Introduction to Haptic Rendering

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Haptic (adj.):

related to the sense of touch.

Graphical Rendering:

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

Haptic Rendering:

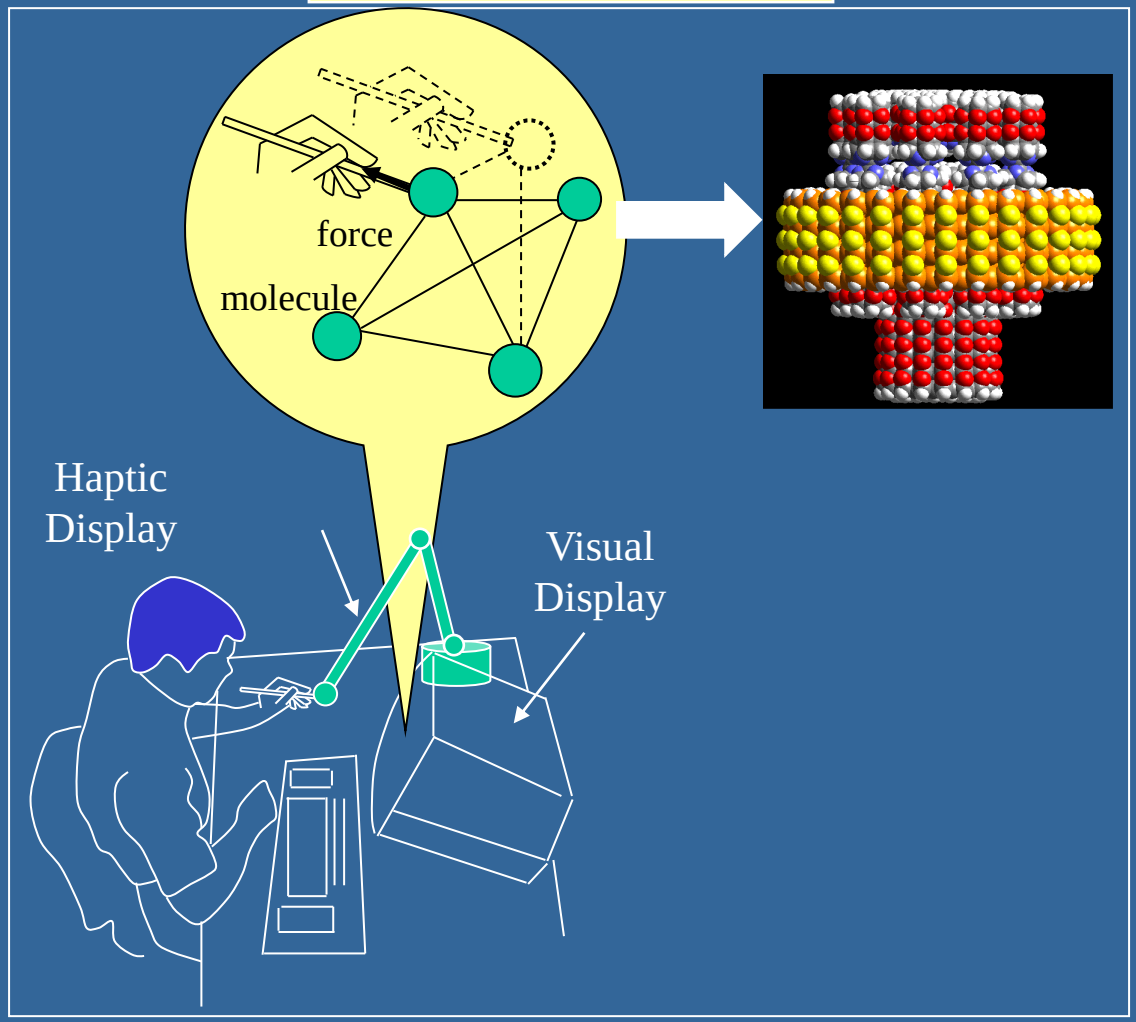
process of displaying synthetically generated 2D/3D haptic stimuli to the user

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

Applications

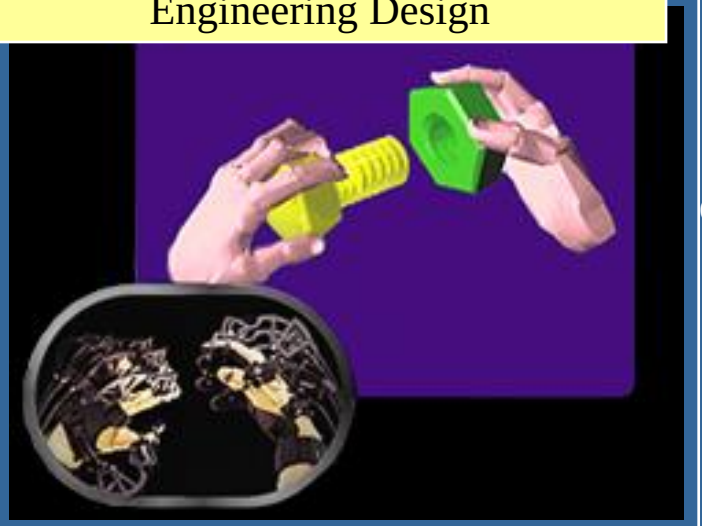
Haptic Feedback for Medical Simulation and Training

Haptic Feedback for Molecular Simulation



Applications

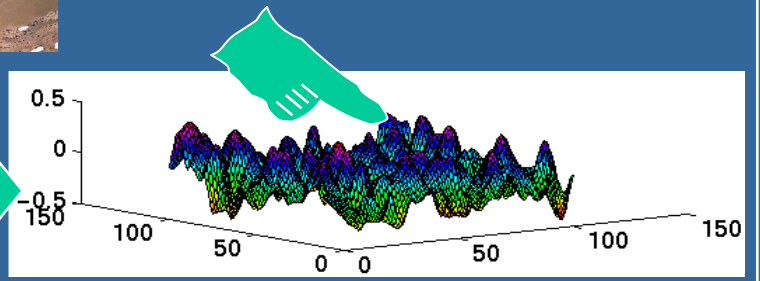
Haptic Feedback for Collaborative Engineering Design



Haptic Visualization

collected data

haptic display

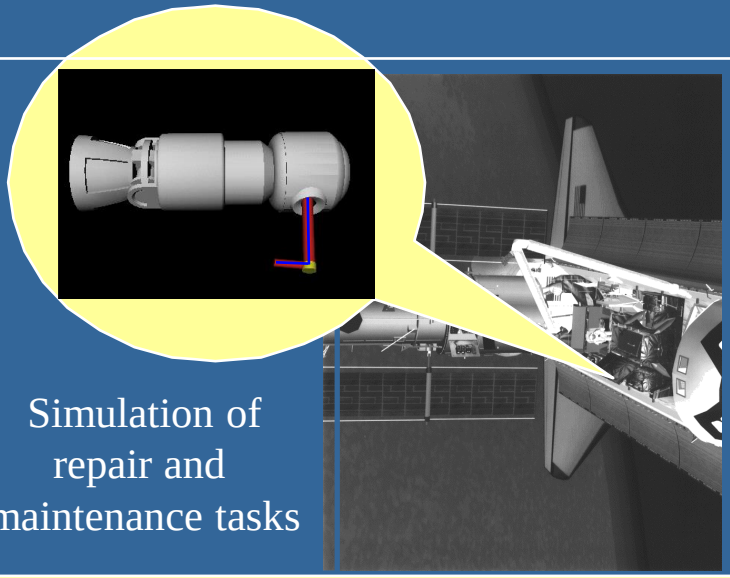


tangible data

Tangible Interfaces

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

Haptic User Interface (HUI)



Simulation of repair and maintenance tasks

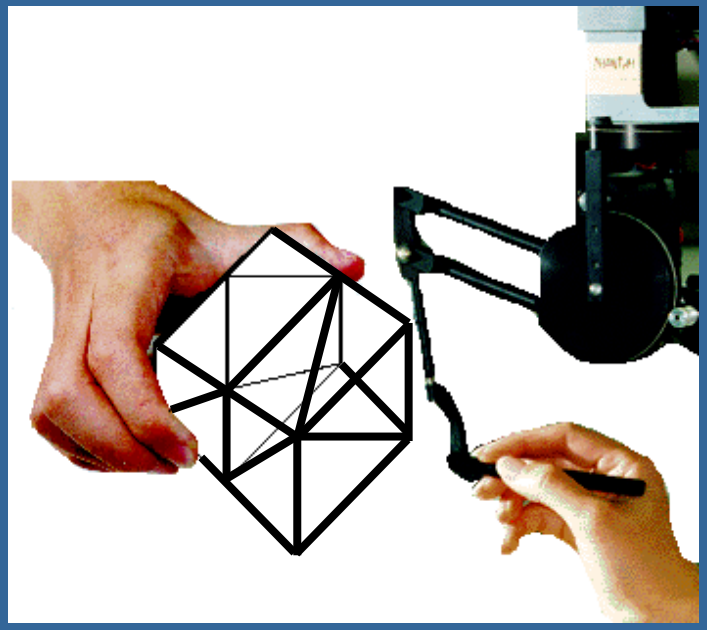
Haptic Feedback for Crew Training

The Power of Touch:

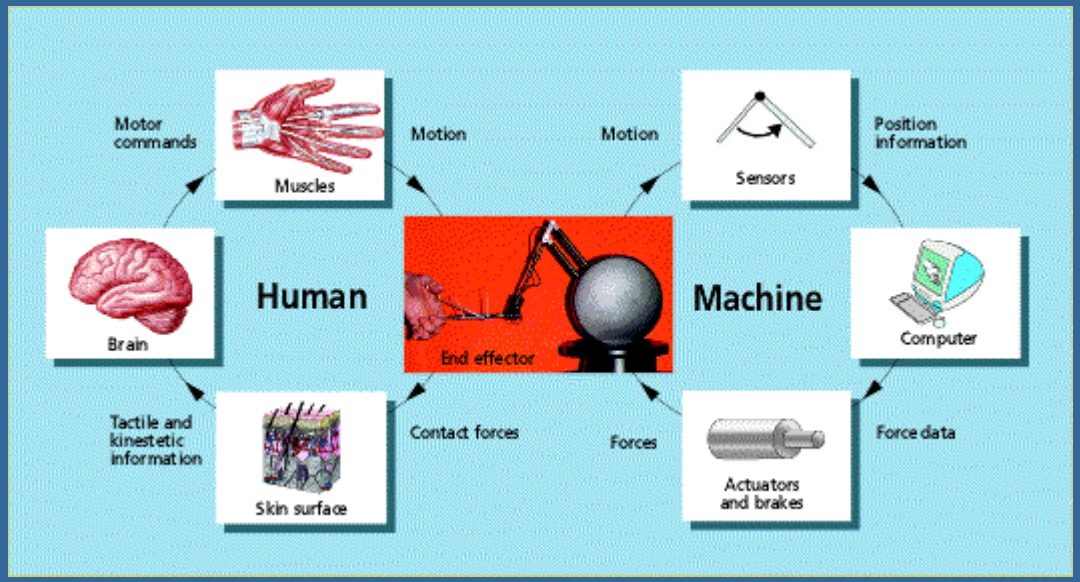
A little evidence can tell you the whole story!

Human vs Machine Haptics:

Human Haptics



Machine Haptics

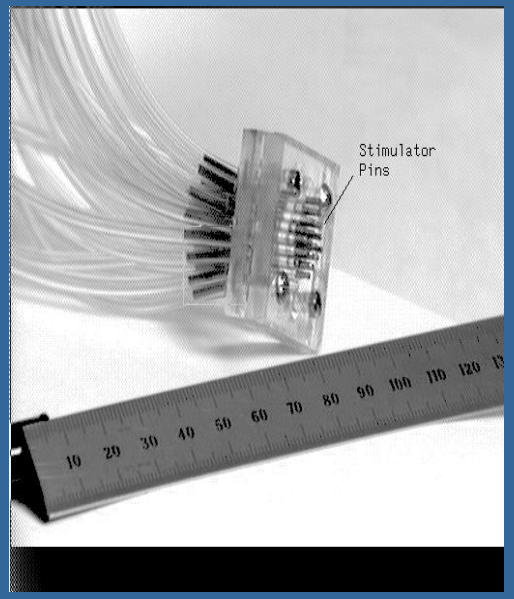


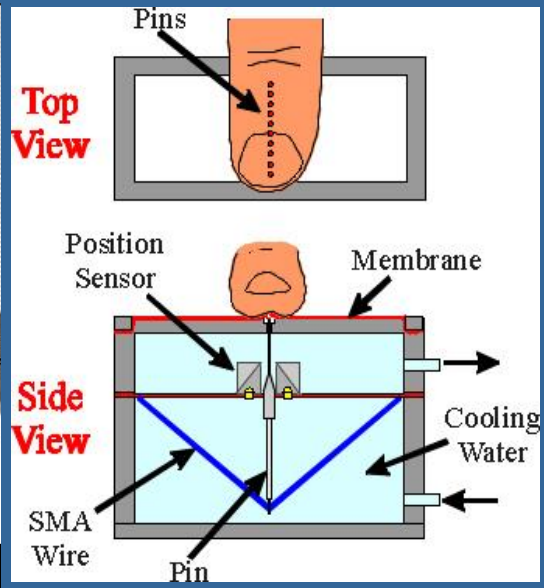
Machine Haptics:

Types of Haptic Devices

Net Force Displays

Tactile Displays



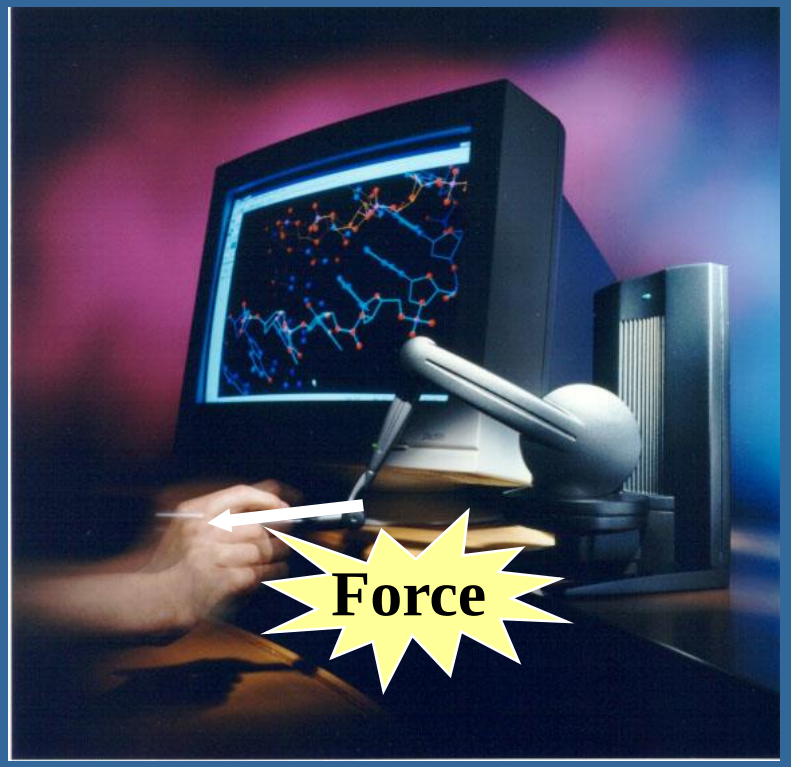


Types of Haptic Devices

Passive

keyboard, trackball, mice, etc.

Active



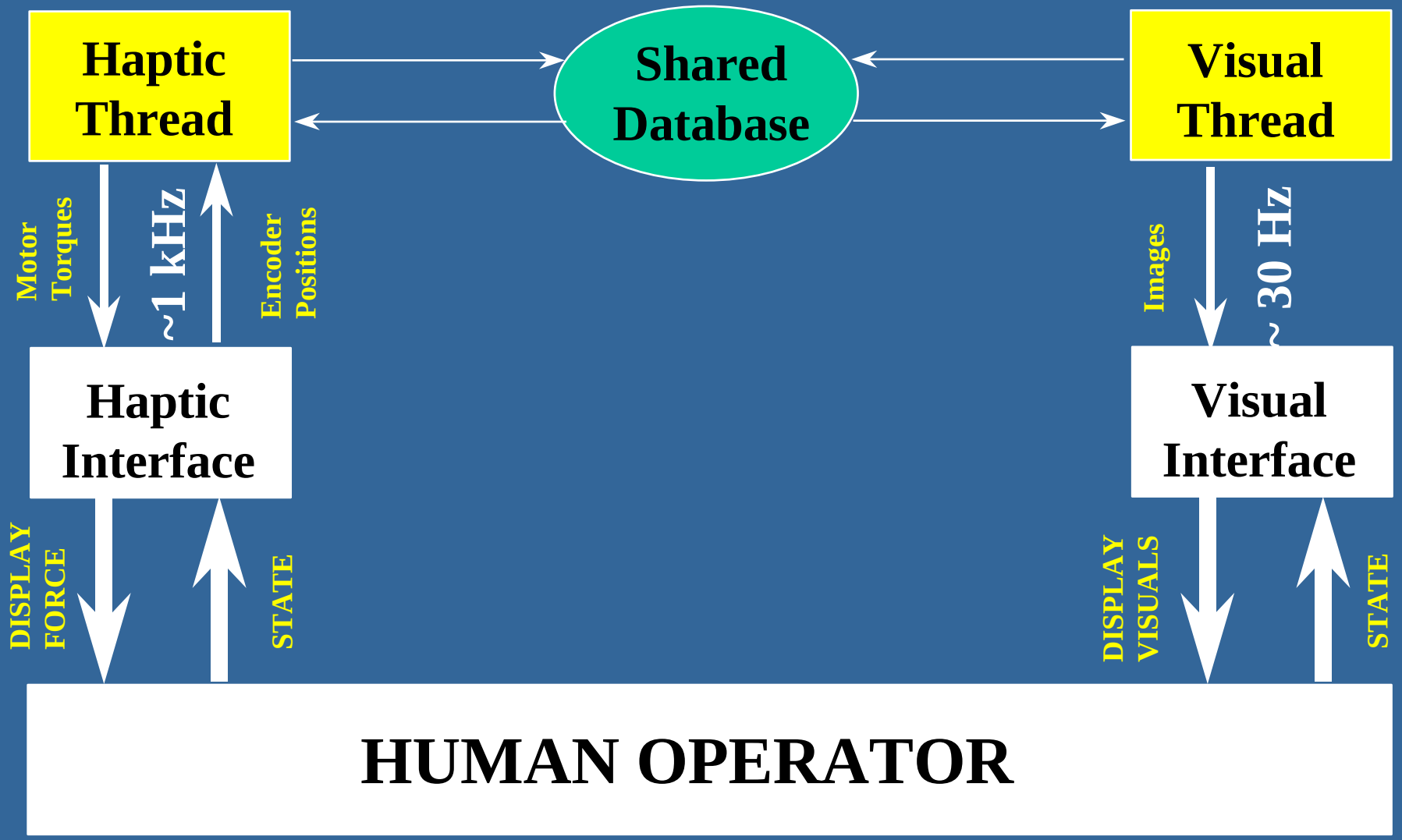
Types of Haptic Devices

Grounded

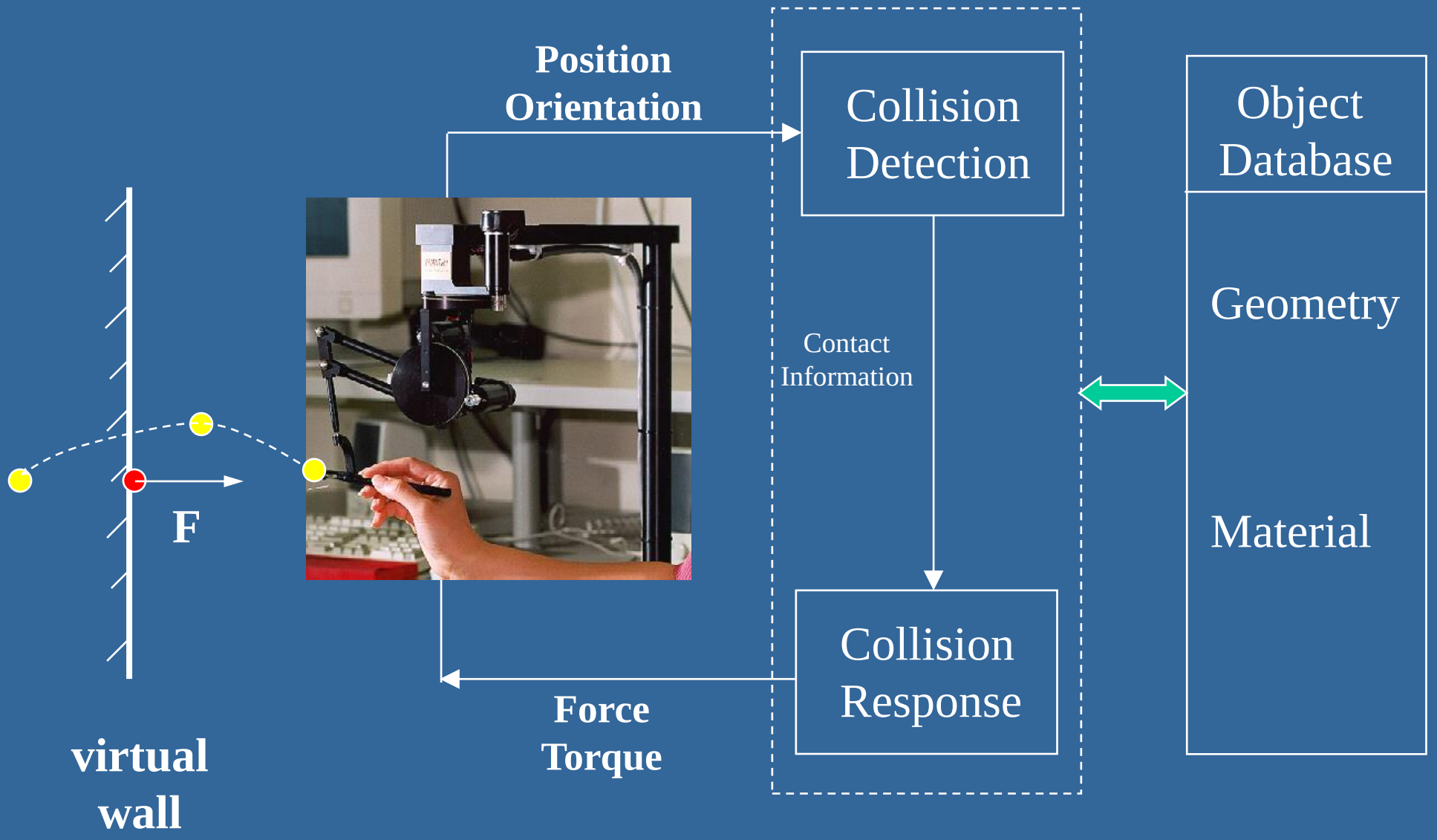
Attached

combined

Integration of Vision and Touch



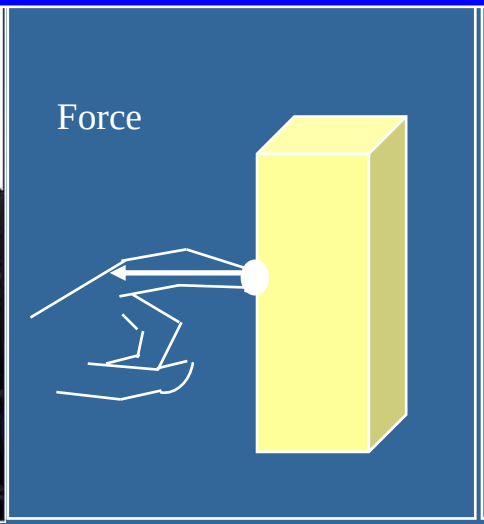
Haptic Rendering with a Force Display



Types of Haptic Interactions with 3D Objects:

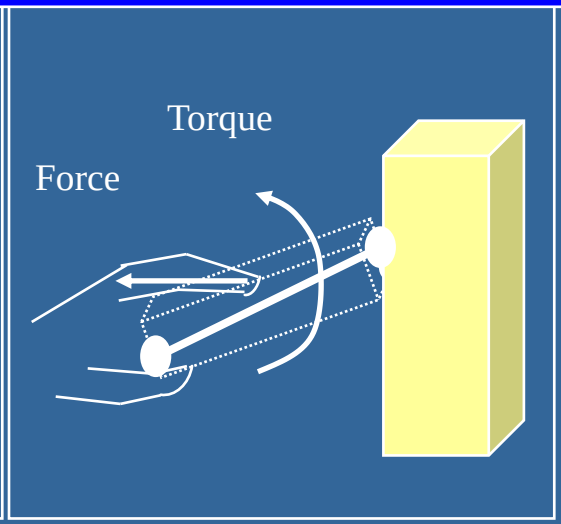
a

b



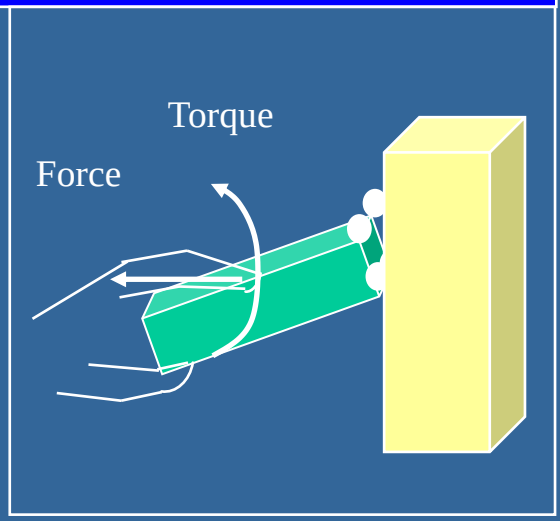
Point-Object

c



Line Segment-Object

d

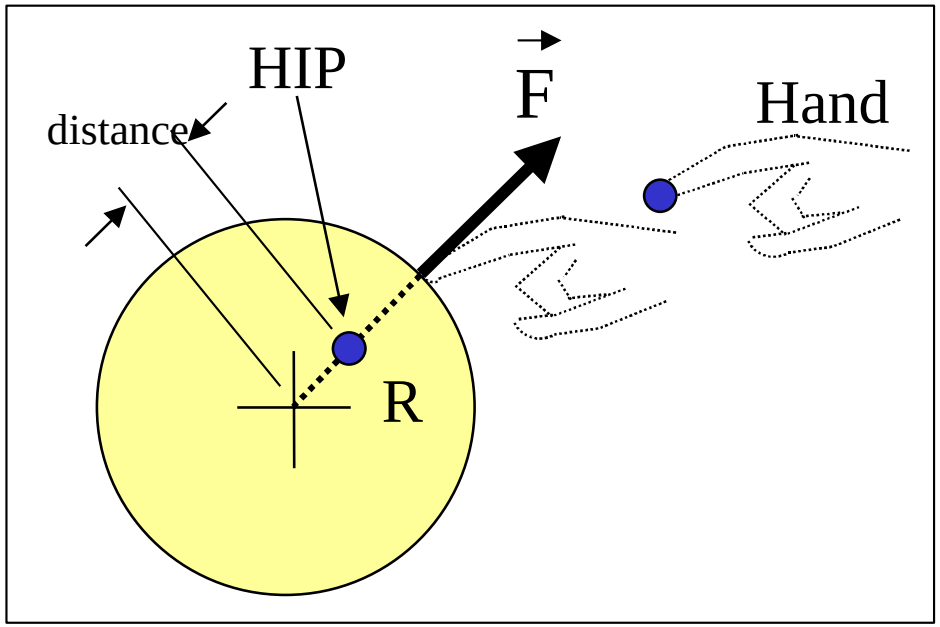


Object-Object

more computation

Haptic Rendering Of 3D Geometric Primitives

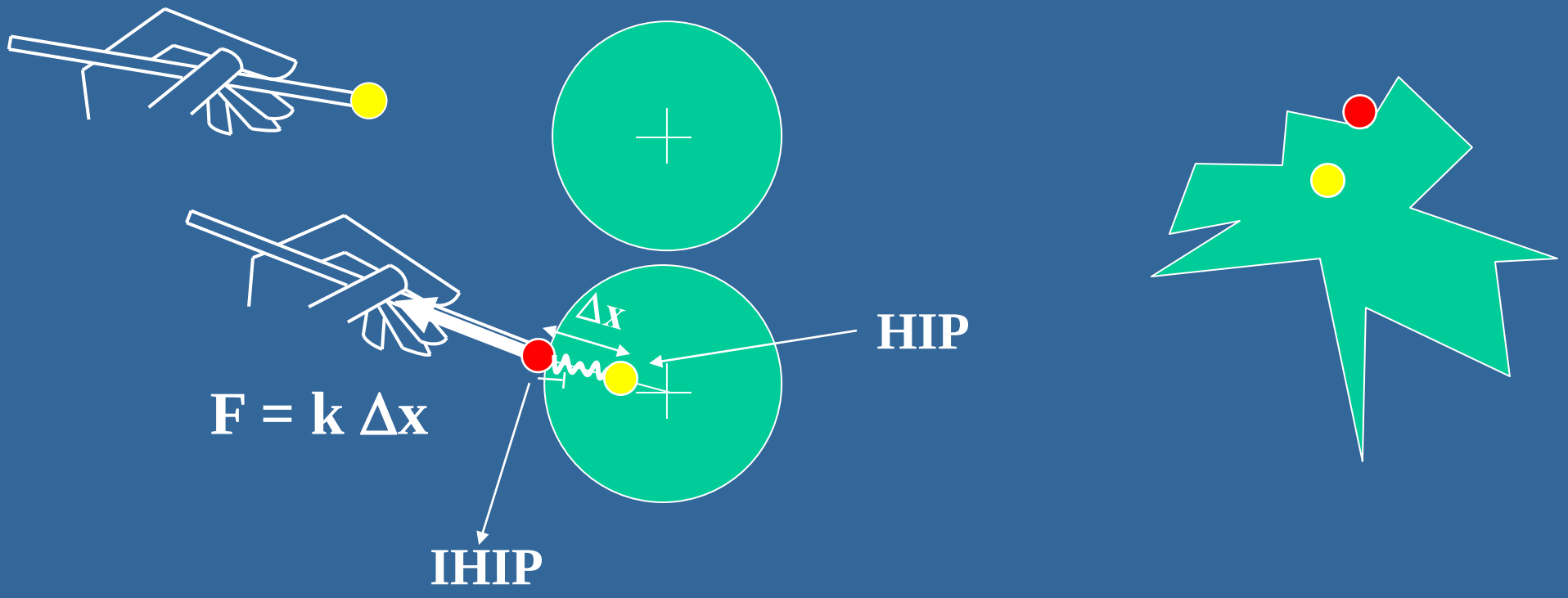
(point-object interaction)




```
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)



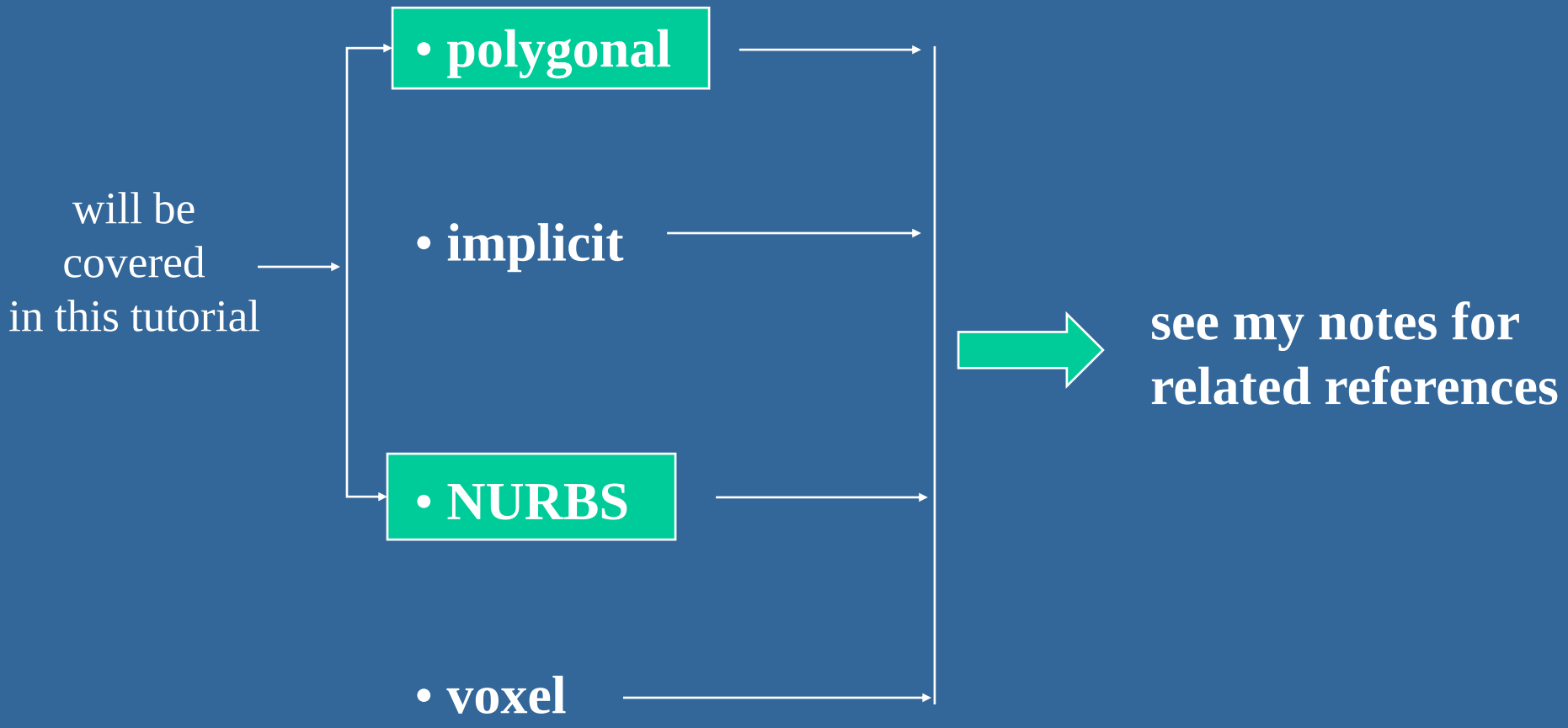
3D Primitives
no problem !

?

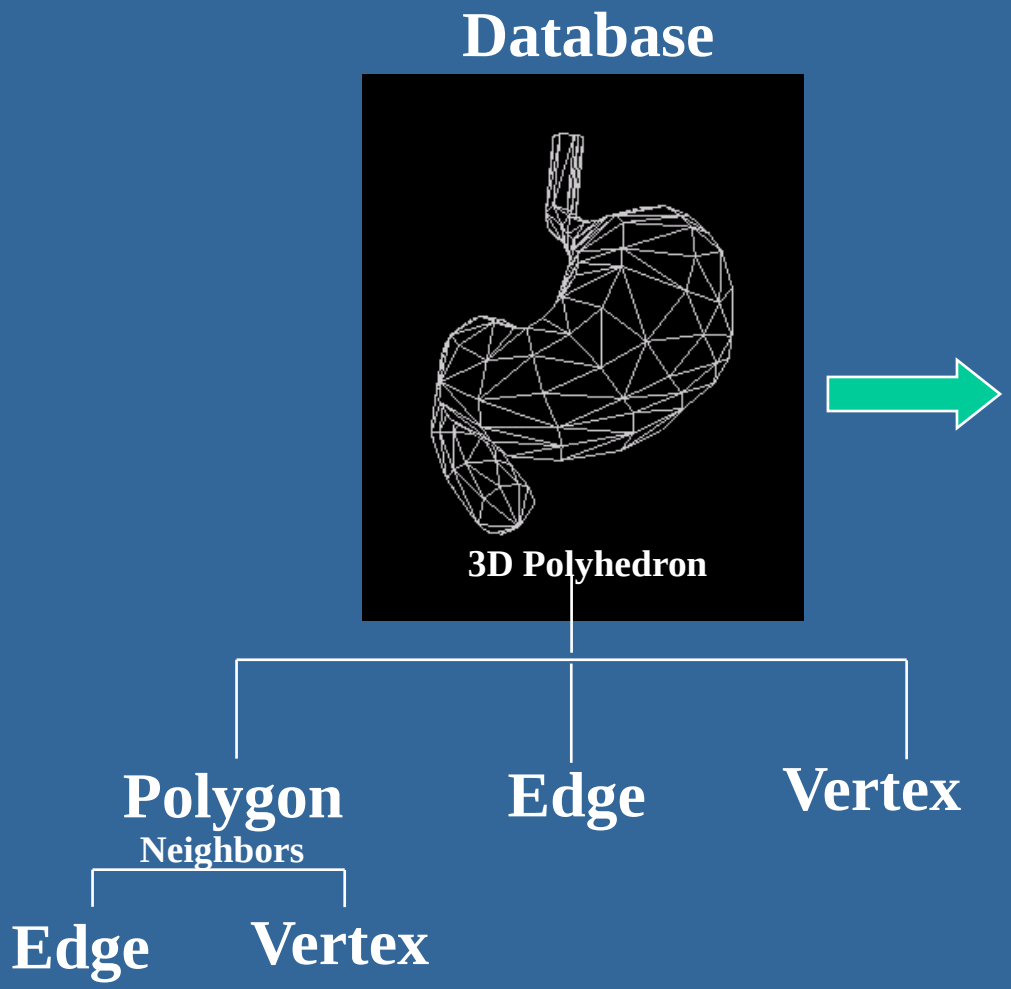
3D Object
- optimization
- rule-based techniques

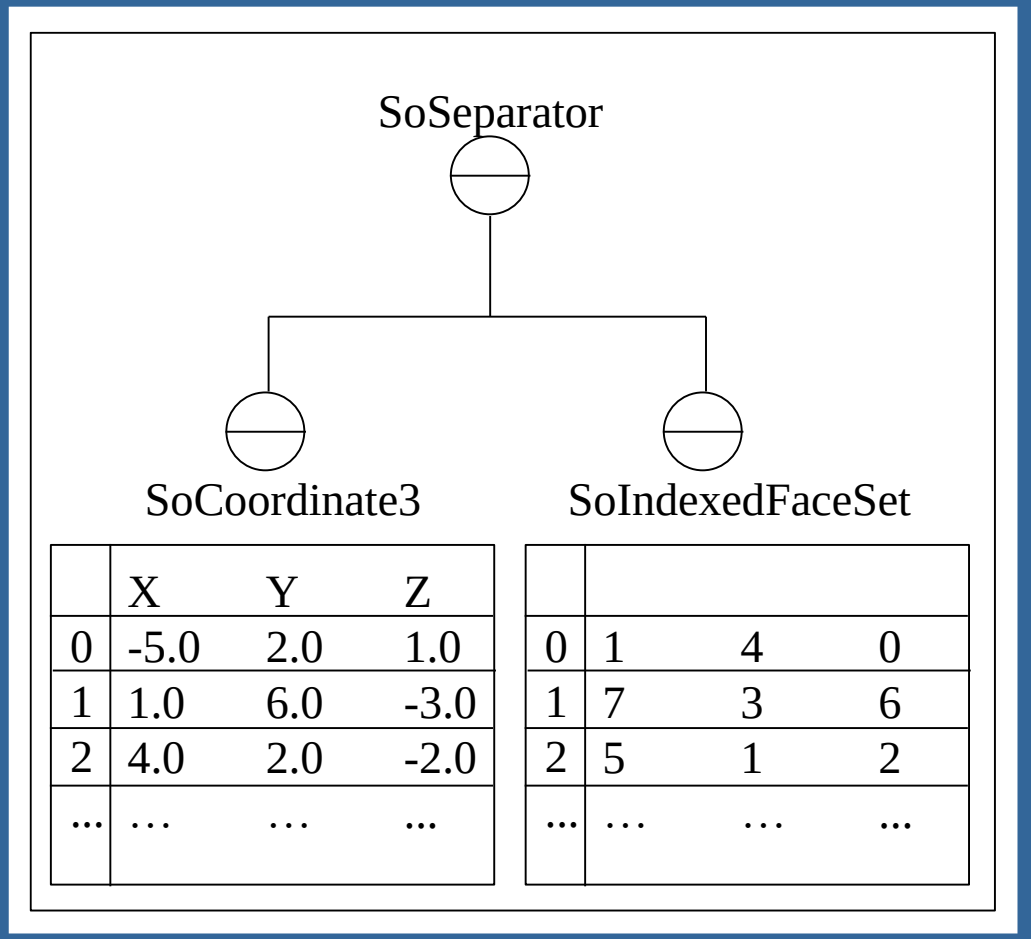
Modeling Choices for 3D Object Representation

(point-object interaction)



Representation of a 3D Polyhedron





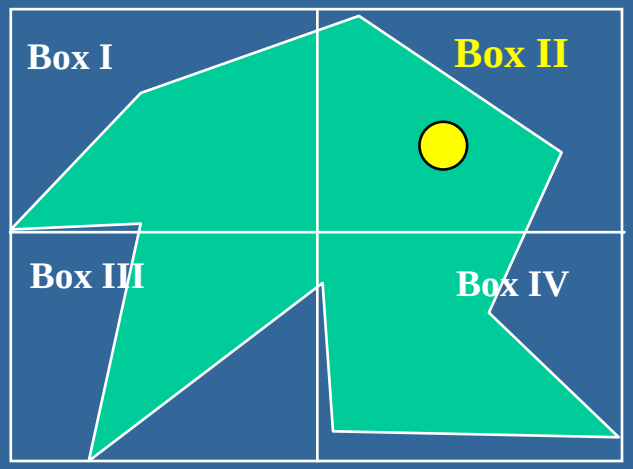
	X	Y	Z
0	-5.0	2.0	1.0
1	1.0	6.0	-3.0
2	4.0	2.0	-2.0
...	…	…	...

0	1	4	0
1	7	3	6
2	5	1	2
...	…	…	...

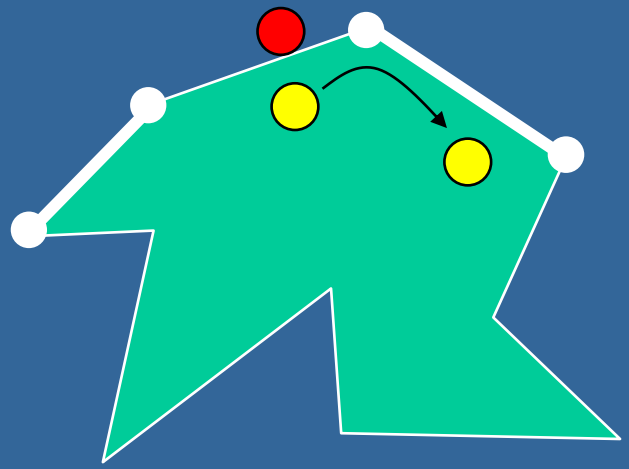
Open Inventor/VRML file

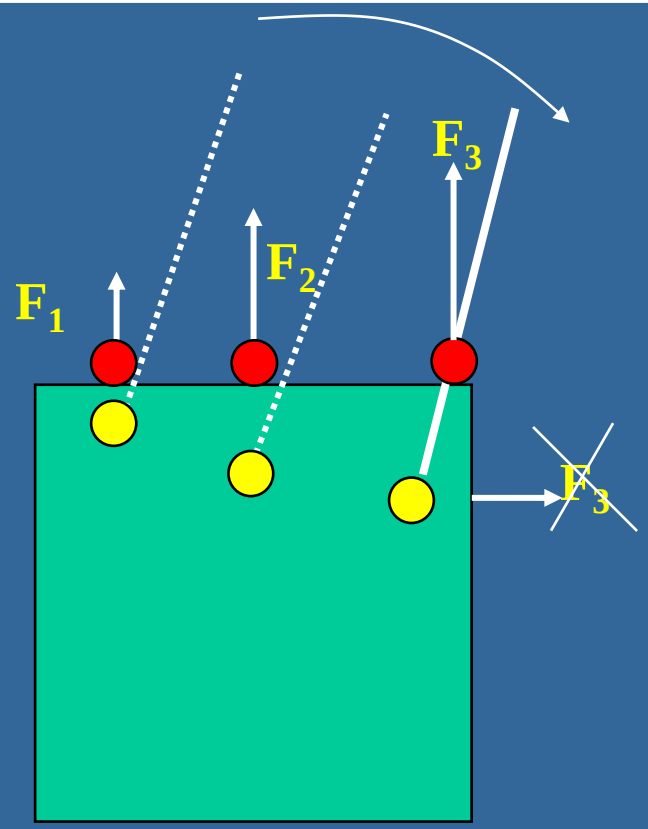
Key Components of the Rendering Algorithm

1) Bounding-box hierarchy



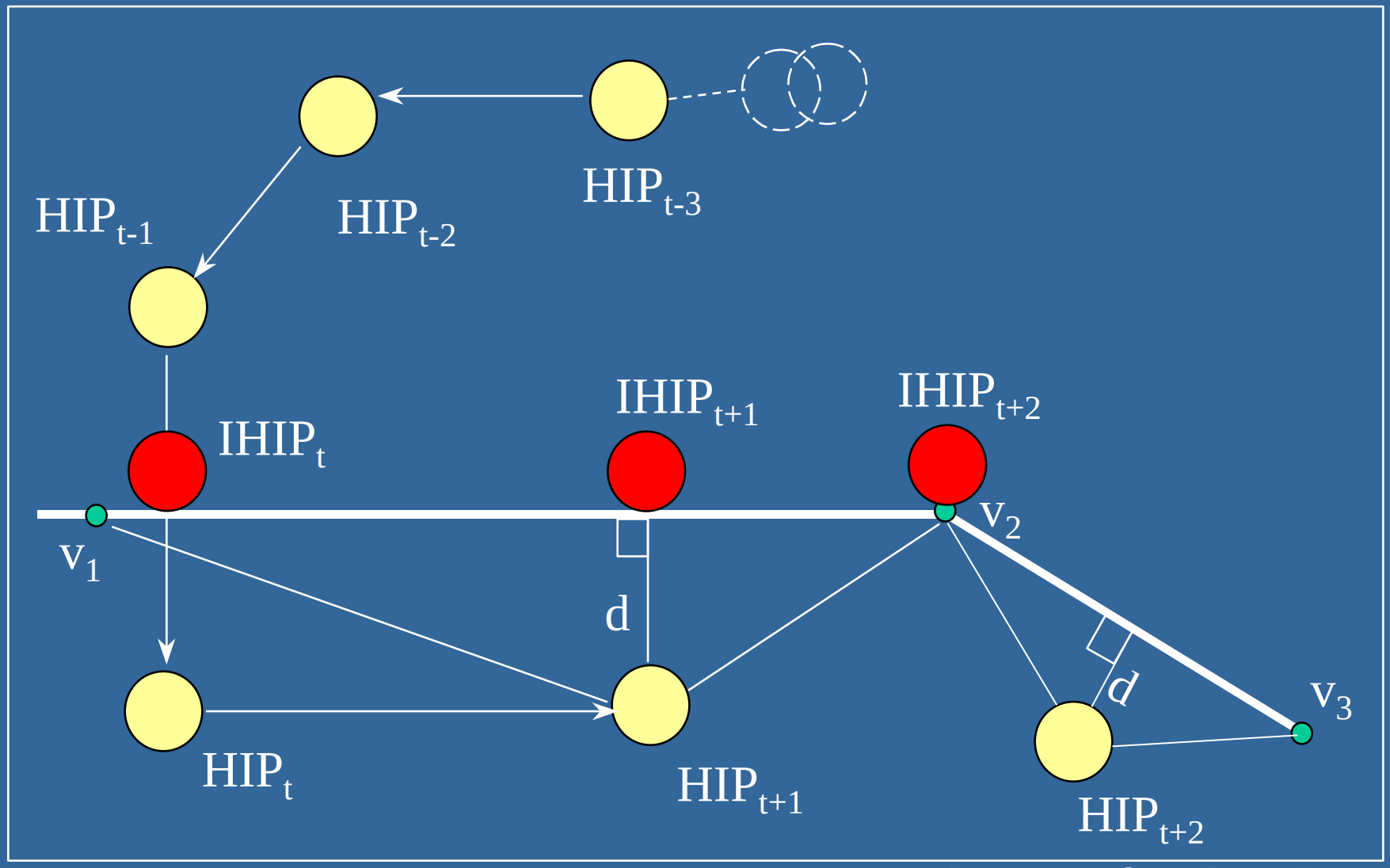
3) Local coherence





2) Contact history

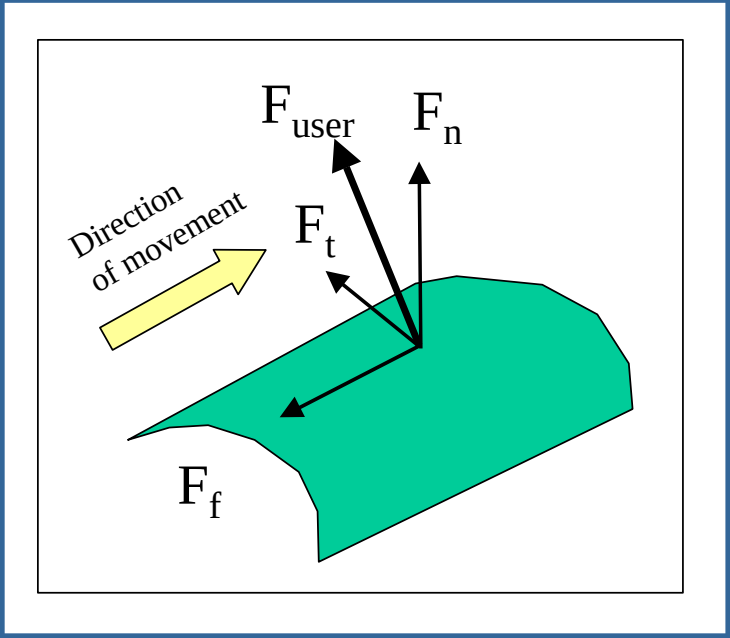
Haptic Rendering of Polygonal Surfaces

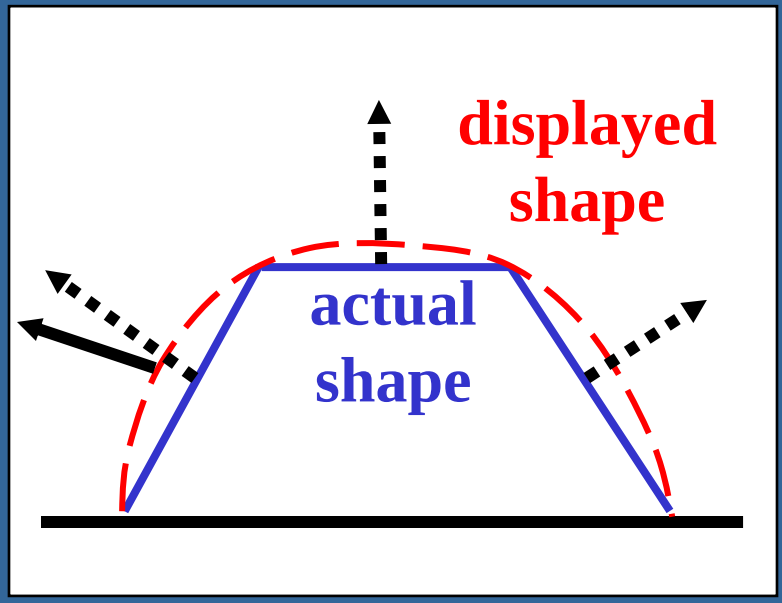


see Ho et al., 1999 for details

Haptic Display of Surface Details

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

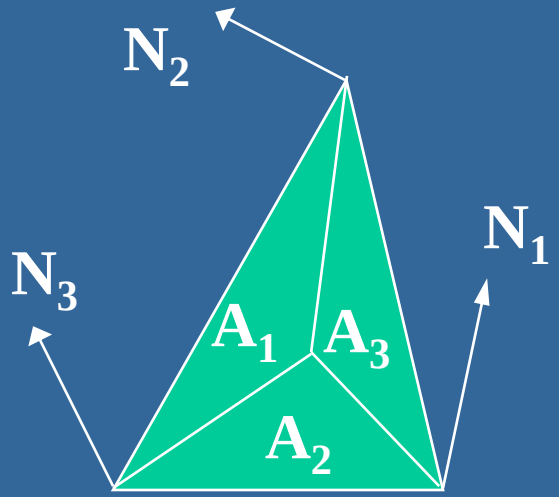




Common Principle: Perturbation of force vector !

Force Shading

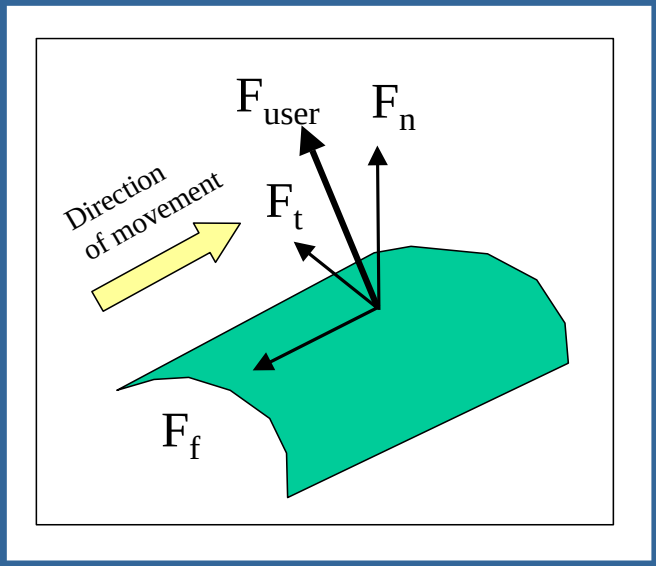
ref: Phong Shading



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

Friction

ref: Mechanics books

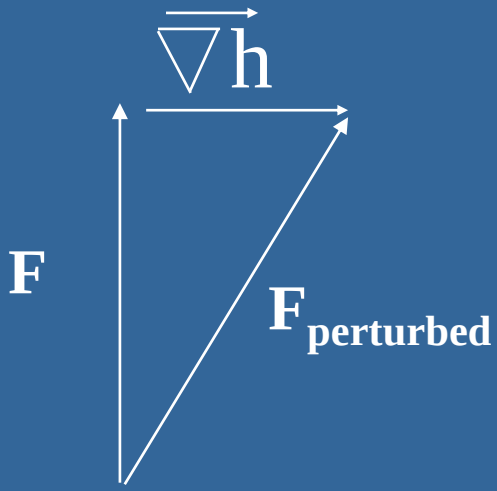


Texture

ref: Bump Mapping

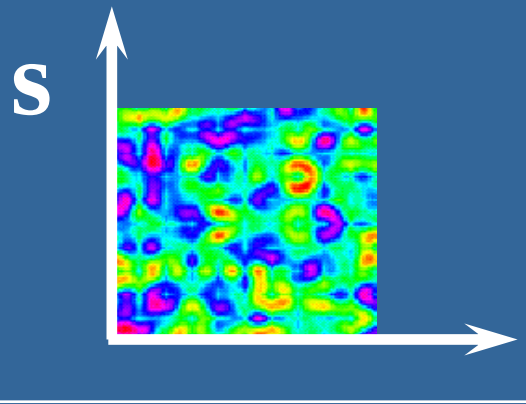
$$\nabla h = \frac{\partial h}{\partial x}\hat{i} + \frac{\partial h}{\partial y}\hat{j} + \frac{\partial h}{\partial z}\hat{k}$$

h(x,y,z) : texture field



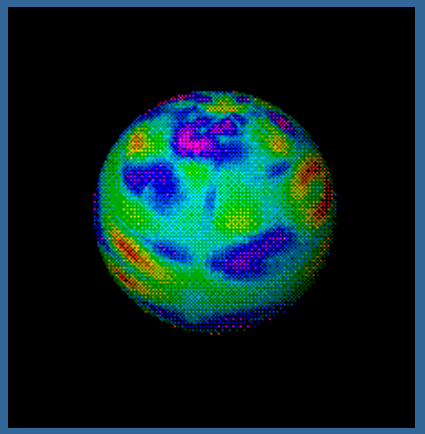
Haptic Texturing

- **image-based**



two-stage mapping

Bier & Sloan, 1986

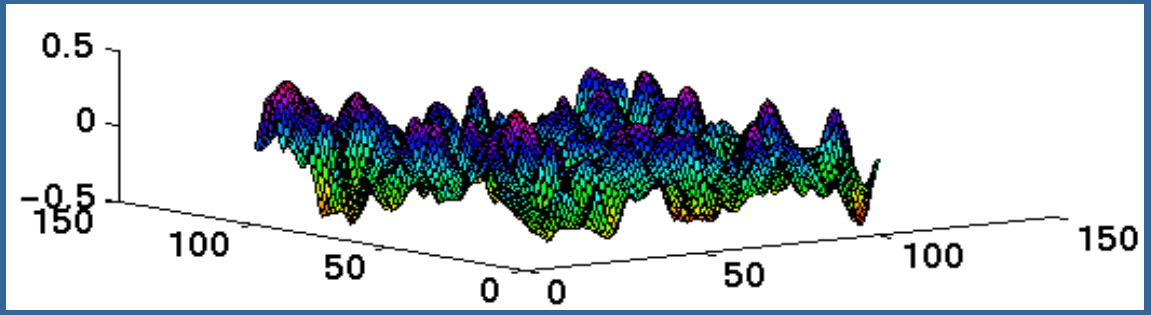


- **procedural**

h(x,y,z)

bump mapping

Blinn, 1978;
Max and Becker, 1994

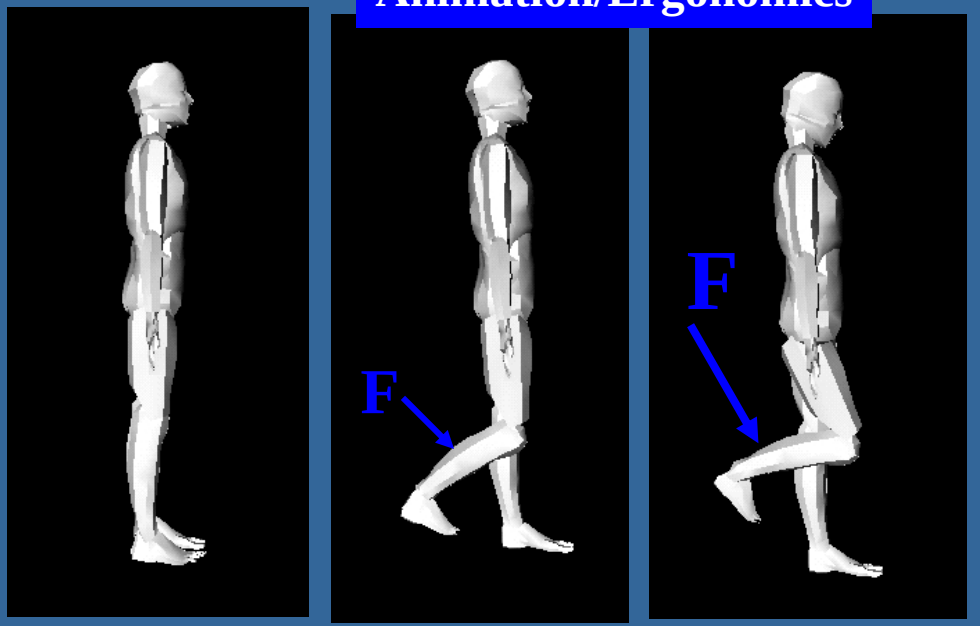


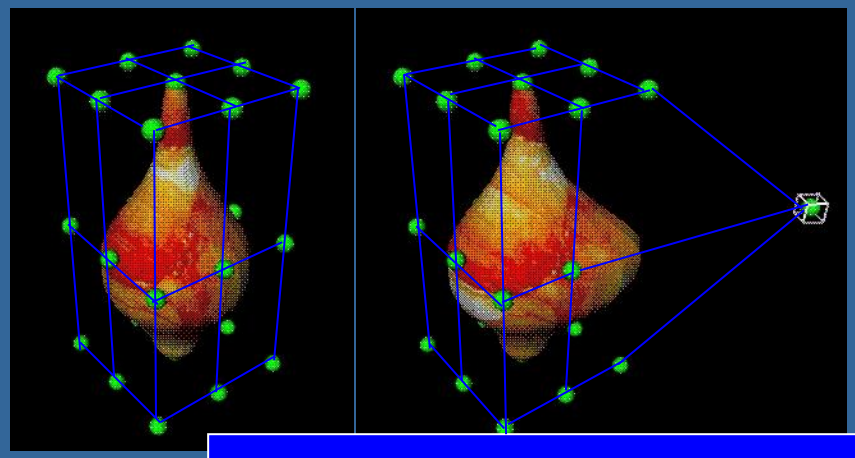
Force-Reflecting Deformable Models:

Real-time FEM

Surgical Simulation

Animation/Ergonomics

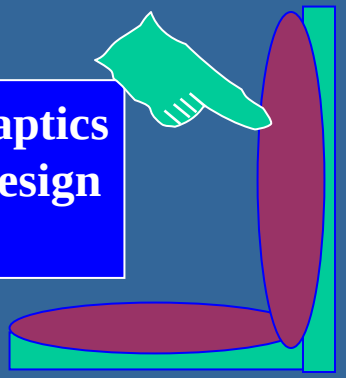




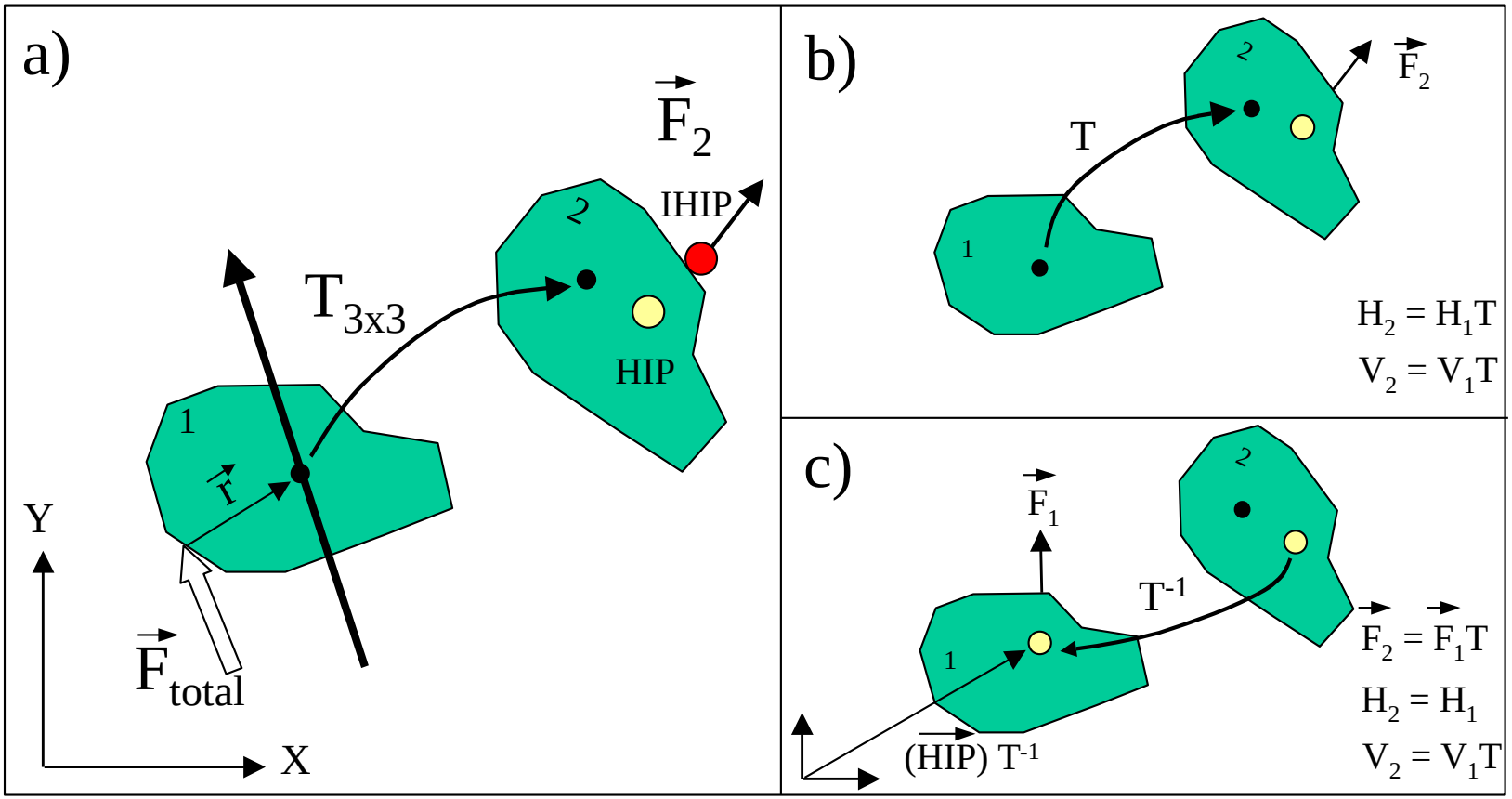
Haptic Sculpting

Free-form Deformation

Web-based haptics for product design and purchase



Rigid Body Dynamics:



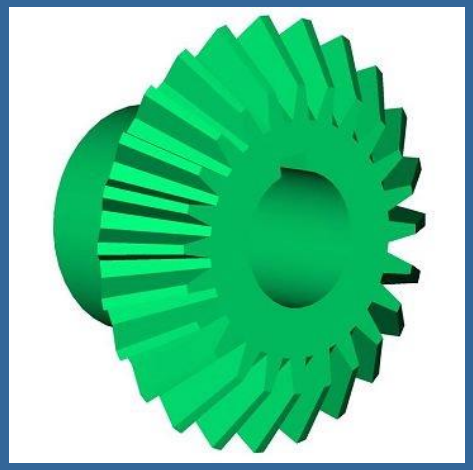
Method (c) is computationally better than (b) !

Recording and Playing-back Haptic Stimuli:

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

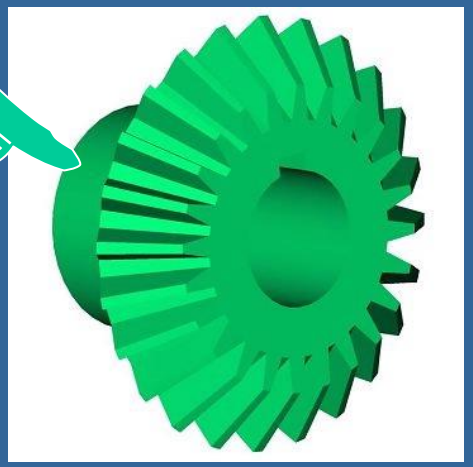
...

Web-based Haptics



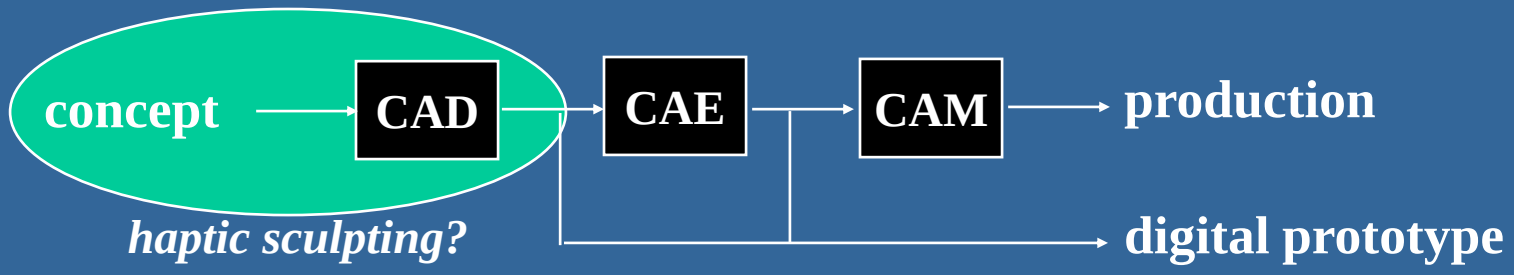
Gear.wrl

+ Haptics



Virtual Prototyping with Haptic Feedback

Problems in Engineering Design:



A few problems with current systems:

- 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**