Introduction to Haptic Rendering

Cagatay Basdogan, Ph.D

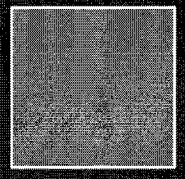
JPL - Virtual Environments Laboratory
California Institute of Technology
(http://eis.jpl.nasa.gov/~basdogan)

Haptic (adj.):

related to the sense of touch.

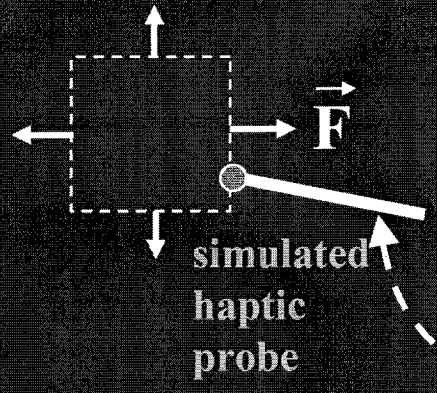
Graphical Rendering:

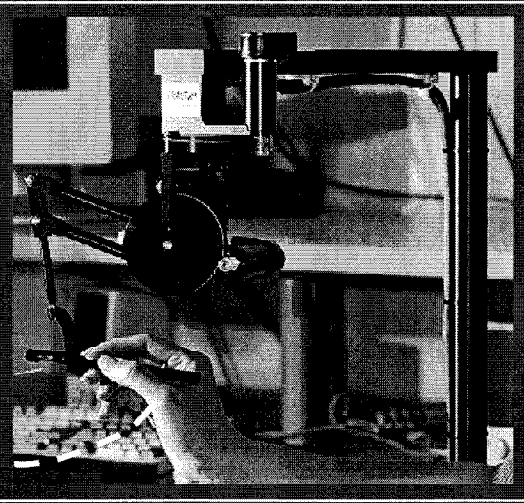
process of displaying synthetically generated 2D/3D visual stimuli to the user



Haptic Rendering:

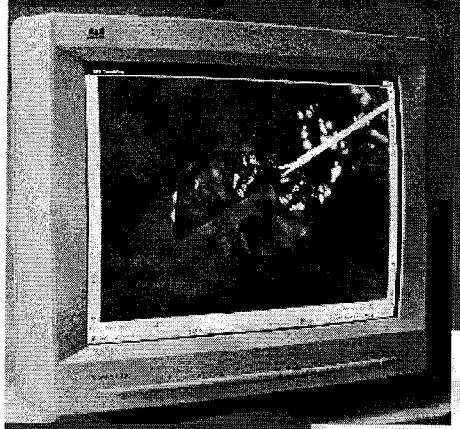
process of displaying synthetically generated 2D/3D haptic stimuli to the user

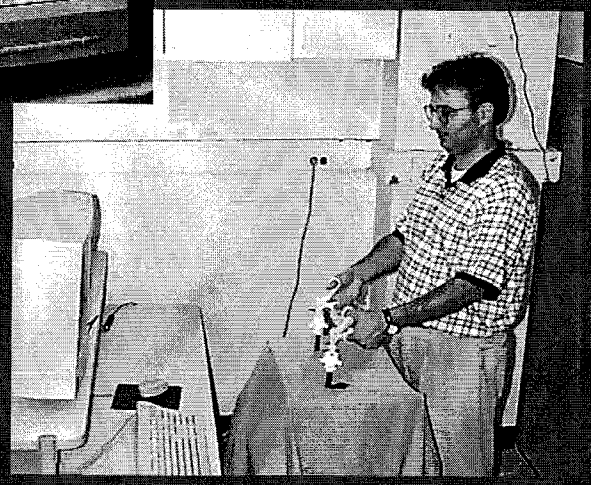




***Haptic Interface*: device for touch interaction in real and virtual worlds**

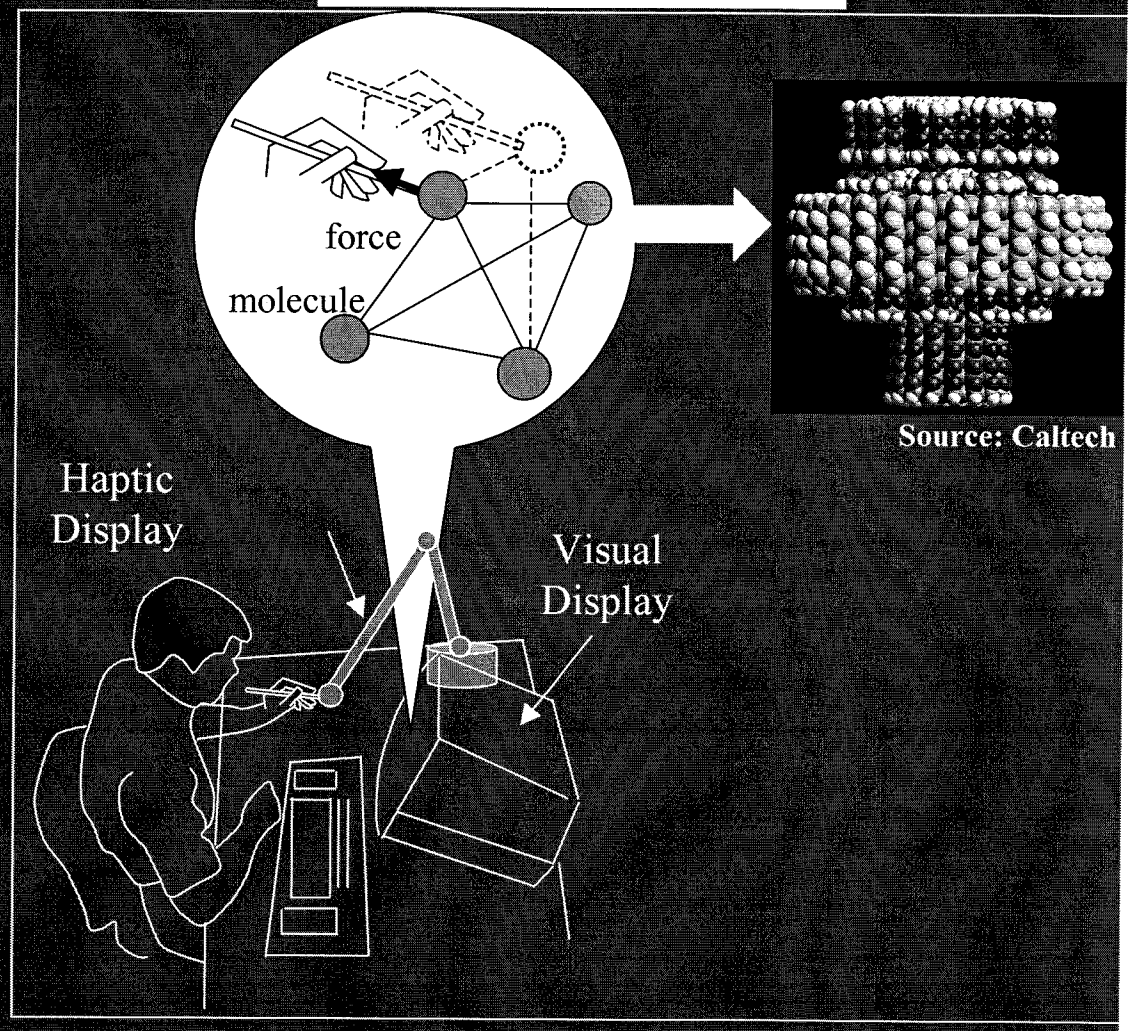
Applications





Haptic Feedback for Medical Simulation and Training

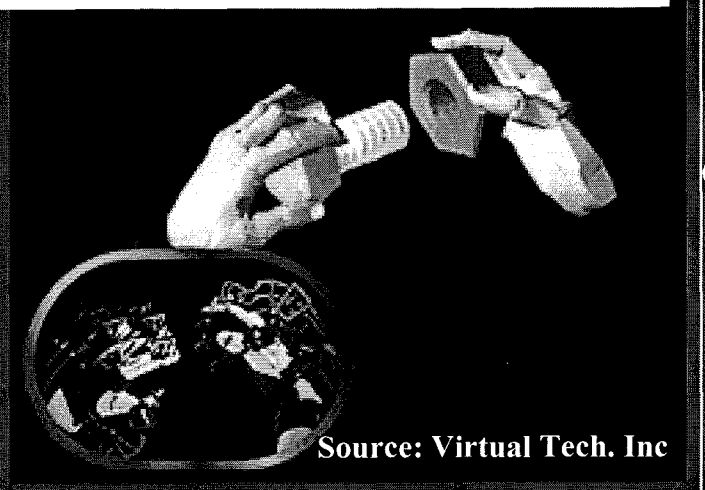
Haptic Feedback for Molecular Simulation



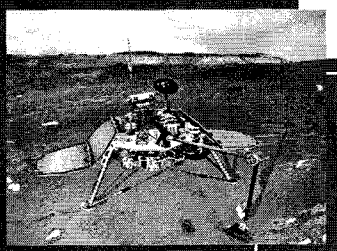
Source: Caltech

Applications

Haptic Feedback for Collaborative Engineering Design

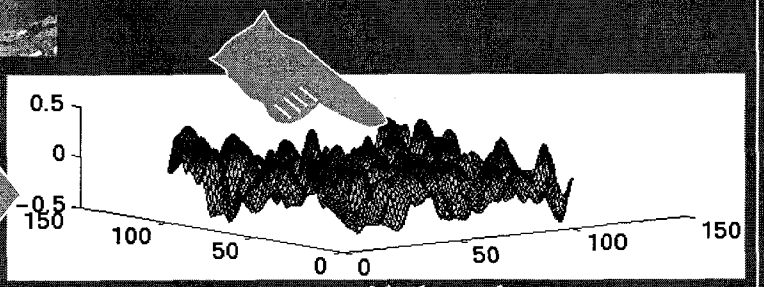


Haptic Visualization



collected data

haptic display

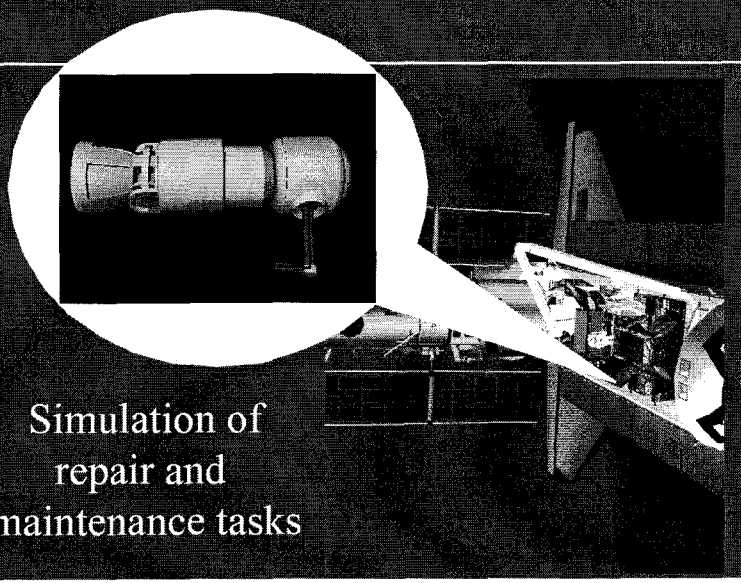


tangible data

Tangible Interfaces

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

Haptic User Interface (HUI)

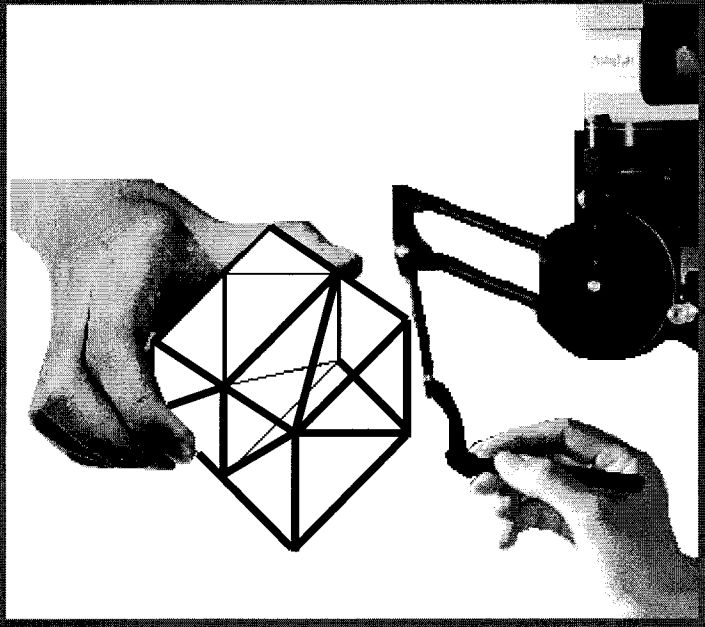


Simulation of repair and maintenance tasks

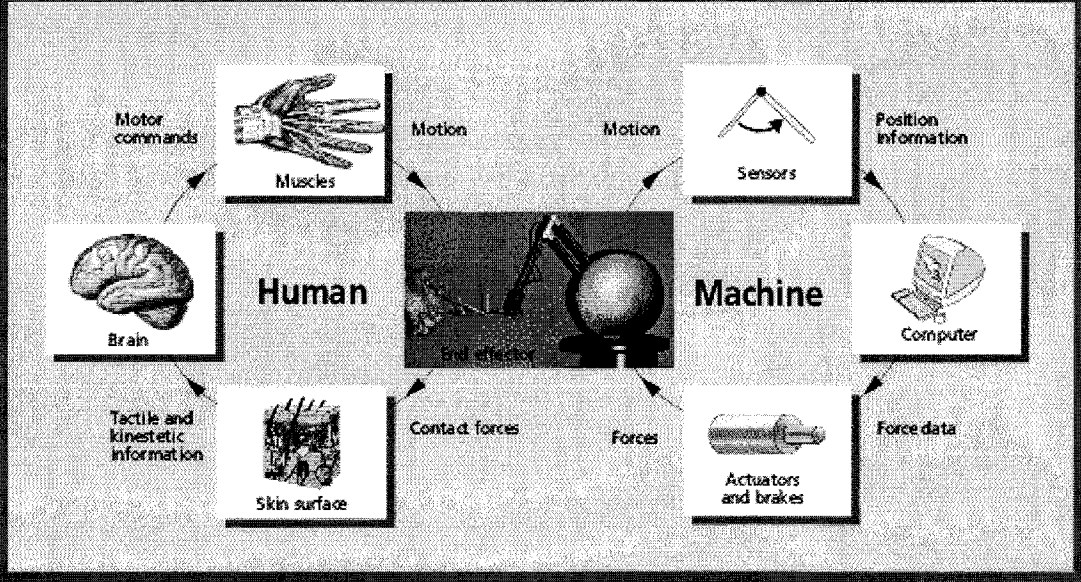
Haptic Feedback for Crew Training

Human vs Machine Haptics:

Human Haptics



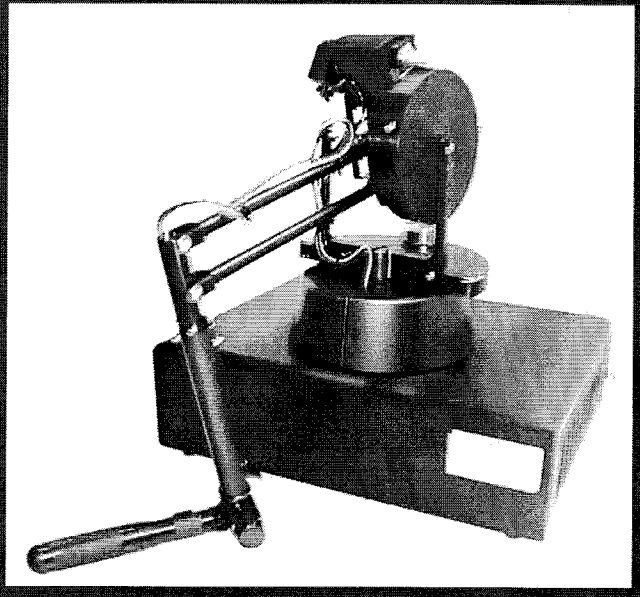
Machine Haptics



Machine Haptics:

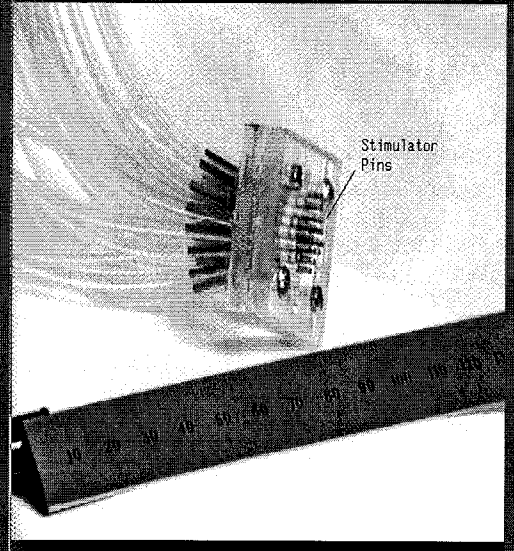
Types of Haptic Devices

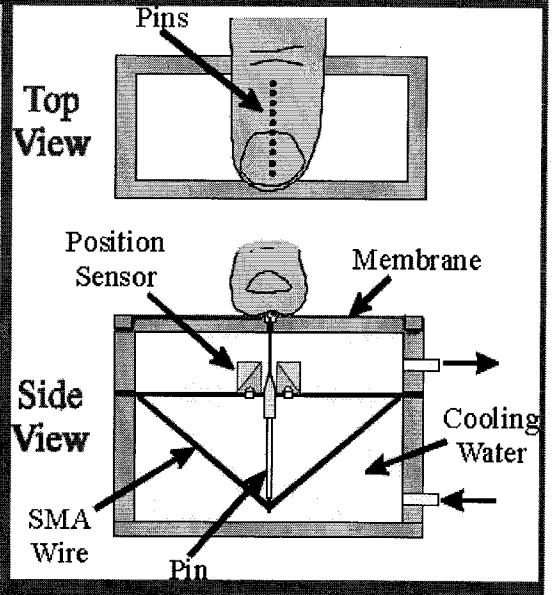
Net Force Displays



Source: Sensable Tech. Inc

Tactile Displays

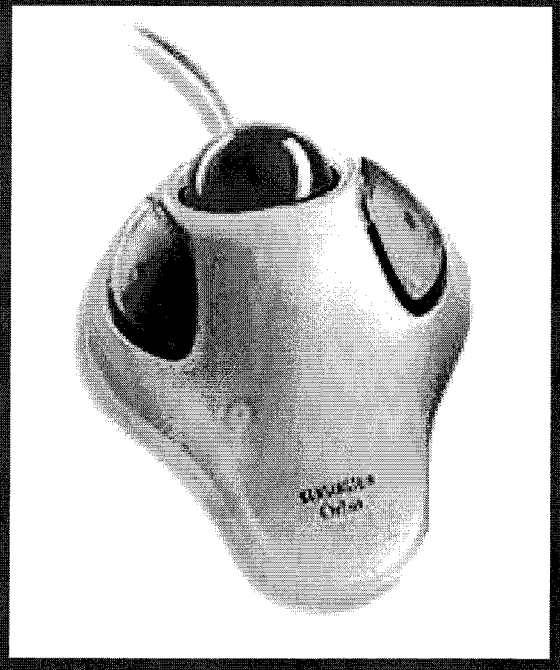




Source: R. Howe, Harvard University

Types of Haptic Devices

Passive



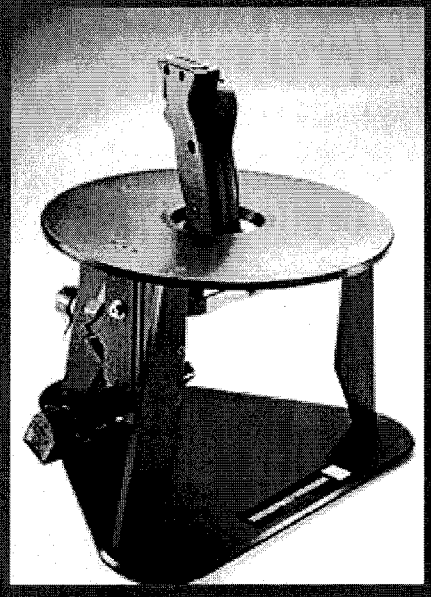
keyboard, trackball, mice, etc.

Active

Source: Sensable Tech. Inc.

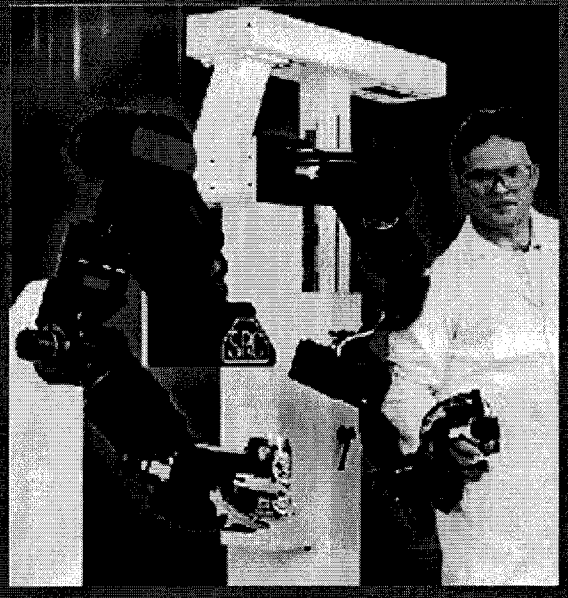
Types of Haptic Devices

Grounded



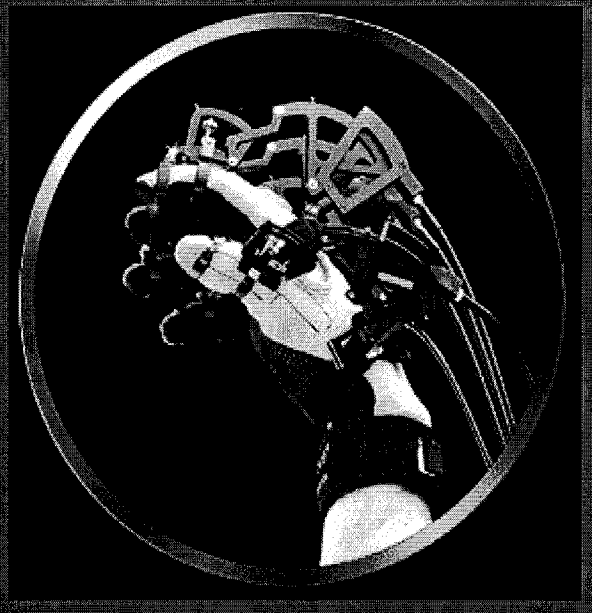
Source: Immersion Corp.

combined



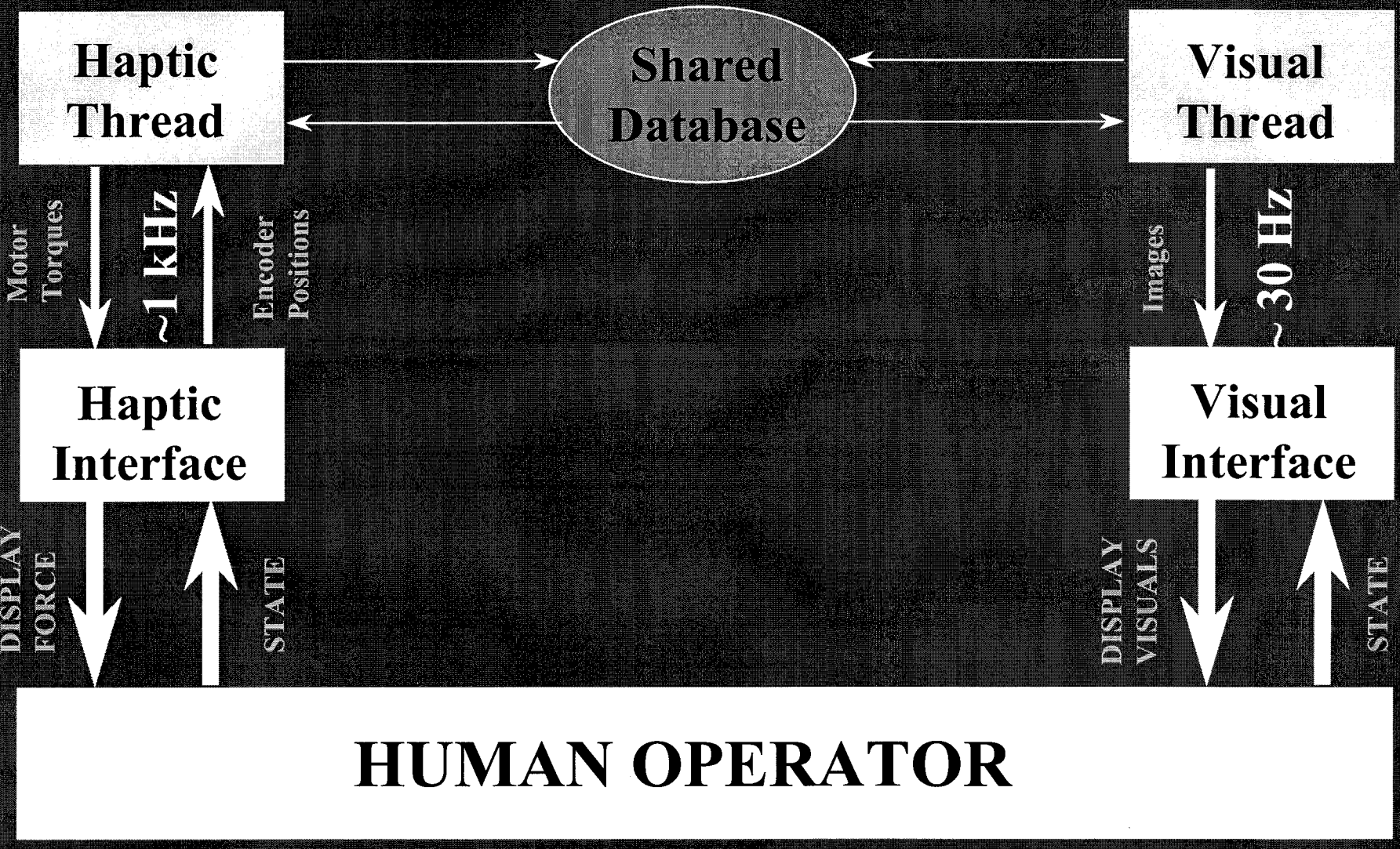
Source: Sarcos Corp.

Attached

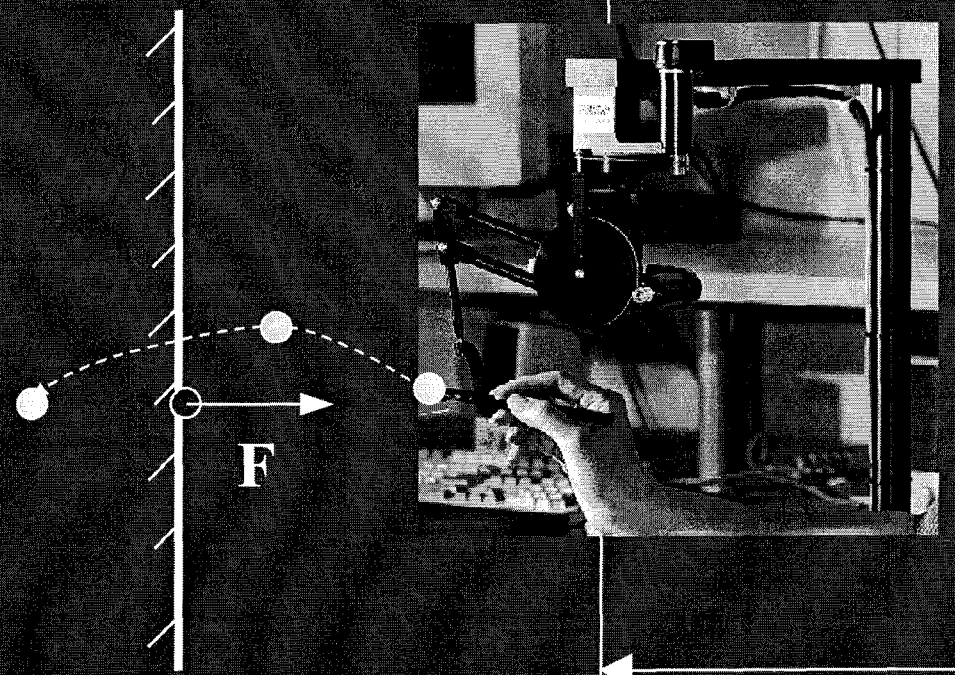


Source: Virtual Tech. Inc.

Integration of Vision and Touch



Haptic Rendering with a Force Display



Position
Orientation

Collision
Detection

Contact
Information

Collision
Response

Force
Torque

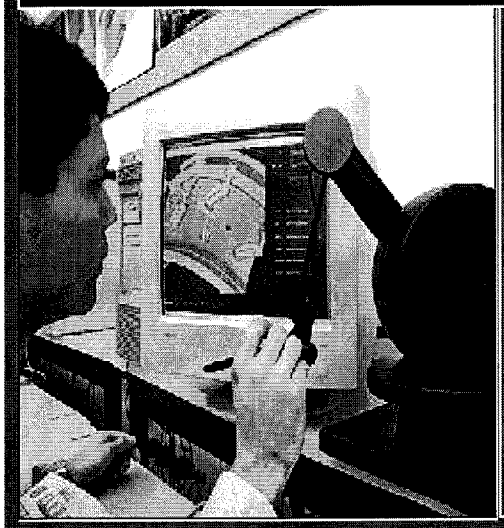
Object
Database

Geometry

Material

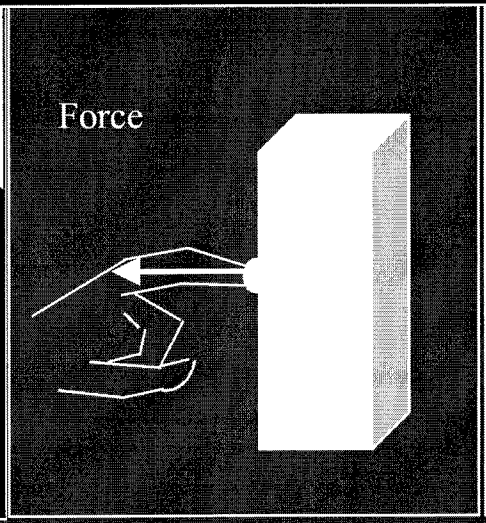
Types of Haptic Interactions with 3D Objects:

a



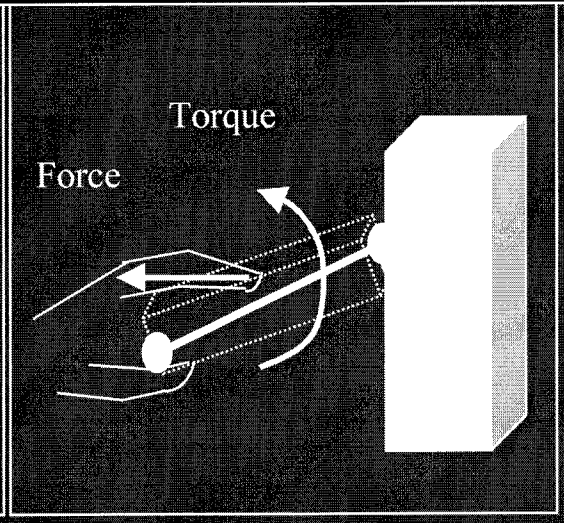
Source: R. Avila, GE Corp.

b



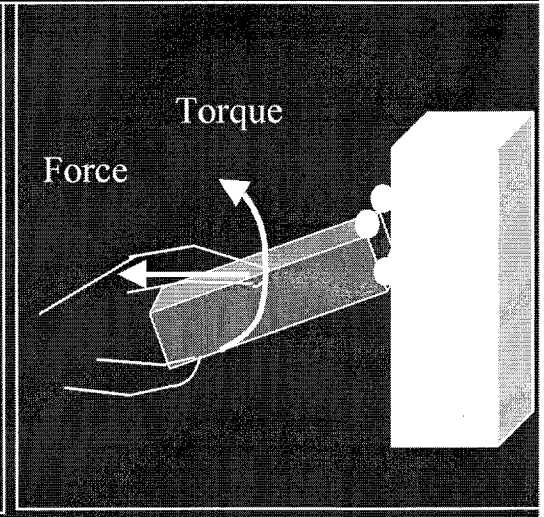
Point-Object

c



Line Segment-Object

d

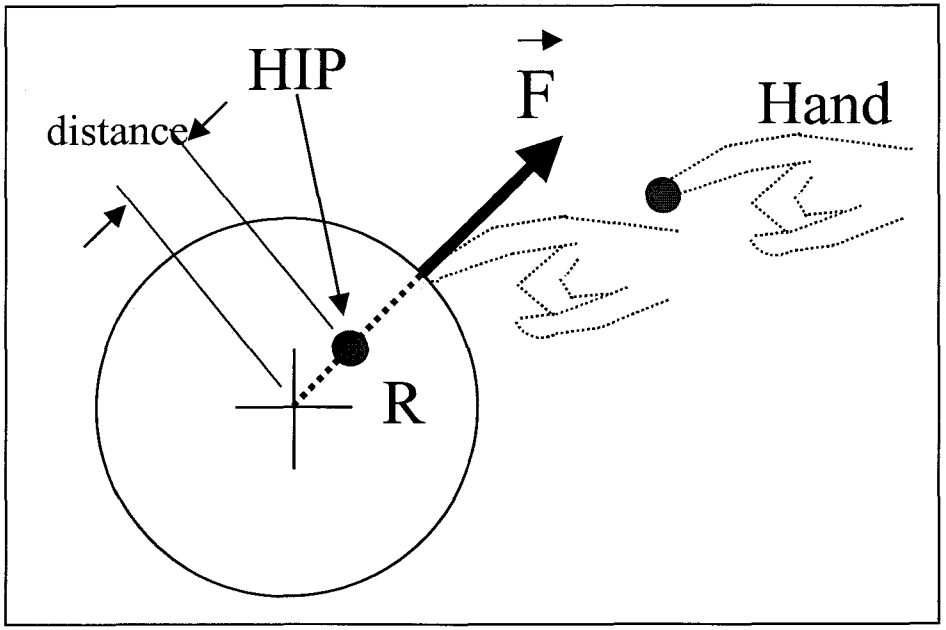


Object-Object

more computation

Haptic Rendering Of 3D Geometric Primitives

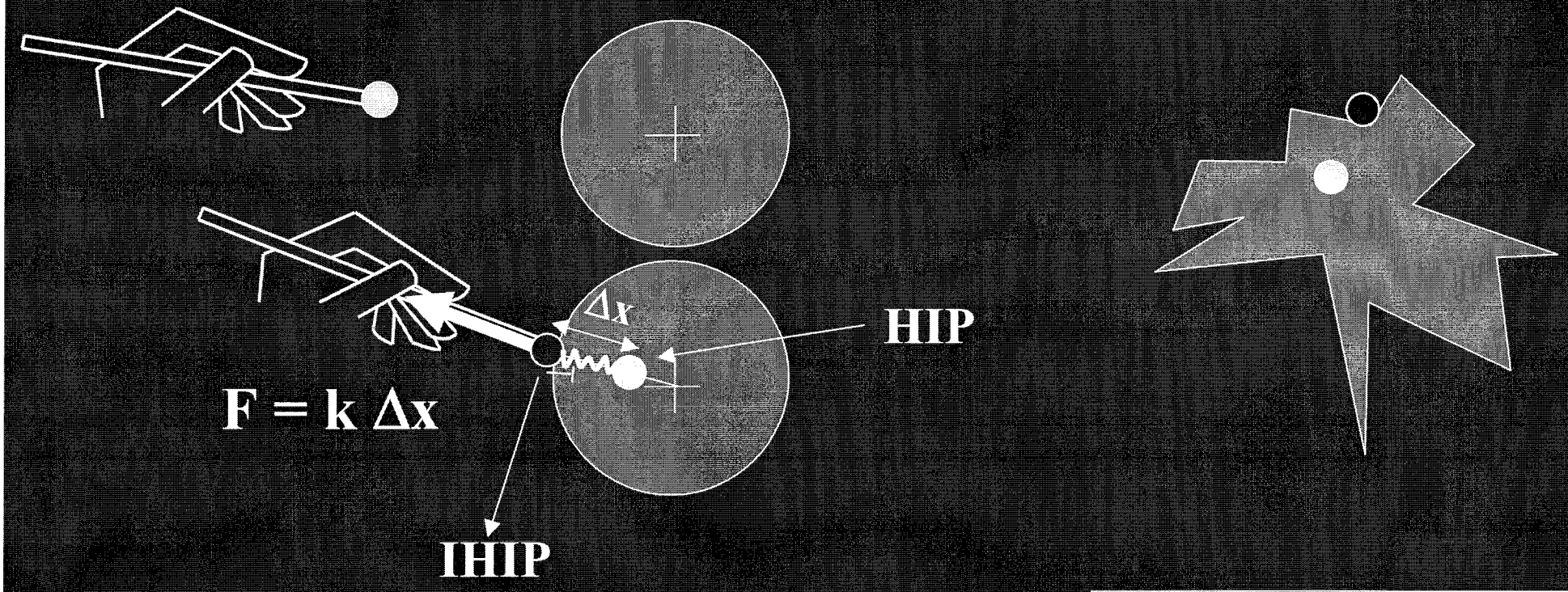
(point-object interaction)




```
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 Objects

(point-object interaction)



$$F = k\,\Delta x$$

3D Primitives
no problem !

?

3D Object
- optimization
- rule-based techniques

Modeling Choices for 3D Object Representation

(point-object interaction)

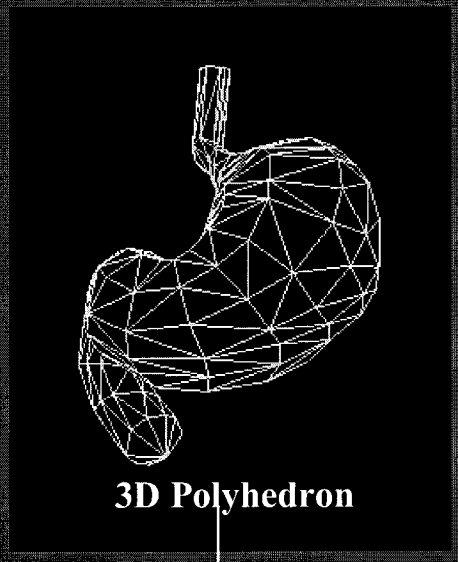
will be covered in this tutorial

- polygonal
- implicit
- NURBS
- voxel

see my notes for related references

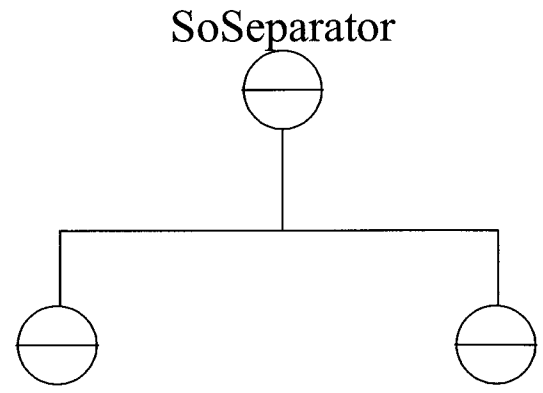
Representation of a 3D Polyhedron

Database



Polygon
Neighbors
Edge **Vertex**

Edge **Vertex**



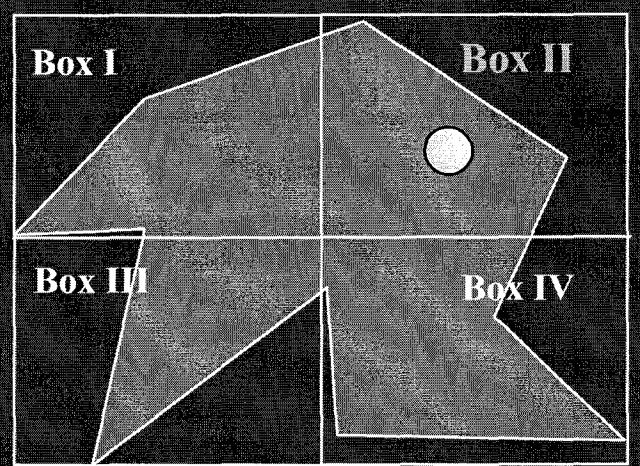
	X	Y	Z
0	-5.0	2.0	1.0
1	1.0	6.0	-3.0
2	4.0	2.0	-2.0
...	...	...	...

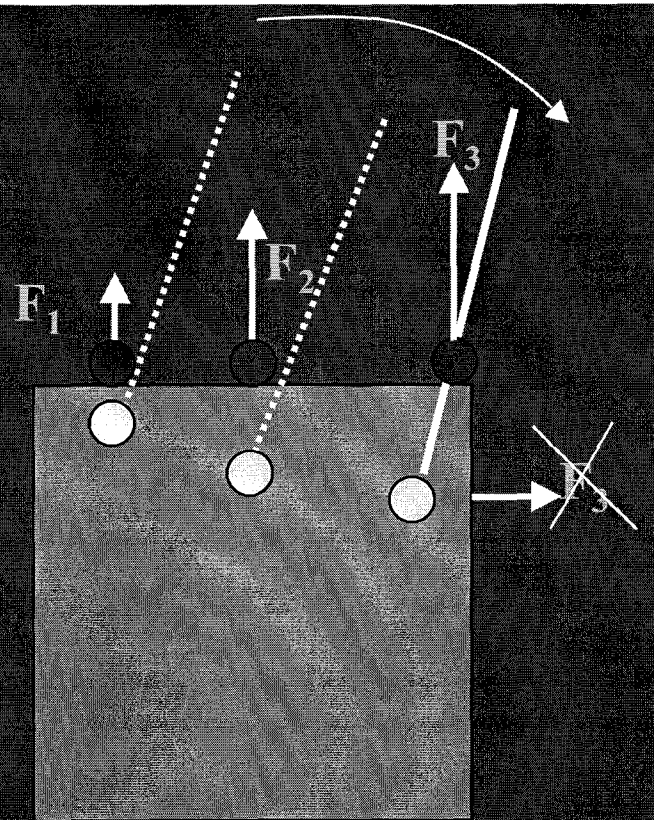
0	1	4	0
1	7	3	6
2	5	1	2
...	...	...	...

Open Inventor/VRML file

Key Components of the Rendering Algorithm

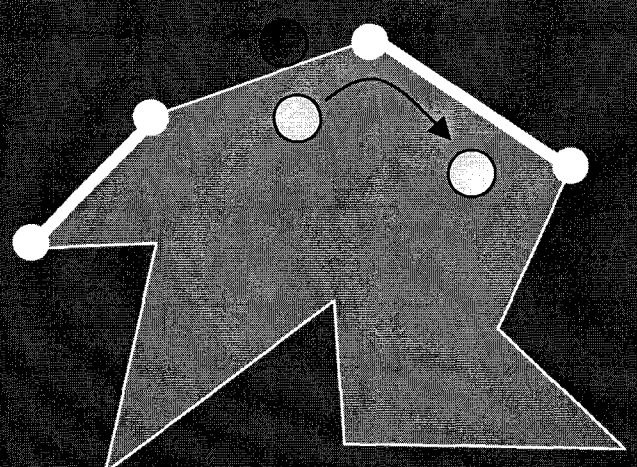
1) Bounding-box hierarchy



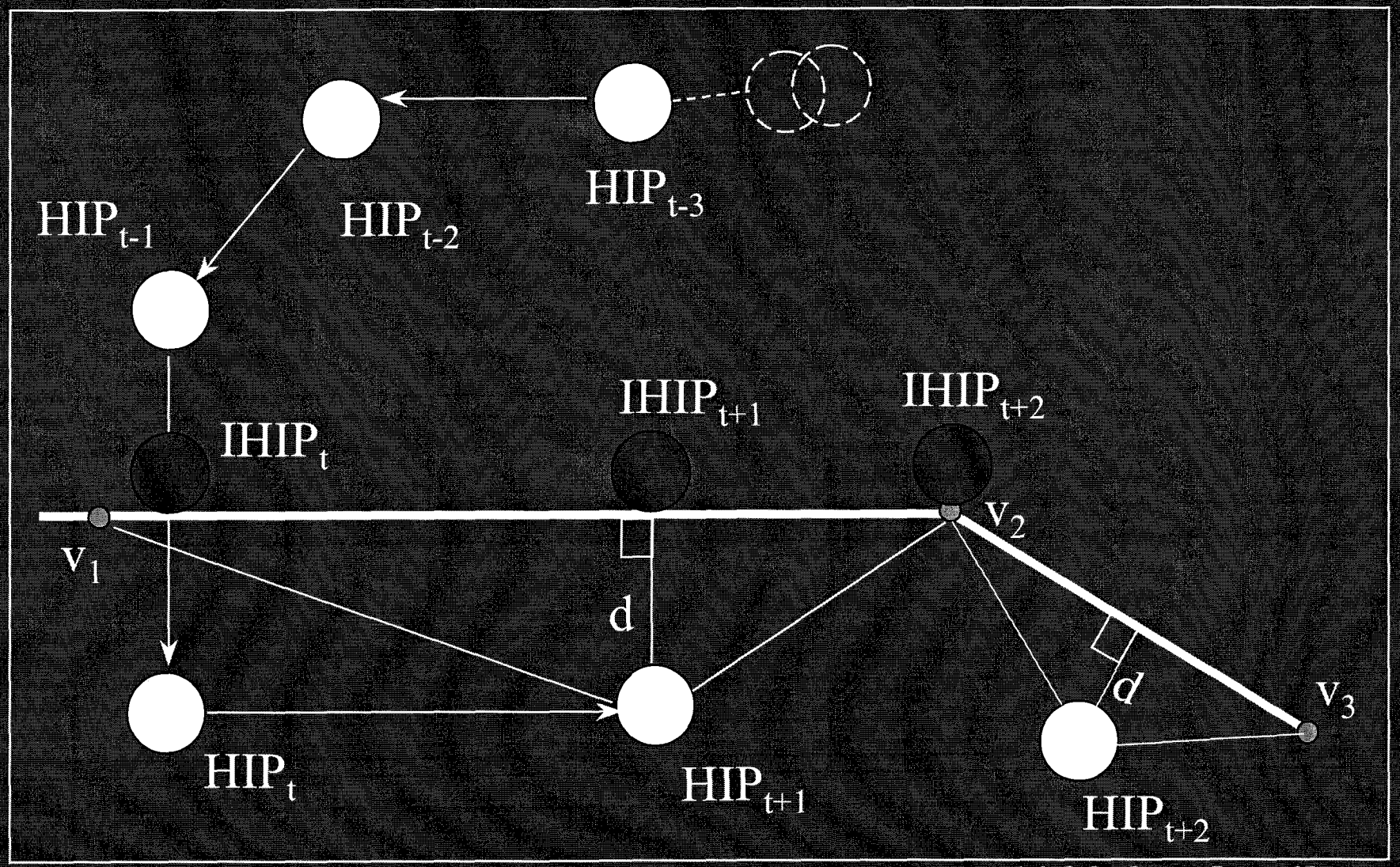


2) Contact history

3) Local coherence



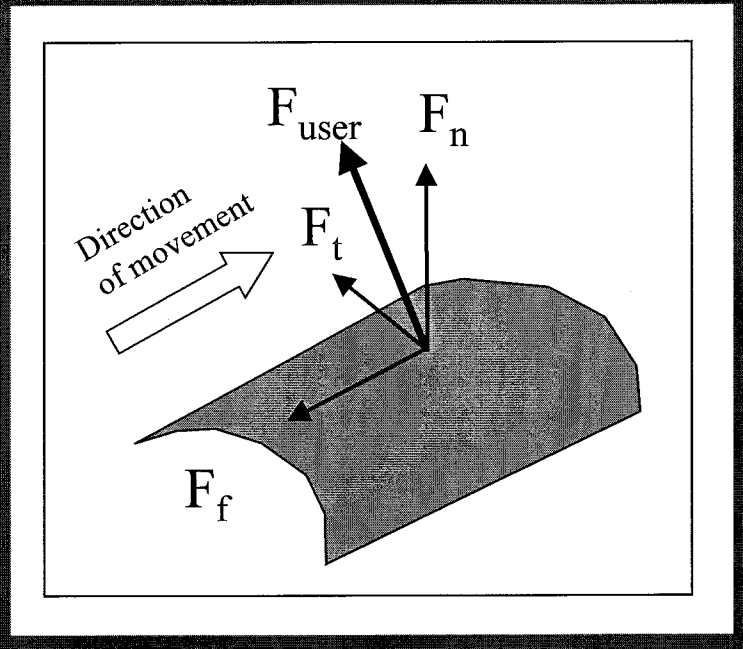
Haptic Rendering of Polygonal Surfaces

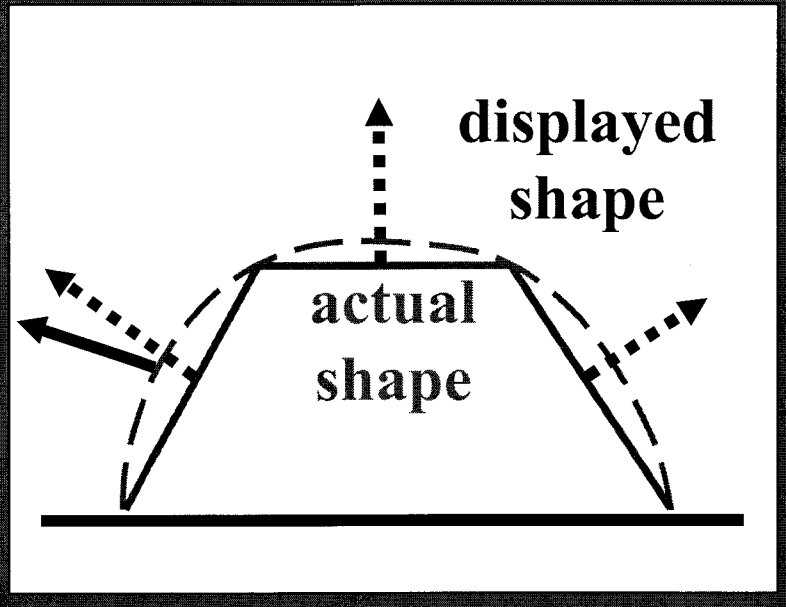


see Ho et al., 1999 for details

Haptic Display of Surface Details

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

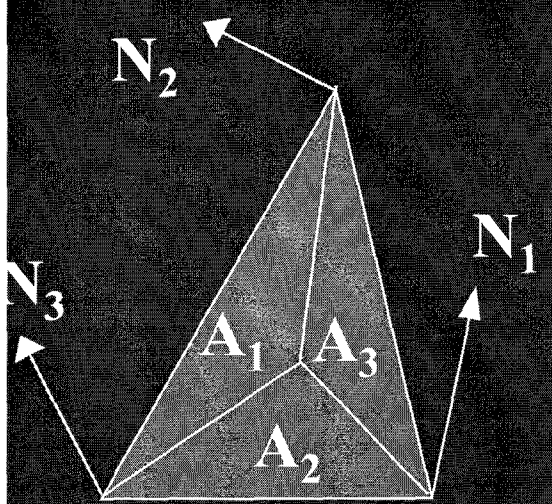




Common Principle: Perturbation of force vector !

Force Shading

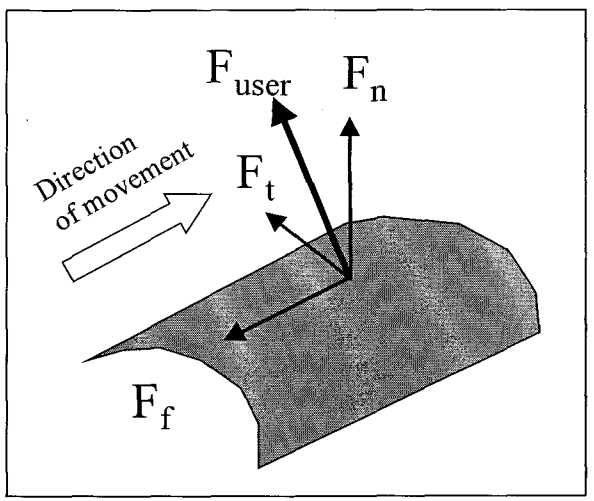
ref: Phong Shading



$$\overset{\updownarrow}{N_s} = \frac{\sum_i^3 A_i . \overset{\updownarrow}{N_i}}{\sum_i^3 A_i}$$

Friction

ref: Mechanics books

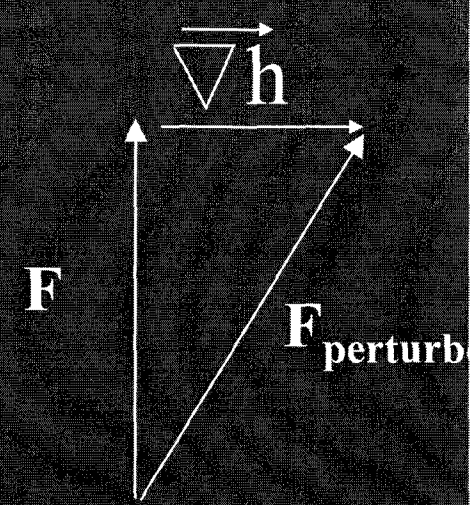


Texture

ref: Bump Mapping

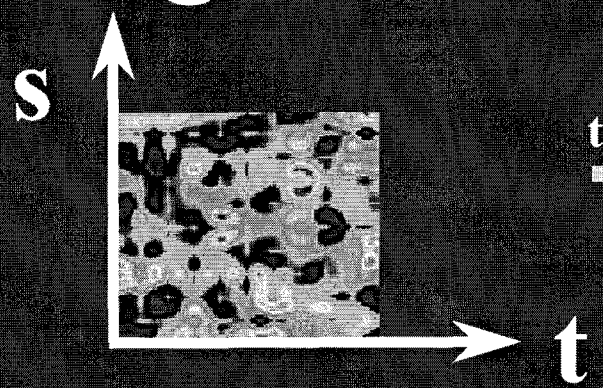
$$\nabla h = \frac{\partial h}{\partial x}\hat{i} + \frac{\partial h}{\partial y}\hat{j} + \frac{\partial h}{\partial z}\hat{k}$$

h(x,y,z) : texture field



Haptic Texturing

- **image-based**



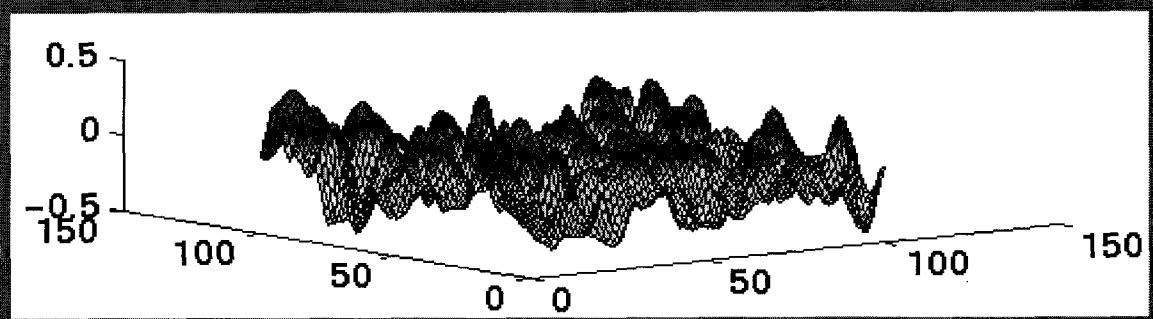
two-stage mapping

Bier & Sloan, 1986

- **procedural**

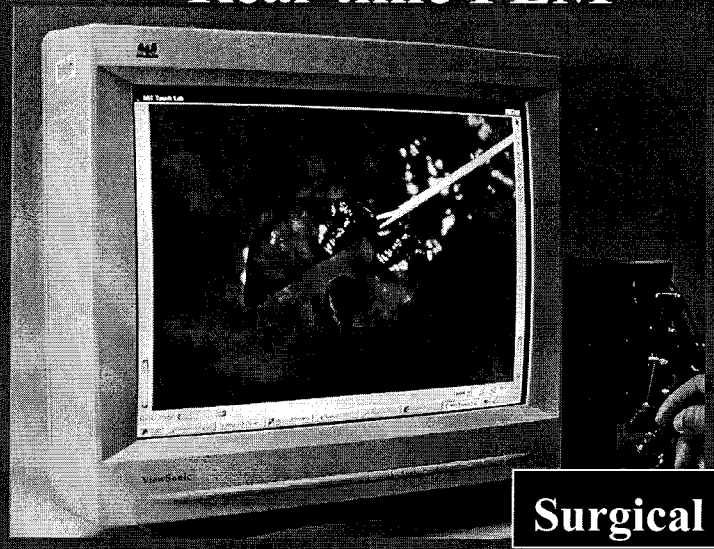
h(x,y,z) $\xrightarrow{\text{bump mapping}}$

Blinn, 1978;
Max and Becker, 1994



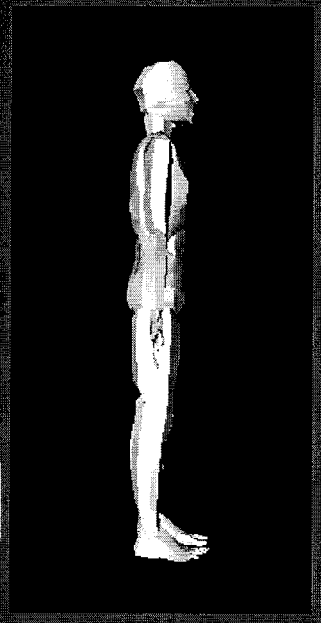
Force-Reflecting Deformable Models:

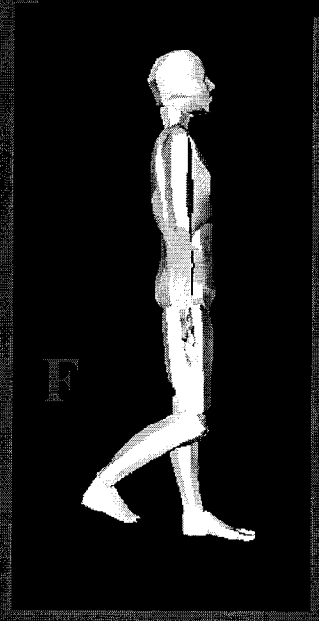
Real-time FEM

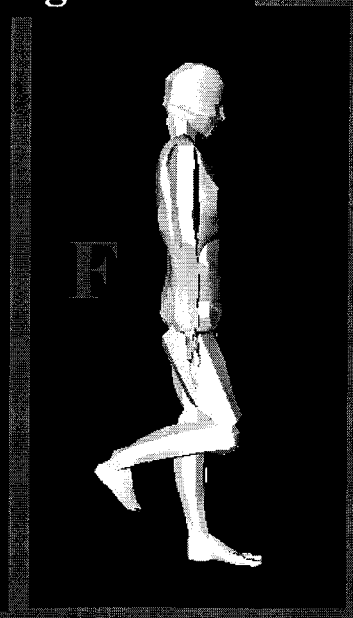


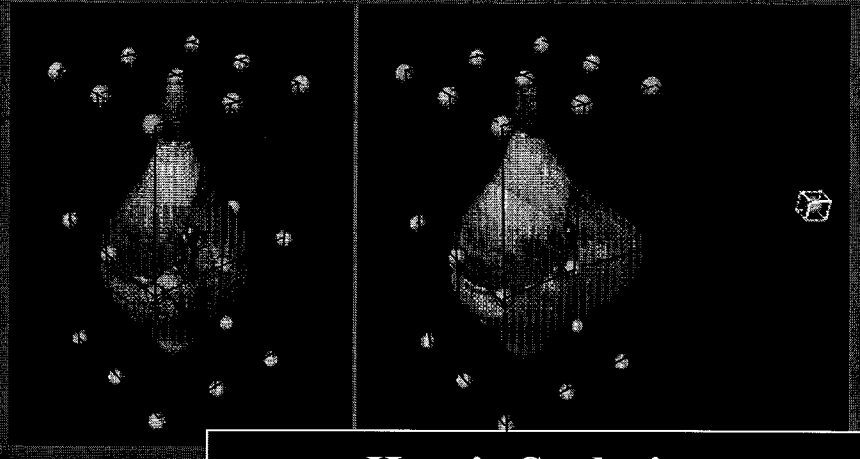
Surgical Simulation

Animation/Ergonomics



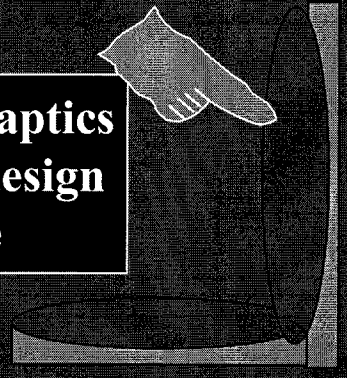






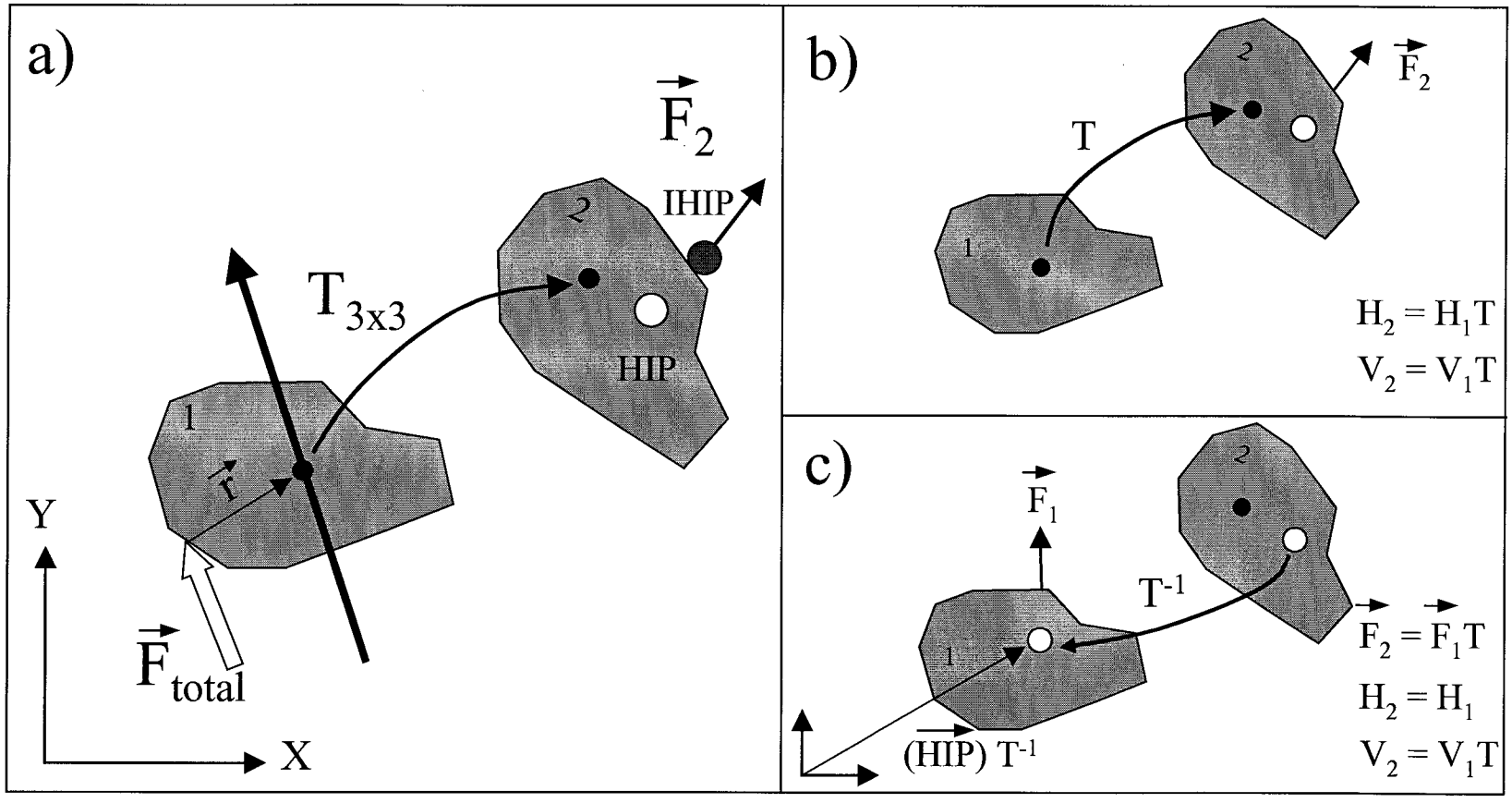
Haptic Sculpting

Free-form Deformation



Web-based haptics for product design and purchase

Rigid Body Dynamics:



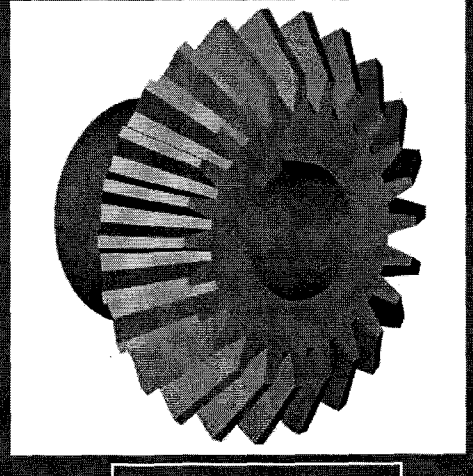
Method (c) is computationally better than (b) !

Recording and Playing-back Haptic Stimuli:

- file format
- data structure
- device independent support
- internet protocol
- data compression

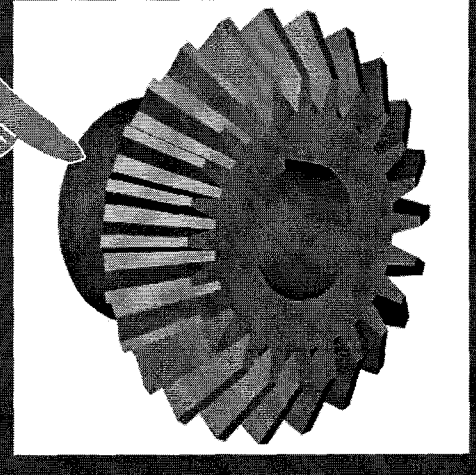
...

Web-based Haptics



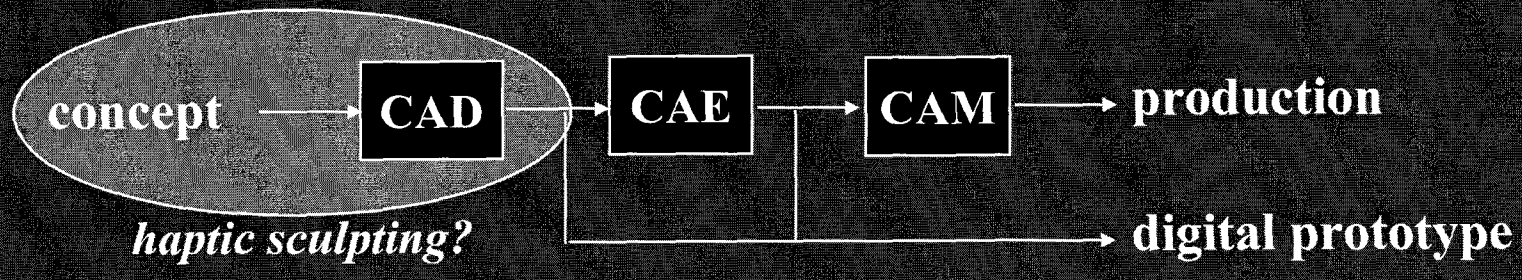
Gear.wrl

+ Haptics



Virtual Prototyping with Haptic Feedback

Problems in Engineering Design:



<u>A few problems with current systems</u>:

- automated systems can not duplicate the knowledge and intelligence of an experienced designer.
- limits the ability of design engineers to experiment with different design configurations.
- design process is slow, sequential, and non-intuitive.
- testing the functionality/ergonomics of a product is costly and requires many iterations

Benefits of Touch Feedback in Engineering Design:

1 *Path planning*
2 *Assembly sequence*
3 *Digital Prototyping*
4 *Functionality & Maintenance*
5 *Ergonomics*

} areas where haptic feedback can contribute significantly to design process

However, haptic feedback can be used for

- finding the insertion/removal paths of objects
- precision mating
- planning the sequence of assembling products
- guiding/constraining the user during digital sculpting
- improving depth perception and resolving visual ambiguities
- testing the functionality of products in virtual worlds
- designing user friendly interfaces