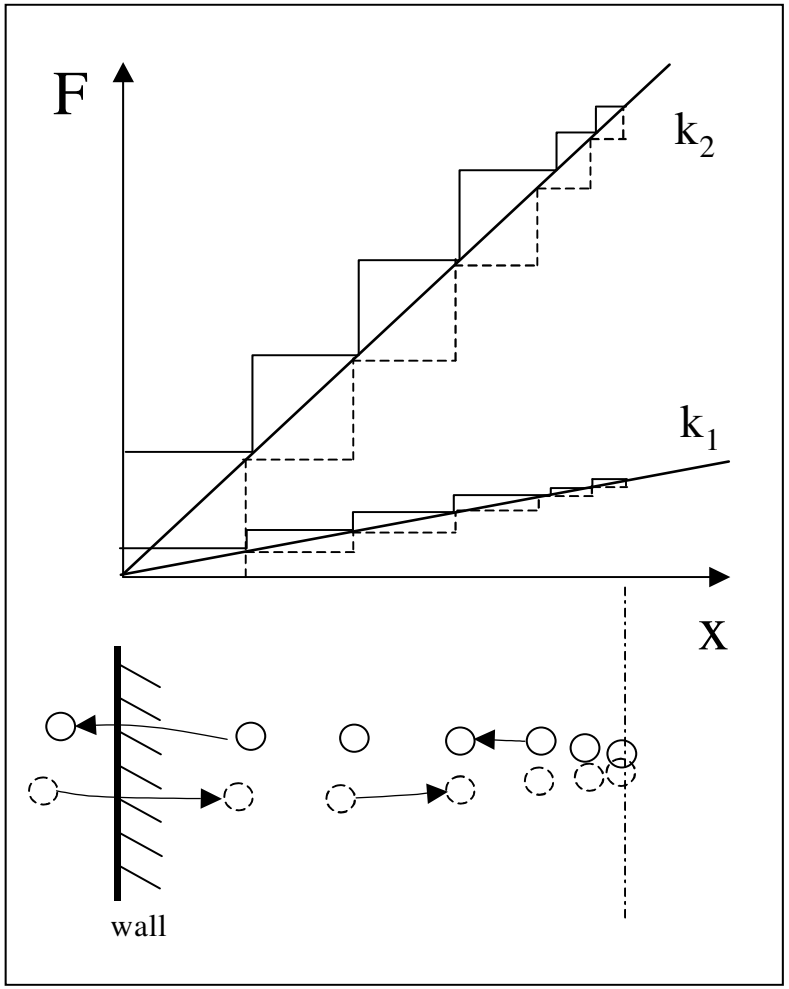
YOUR CODE COMES HERE …

- collision detection
- collision response

send_force (Vector force);



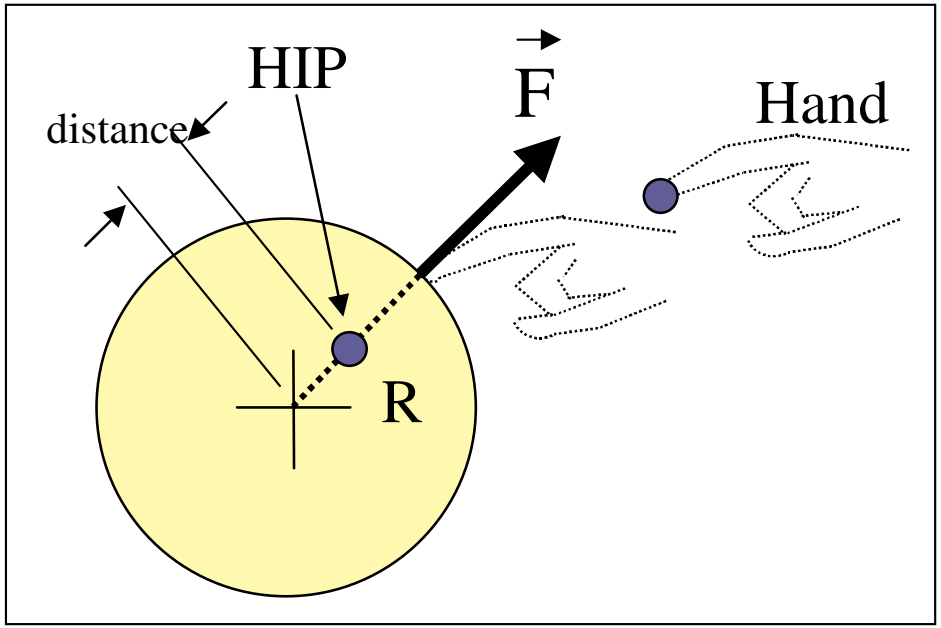
Point-Based Haptic Interaction



How to pick the right "k" value ?

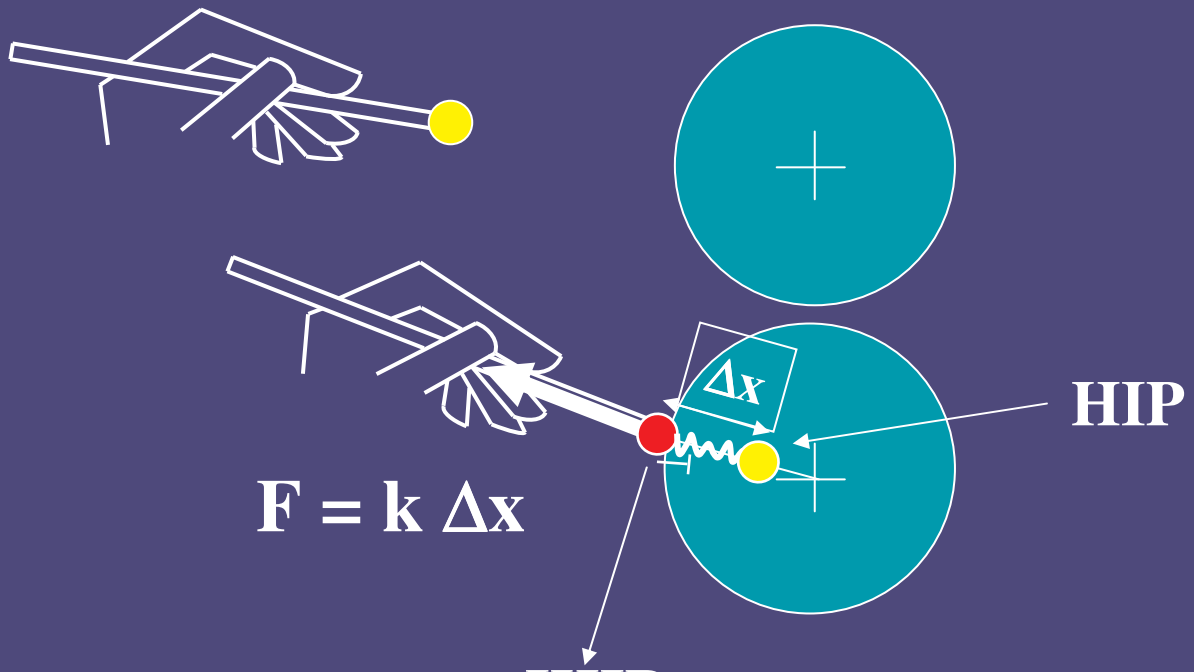
Large "k"-> vibration
Small "k" -> soft wall

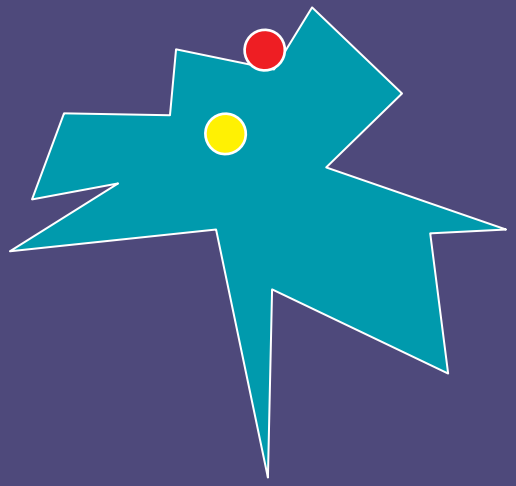
Haptic Rendering Of 3D Geometric Primitives




```
void calculate_force (Vector &force)
    {
        float X, Y, Z, distance;
        float R = 20.0;

        X = HIP[0]; Y = HIP[1];  Z = HIP[2];
        distance = sqrt(X*X + Y*Y + Z*Z);

        if(distance < R)  //collision check
        {
            force[0] = X/distance * (R-distance);
            force[1] = Y/distance * (R-distance);
            force[2] = Z/distance * (R-distance);

        }

    }
```

Haptic Rendering of 3D Polyhedron



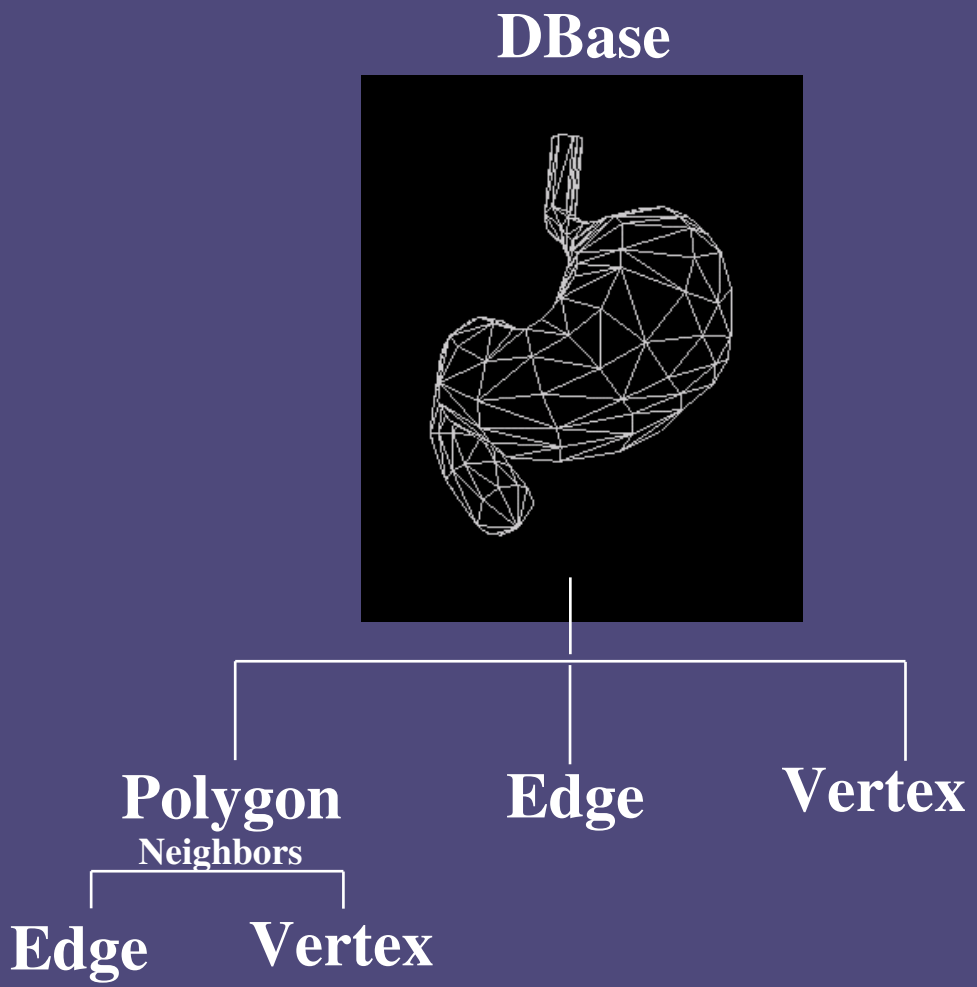


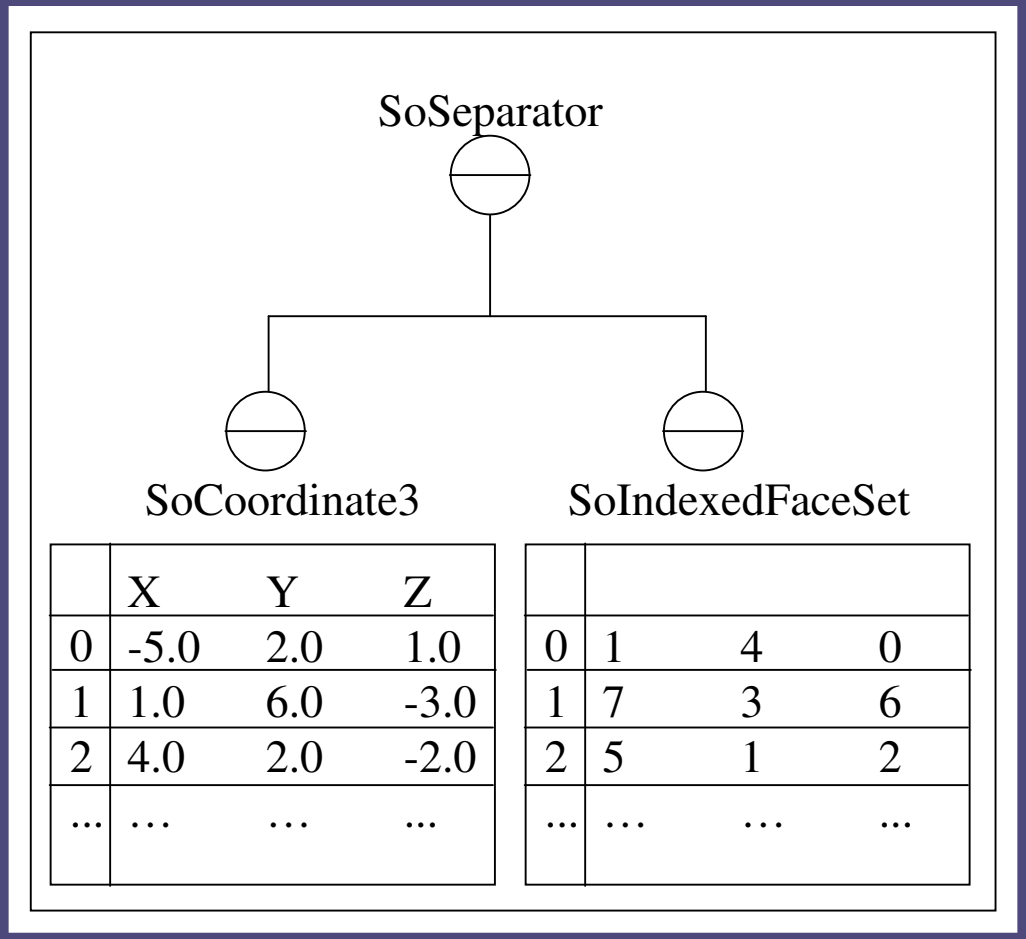
3D Primitives
no problem !

?

3D polyhedron
- optimization
- rule-based techniques

Representation of 3D Polyhedron





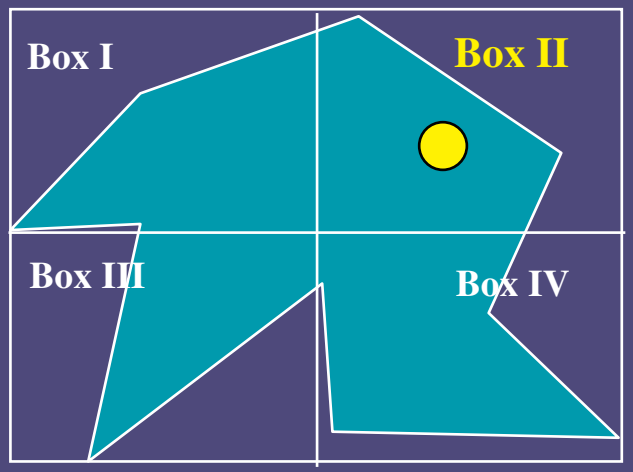
	X	Y	Z
0	-5.0	2.0	1.0
1	1.0	6.0	-3.0
2	4.0	2.0	-2.0
...	…	…	...

0	1	4	0
1	7	3	6
2	5	1	2
...	…	…	...

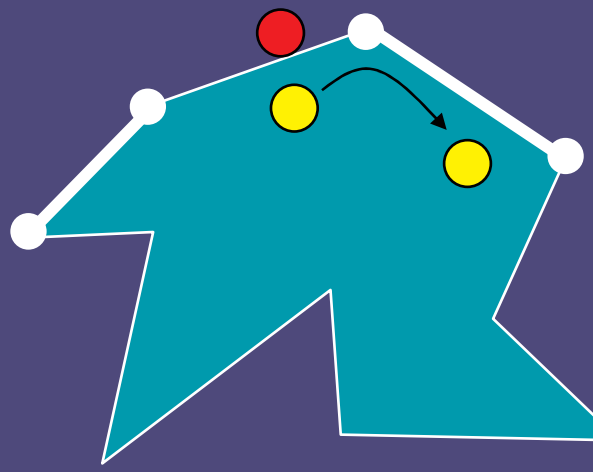
Open Inventor/VRML file

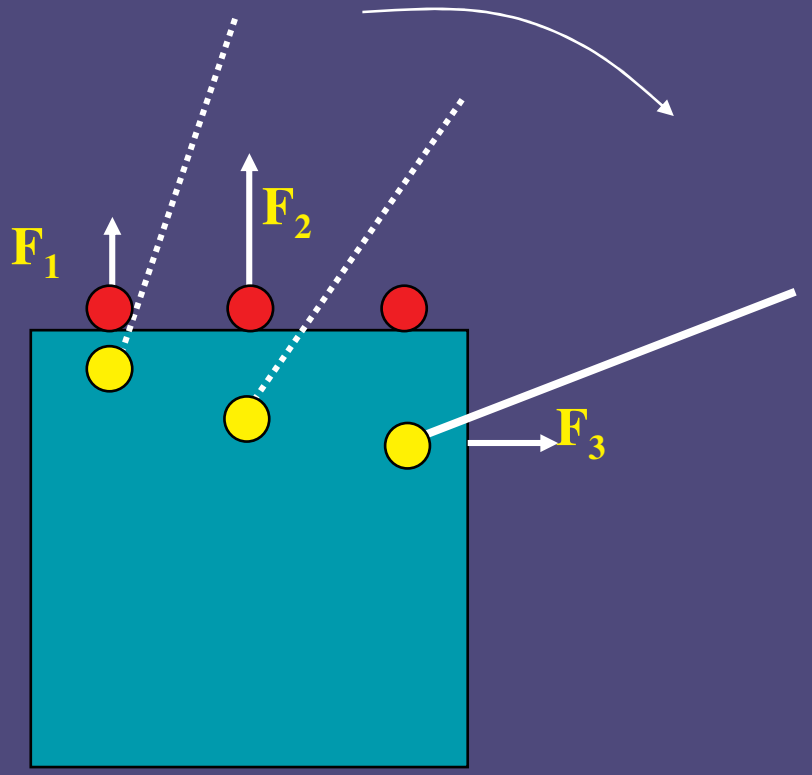
Key Components of the Rendering Algorithm

1) Bounding-box hierarchy



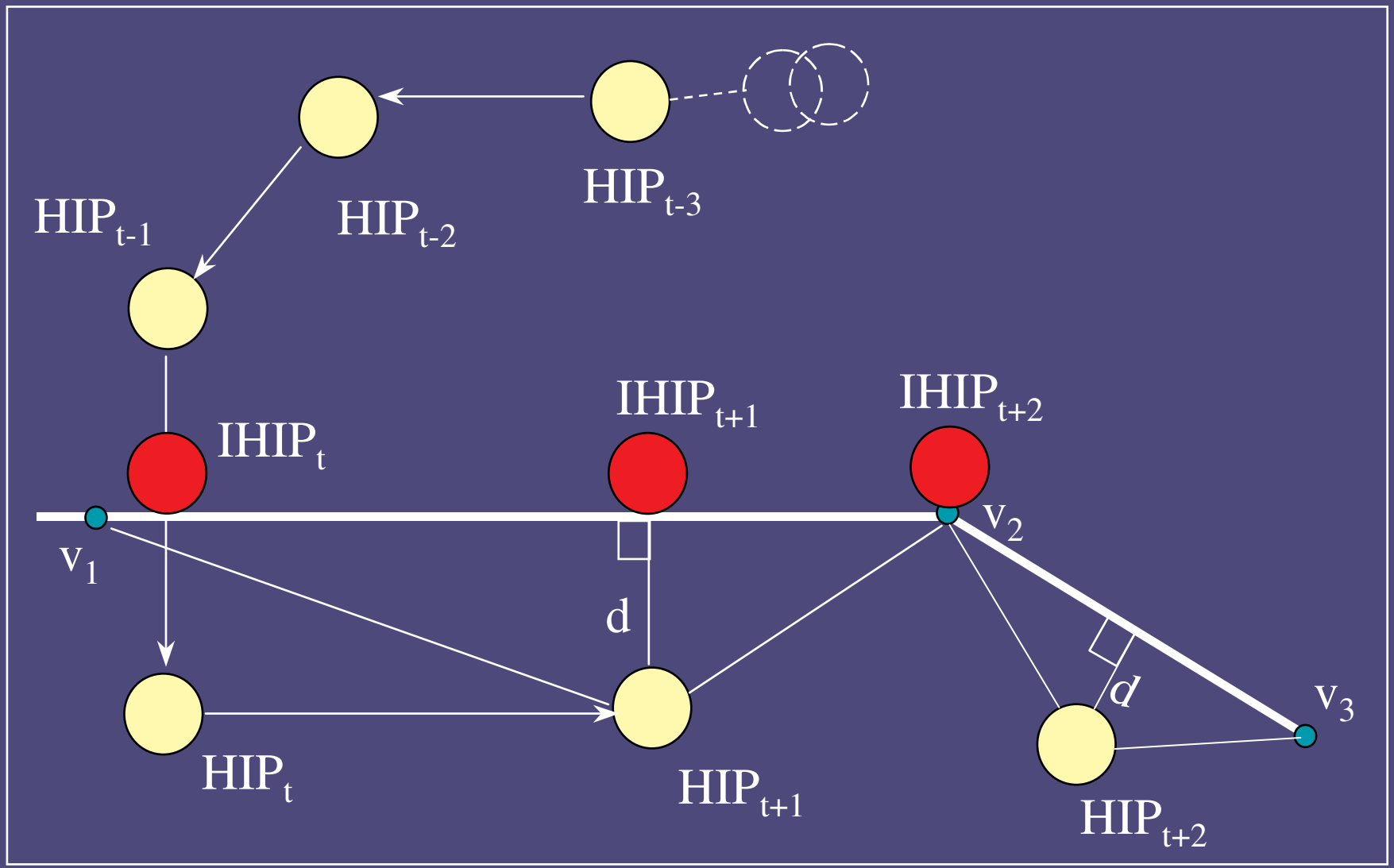
3) Local coherence





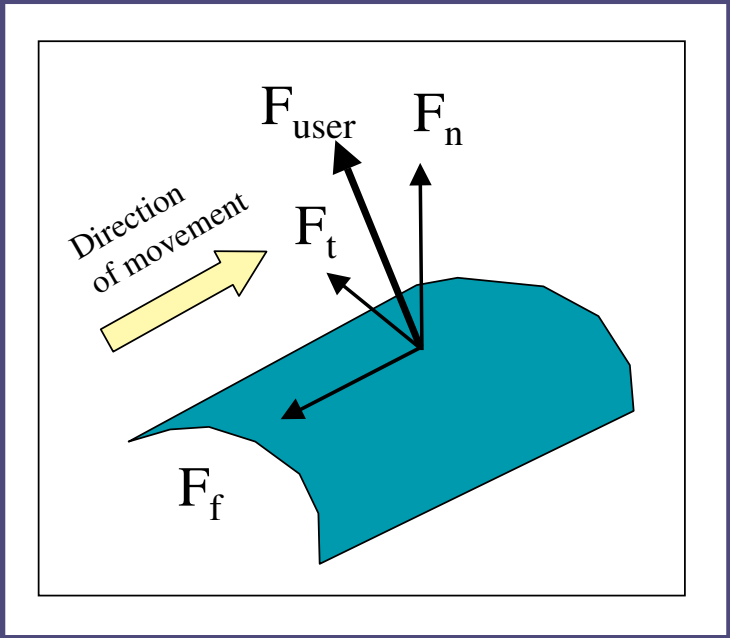
2) Contact history

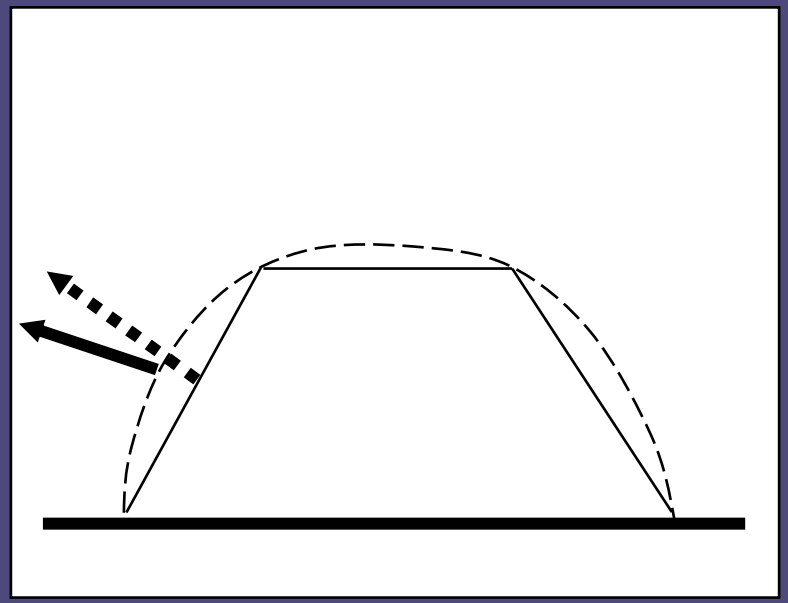
Haptic Rendering of Polygonal Surfaces



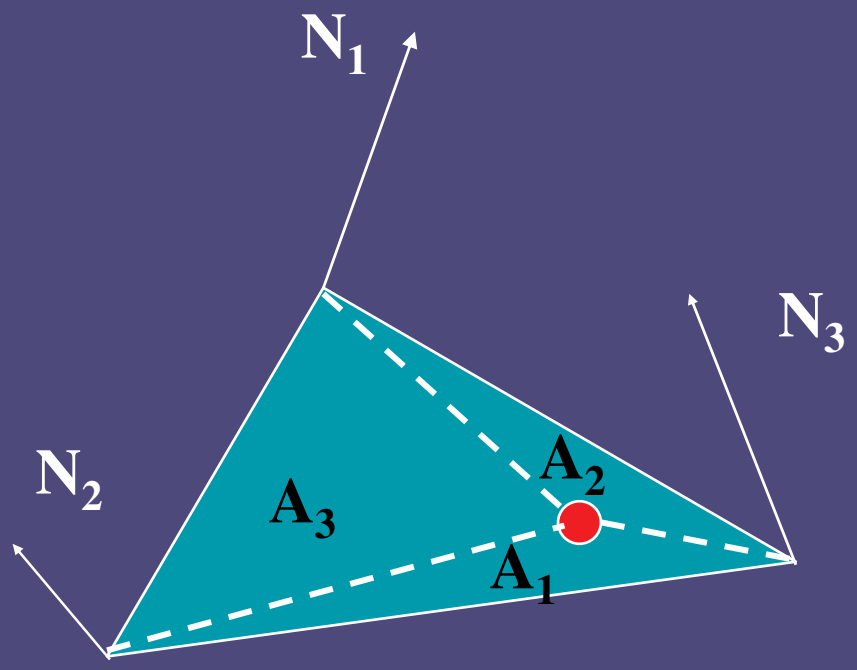
Haptic Display of Surface Details

- Haptic smoothing of object surfaces
- Rendering of haptic textures
- Haptic rendering of surfaces with friction





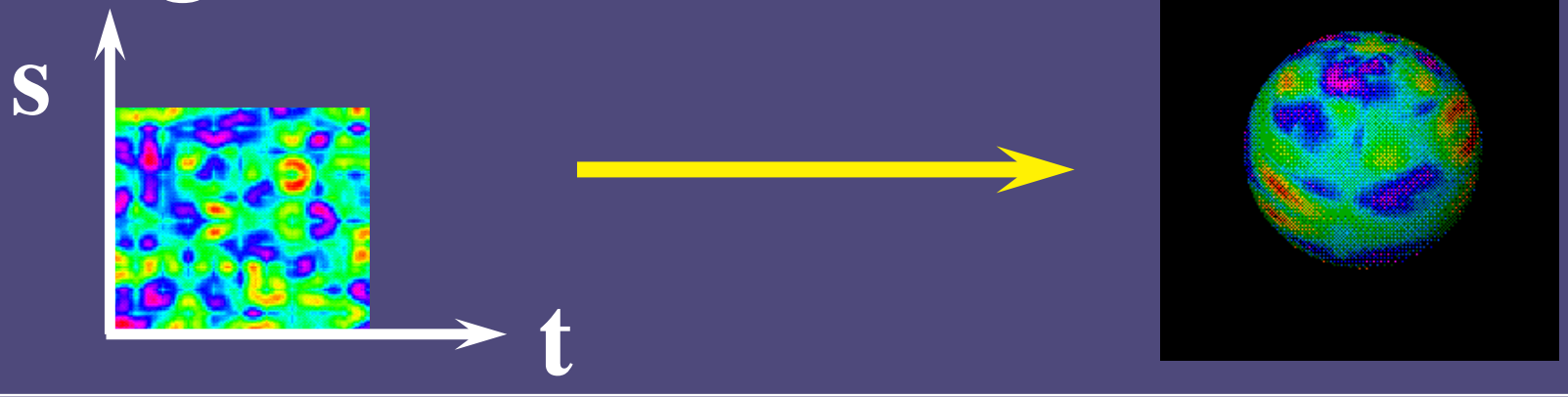
Force Shading: Haptic Smoothing



$$\vec{N}_s = \frac{\sum_i^3 A_i . \vec{N}_i}{\sum_i^3 A_i}$$

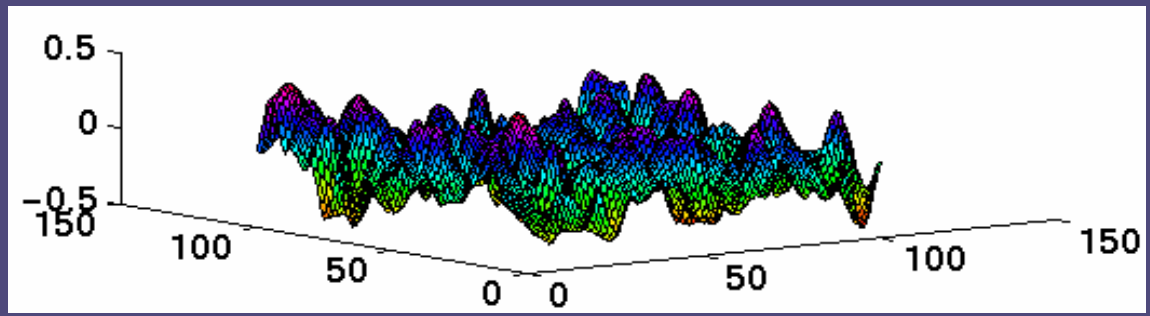
Haptic Texturing

- **image-based**



- **procedural**

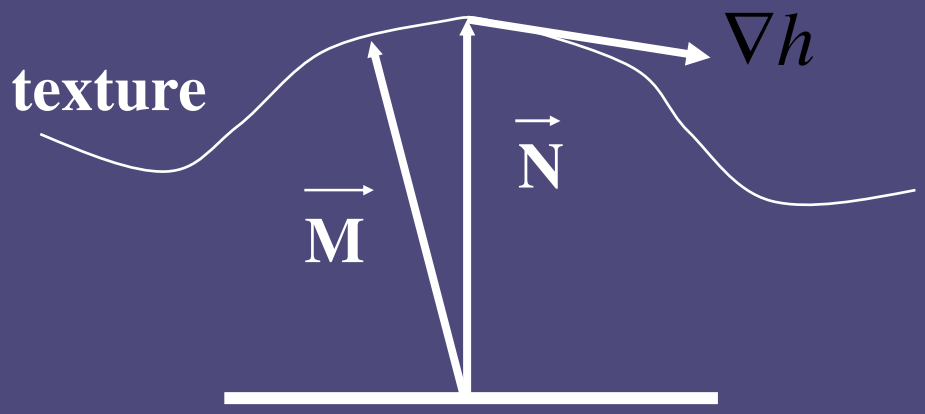
h(x,y,z)



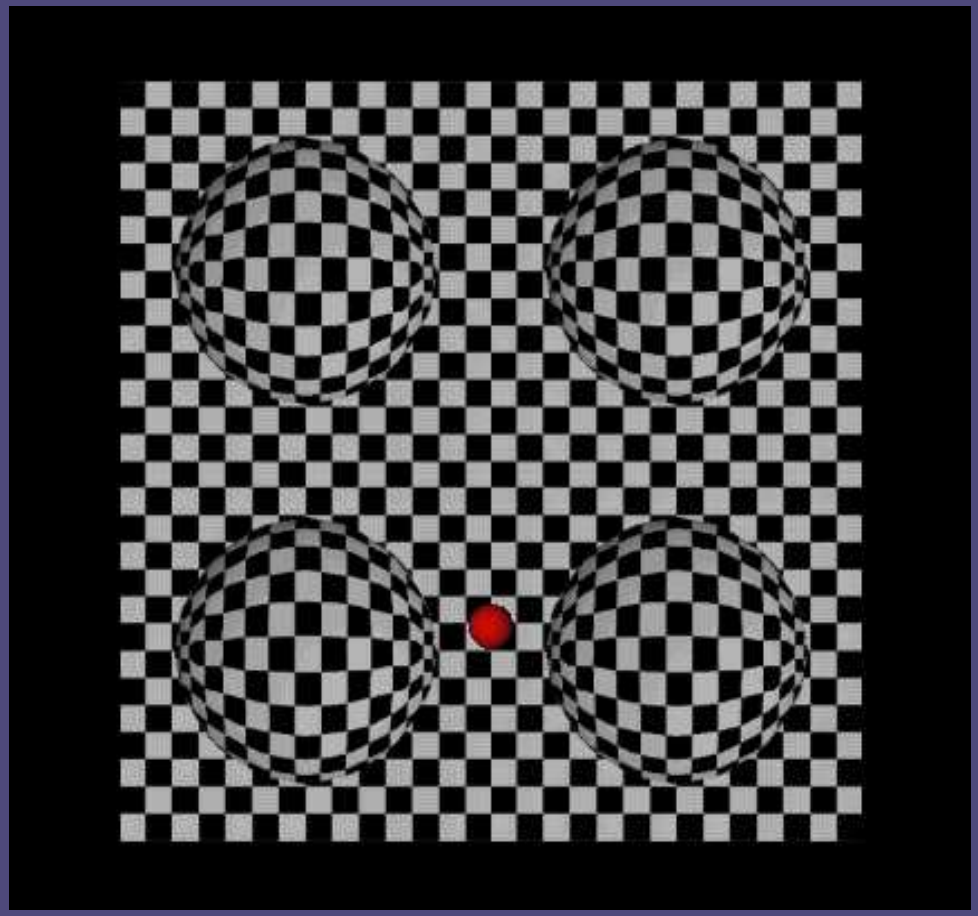
Haptic Texturing

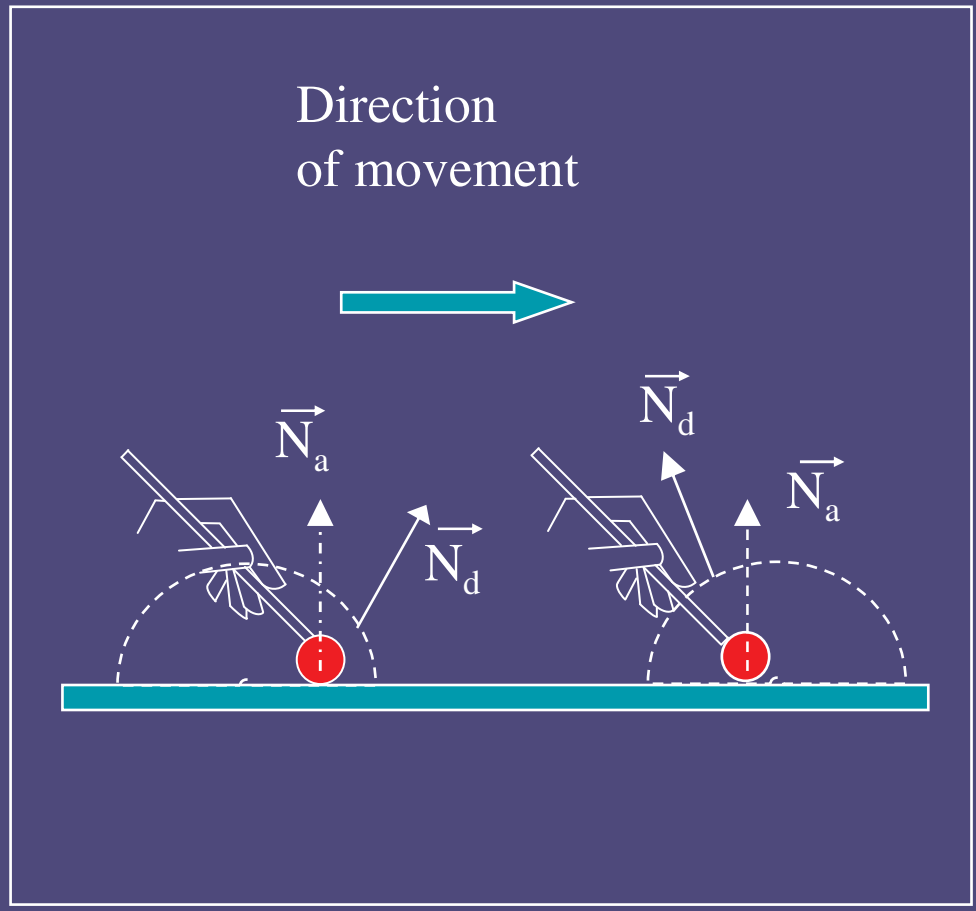
$$\vec{M} = \vec{N} - \nabla h + (\nabla h . \vec{N})\vec{N}$$

$$\nabla h = \frac{\partial h}{\partial x}\hat{i} + \frac{\partial h}{\partial y}\hat{j} + \frac{\partial h}{\partial z}\hat{k}$$



Visual-Haptic Illusion

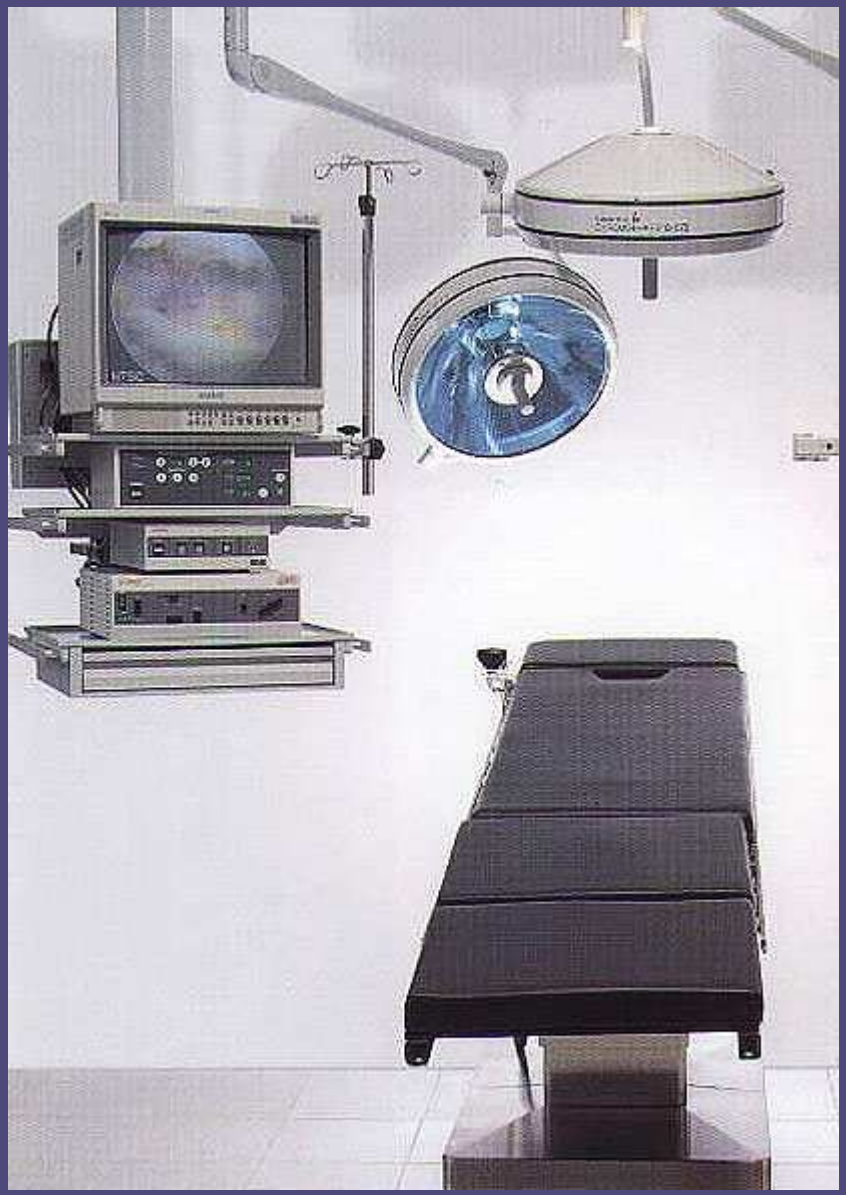


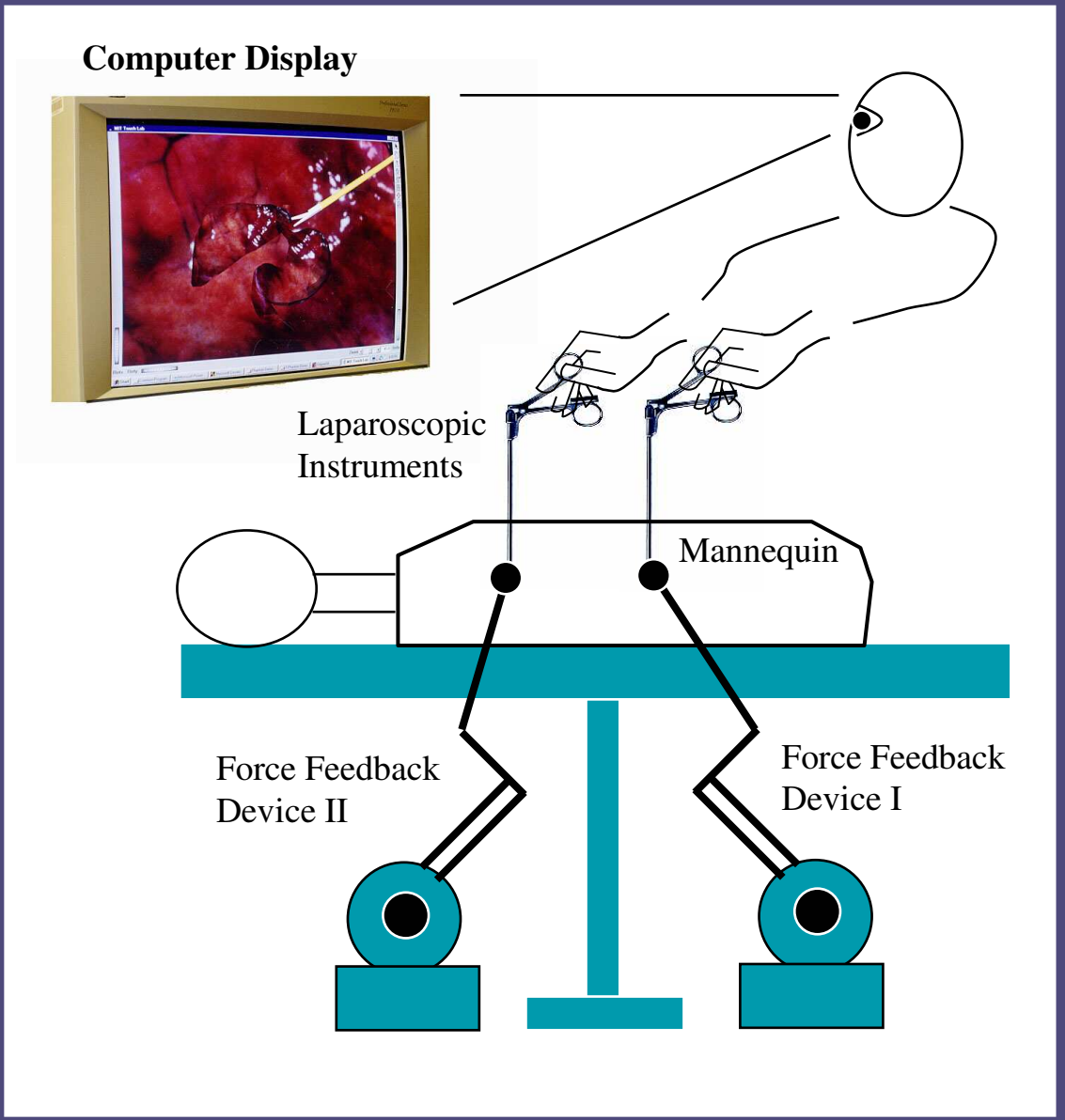


Part II. Applications/Experimental Studies:

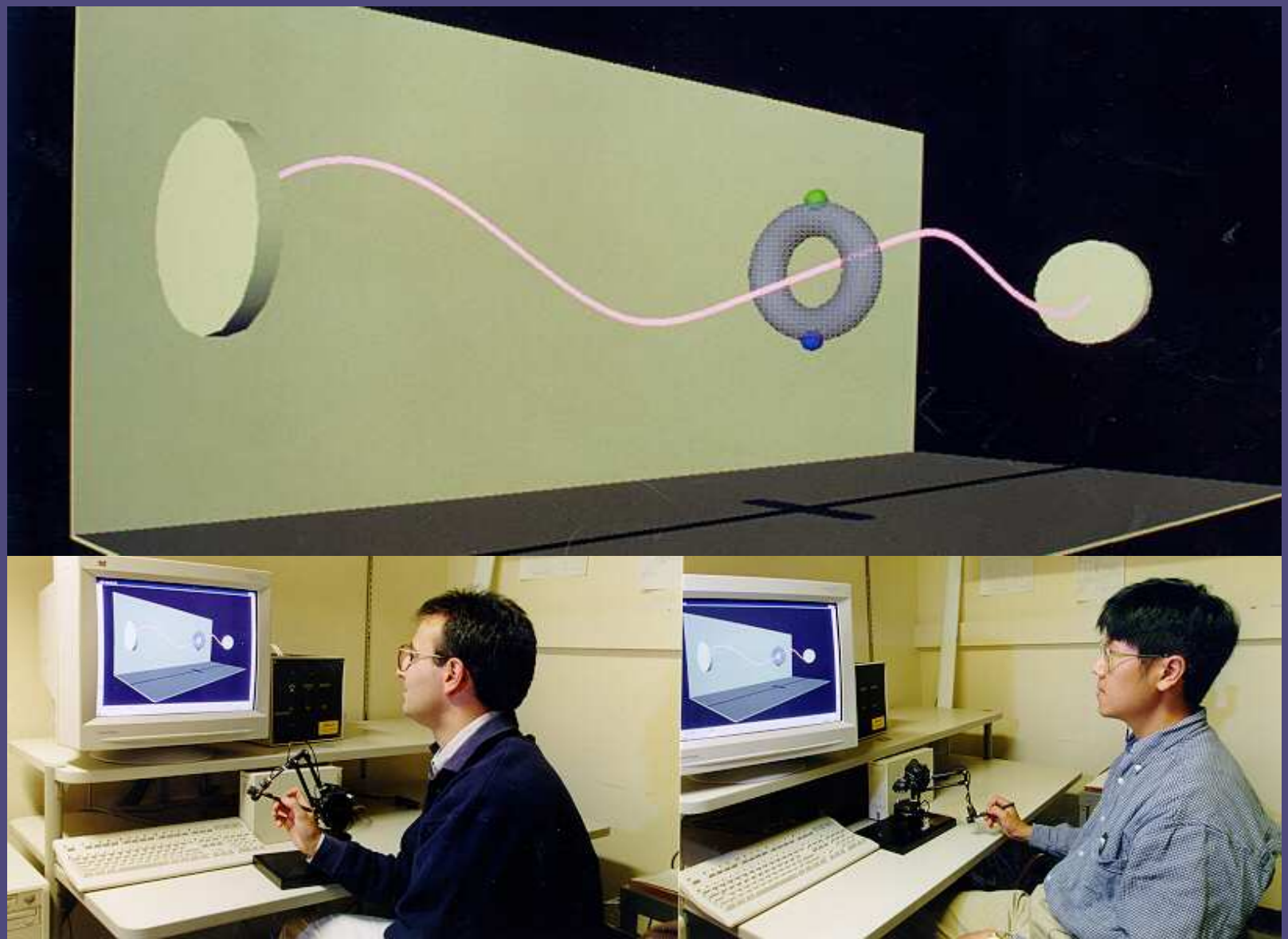
a. Surgical Simulation
b. Shared Virtual Environments
c. Human Perception and Cognition
d. Visualization

I. Simulation of Laparoscopic Procedures





II. Shared Virtual Environments:



Experimental Protocol

Conditions:

Condition I: visual and haptic feedback together

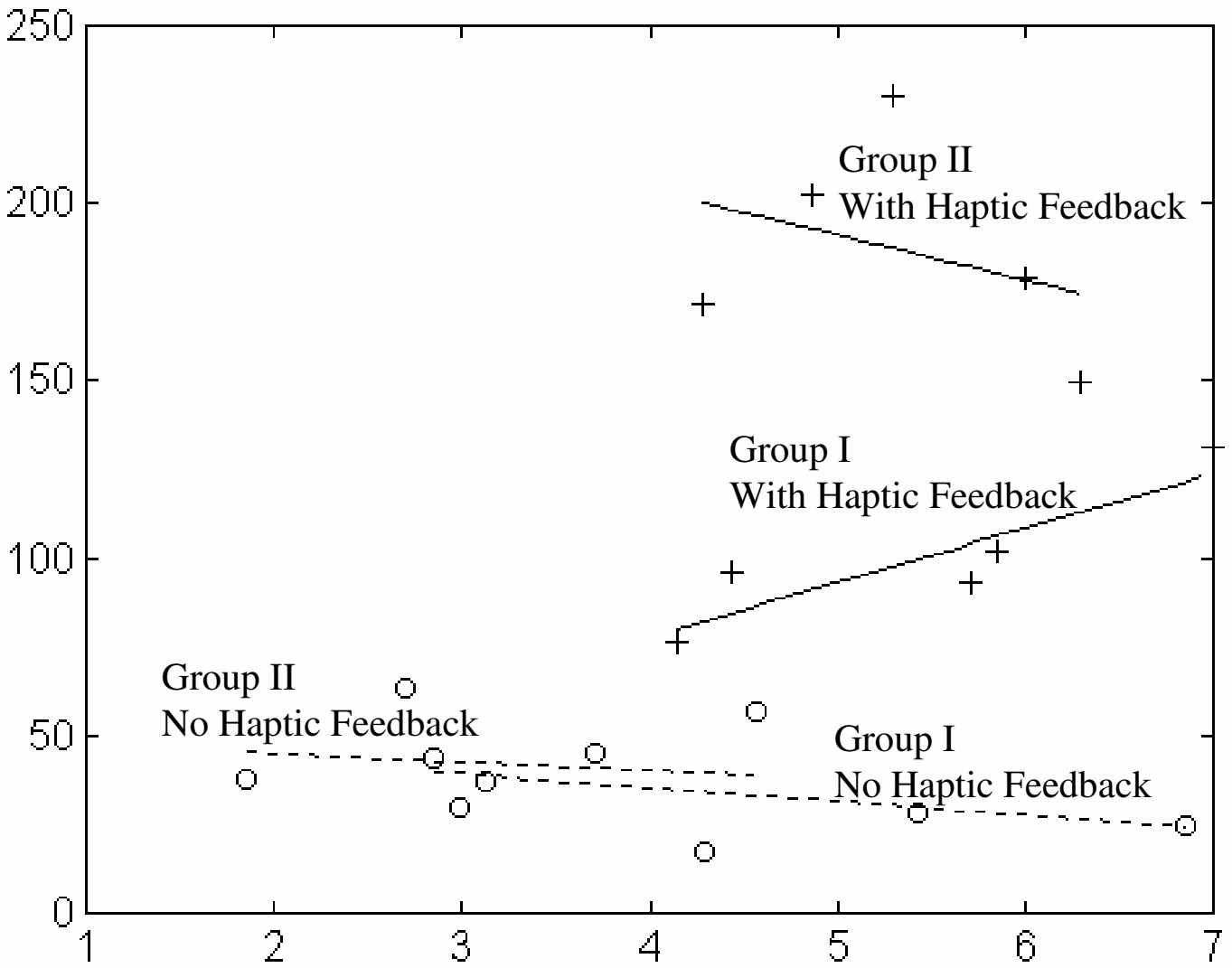
Condition II: visual feedback only

Order:

Group I	Condition I, Condition II
Group II	Condition II, Condition I

Number of Trials:

Subjects repeated the experiment at least 10 times for each condition


Performance Measure
250
200
150
100
50
0
1
2
3
4
5
6
7
Group II
With Haptic Feedback
Group I
With Haptic Feedback
Group II
No Haptic Feedback
Group I
No Haptic Feedback
Subjective Measure

Some Observations

- Social aspects seem to play an important role in SVEs.

  Some of the subjects did not want to meet with their remote partner because they felt that they did not perform well and did not want to get embarrassed.

  One subject indicated that the red color generated a stress on him.

- Haptic feedback may be useful in understanding the (1) emotional feelings and (2) personality characteristics of a remote partner in SVEs.

  Most of the subjects associated "force feedback + expert behavior" with male gender, power, self-confidence, and aggressiveness. When there was no feedback, they were less sure, but they thought that they were playing with a patient female.

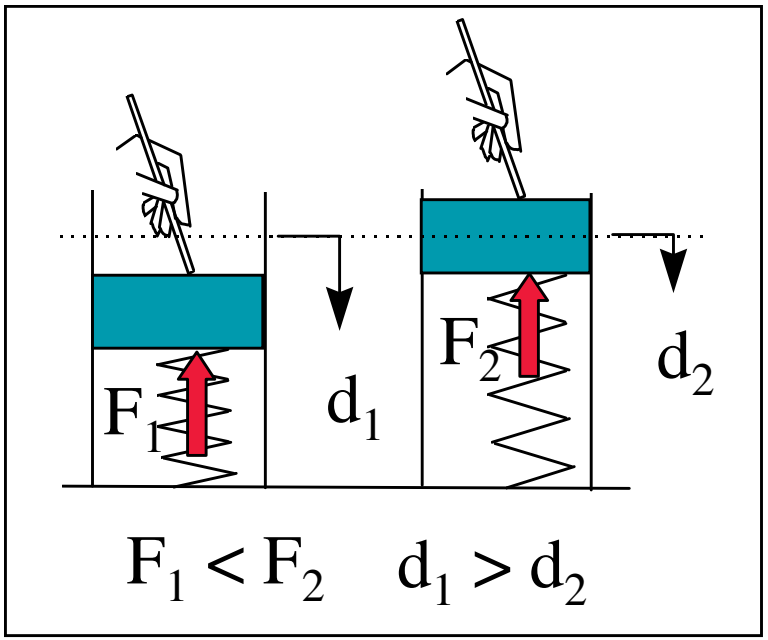
- Vibratory feedback may be helpful as a way of communication in SVEs.

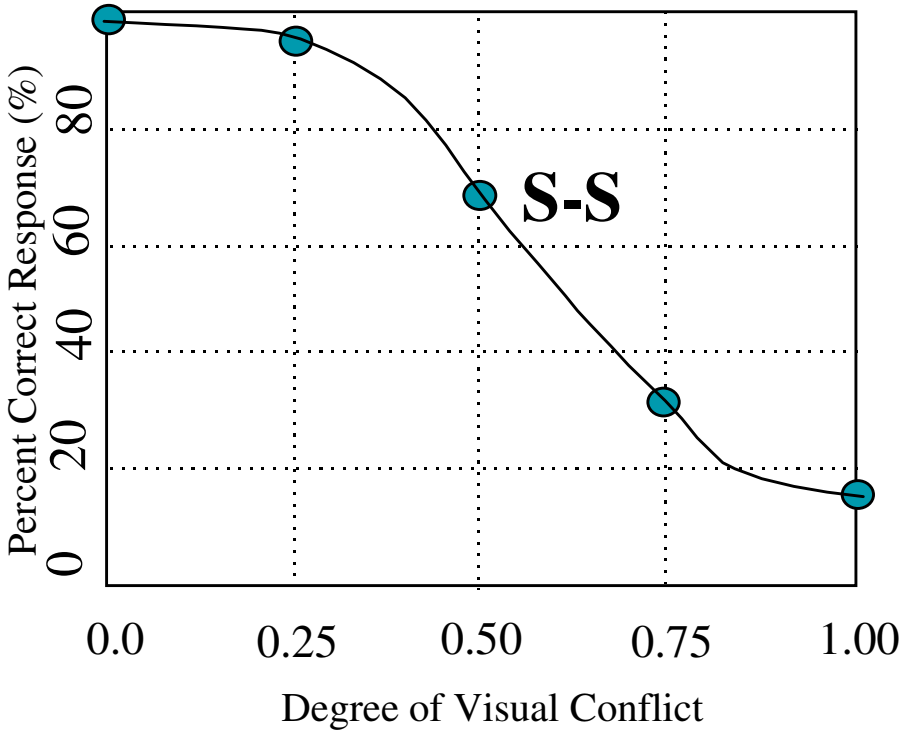
  One subject opted to shake the ring to inform/warn his partner of an error.

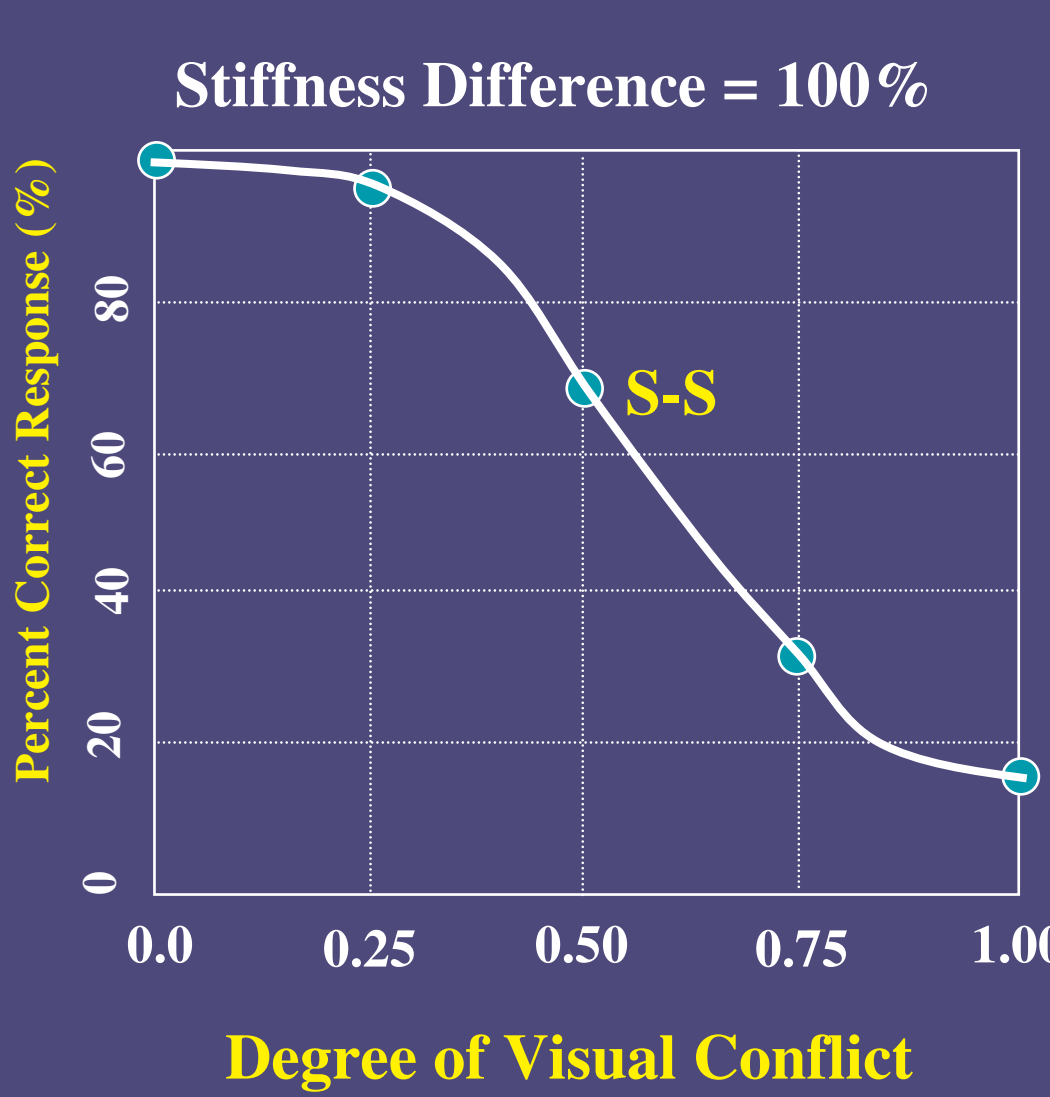
- Some subjects emphasized the lack of verbal communication and visual depth cues, especially when there is only visual feedback provided to them.

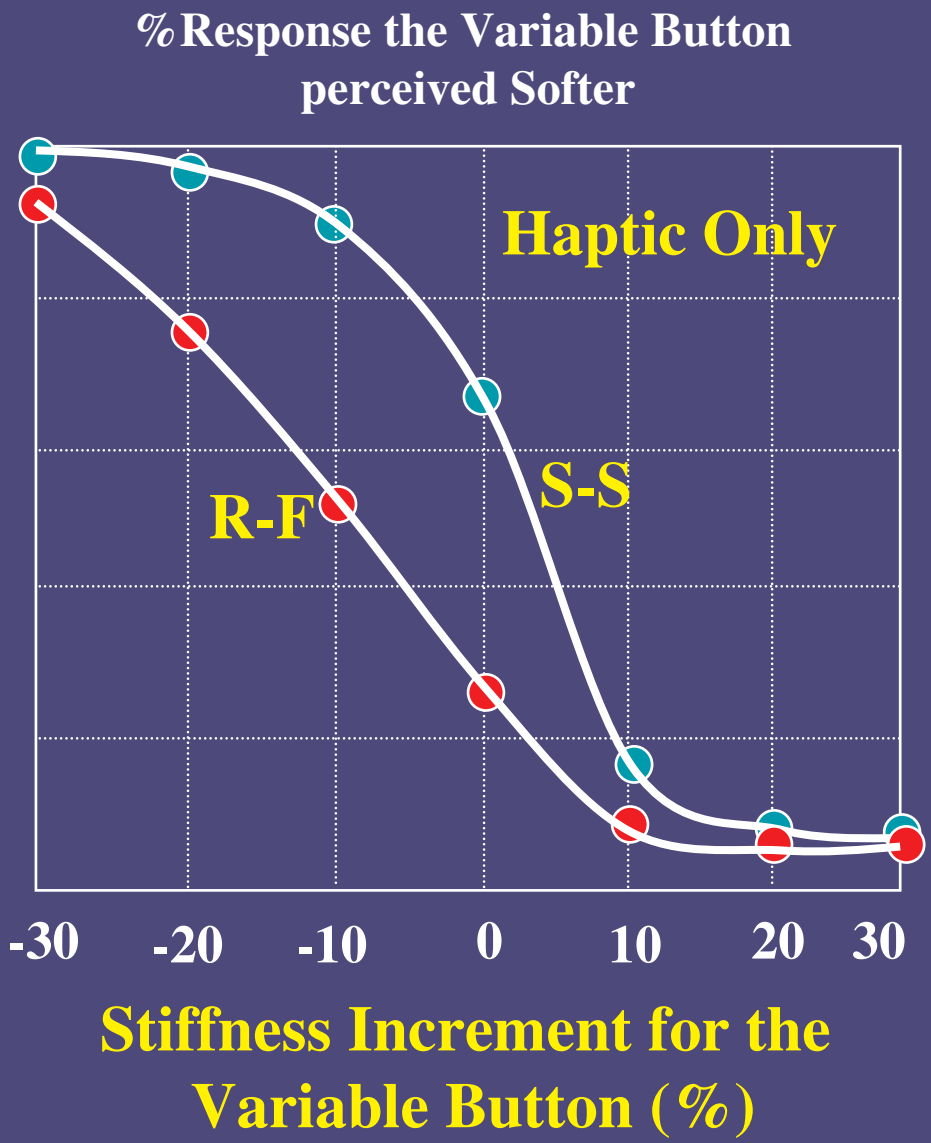
- Most subjects felt that they were playing with another human being instead of a computer, especially when there is a force feedback, though they did not know why they felt that way. Some reported the quick response of the remote partner and the "*realness*" of the negotiations that took place with the remote partner.

III. Human Perception and Cognitive Performance






Stiffness Difference = 100%
Percent Correct Response (%)
0
20
40
60
80
S-S
0.0
0.25
0.50
0.75
1.00
Degree of Visual Conflict


% Response the Variable Button perceived Softer
Haptic Only
S-S
R-F
-30
-20
-10
0
10
20
30
Stiffness Increment for the Variable Button (%)

IV. Haptic Visualization of Martian Rocks