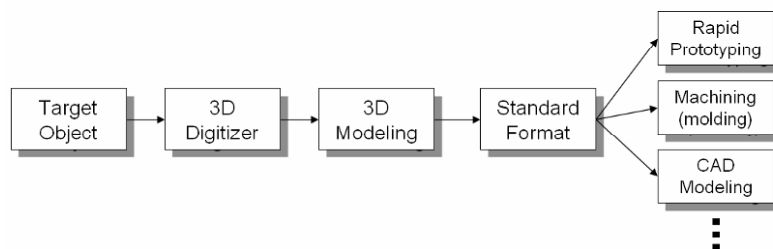




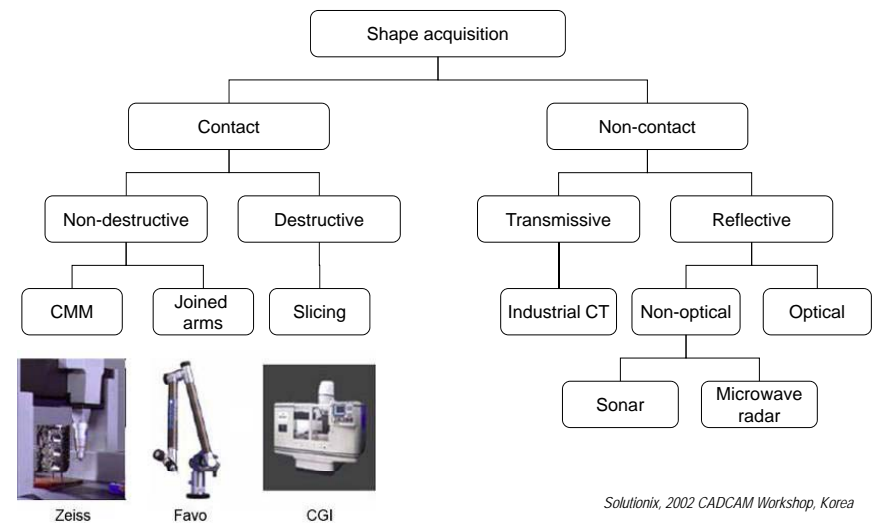
Introduction of RE

- Three-dimensional data which is captured in computerized form from physical models or products
- Two main phases
 - Digitizing or measuring of a part
 - Three-dimensional modeling of the part from the digitized data



General process of reverse engineering

Digitizing or Measuring Methods



Solutionix, 2002 CAD/CAM Workshop, Korea

Coordinate Measuring Machine (CMM)

- Move a measuring probe to determine coordinates of points on a work piece surface



Browne & Sharpe, North Kingstown, Rhode Island

5

Jointed Arm

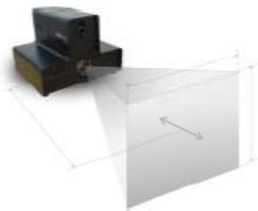
- Phantom Arm haptic finger device
 - Pointing tool on a virtual model
 - Allows dynamic 3D modification



6

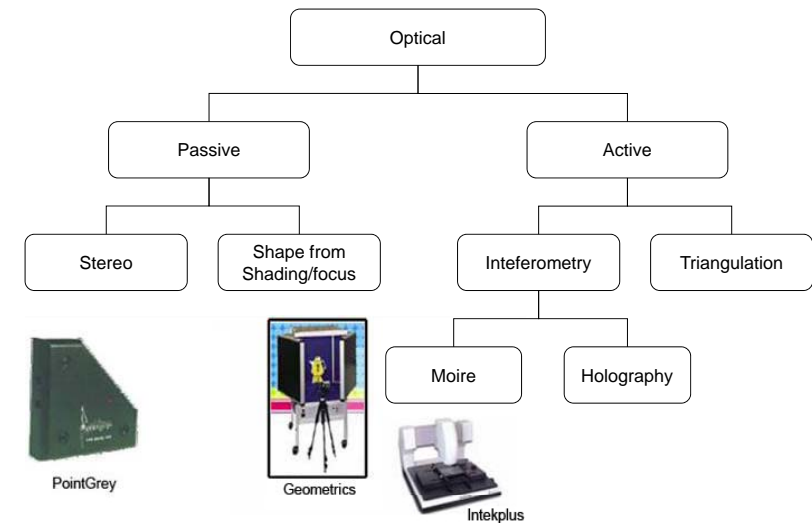
Scanners

- Acquire data by interpreting the interactions of target volumes with various forms of energy
 - Light
 - Laser beams
 - X-rays



7

Scanning Methods



8

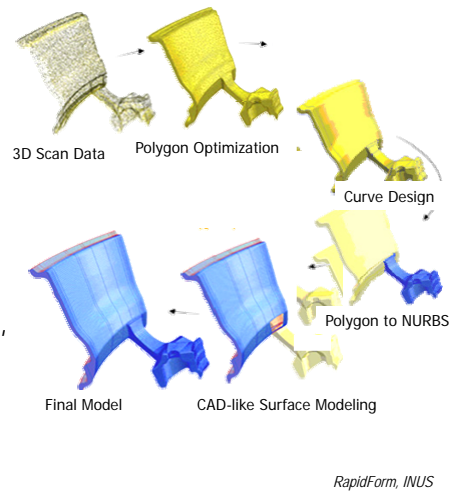
Scanners (cont.)

Pros

- Non-contact
- Various profiles can be corrected include free-surface
- Fast acquisition
- High resolution

Cons

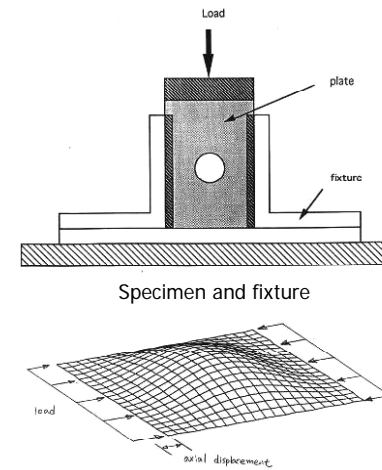
- Partial acquisition
- Sensitive to surface roughness, transparency, shininess, color, variations, darkness, inter-reflections



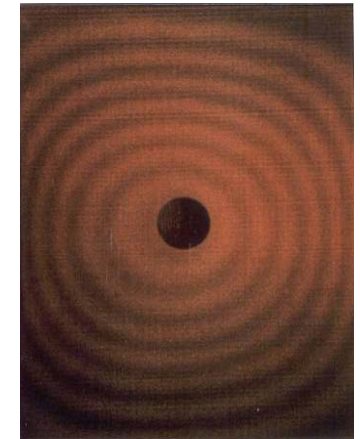
9

Moire interferometry

Example of buckled plate



Out-of-plane displacement of buckled plate



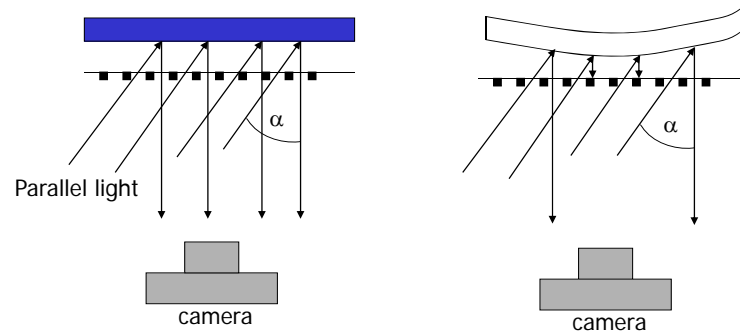
D=0.5 in at 900 lb

10

Shadow Moire interferometer

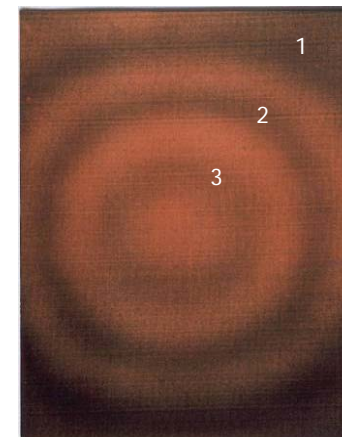
$$\Delta z = d / \tan \alpha$$

where d = grid density eg. 1mm gap

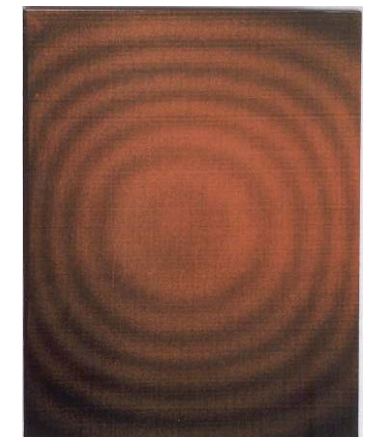


11

Out-of-plane deformation by fringes



D=0 in at 700 lb

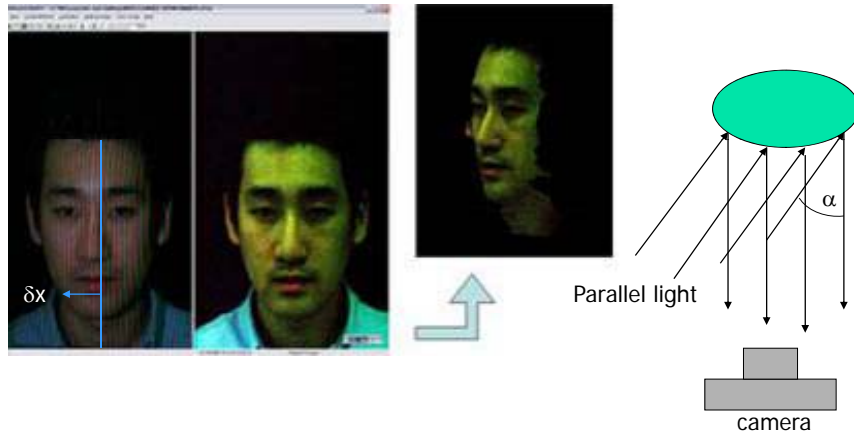


D=0 in at 900 lb

12

Moire type 3D scanner

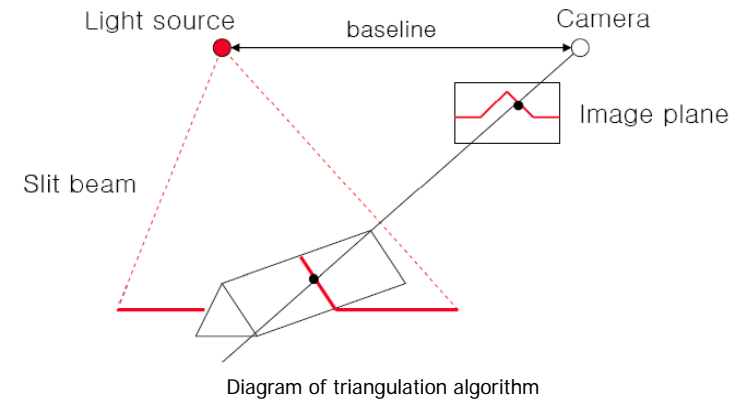
- $\delta z = \delta x / \tan \alpha$



13

Optical Triangulation Algorithm

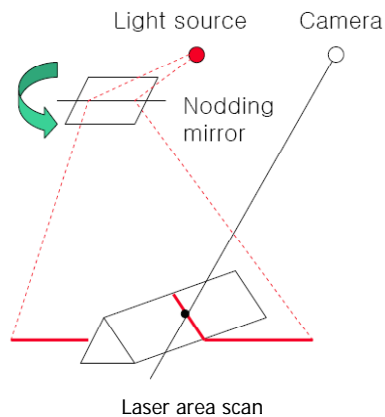
- Z-axis are calculated using Triangulation algorithm after spot light or slit beam shot



14

Laser Scan – Area

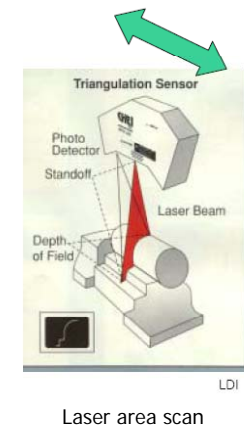
- Camera is fixed while light source is moving
- Simple architecture
- Area scanning available
- For higher accuracy, accuracy of mechanical device is important



15

Laser Scan – Line

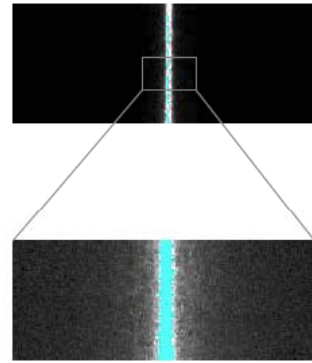
- Camera and light source are moving simultaneously
- Uniform resolution can be achieved
- Complex hardware configuration



16

Laser Scan (cont.)

- **Pros**
 - Good depth to various profile
 - Small energy consumption
- **Cons**
 - Hazardous to human eyes
 - Line scan: long scanning time
 - Area scan: difficult to calibrate
 - Shape edge problem

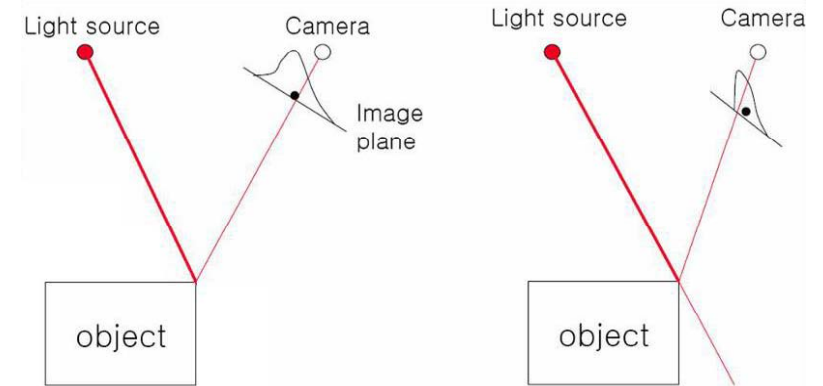


Real3D
Laser on the object

17

Shape Edge Problem

- **Slit beam on edges**



18

Laser Scan – Example



Cyberware

Line laser +
Liner robot



3dscanners

Line laser +
Articulated arm



Steinbichler

Line laser +
Gyroscope

19

Spatial Encoding

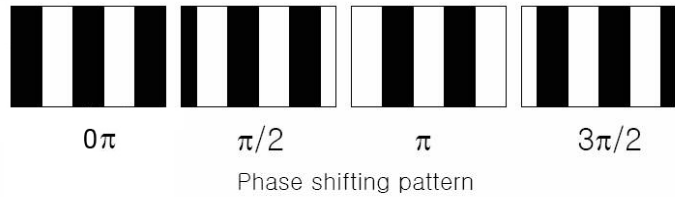
- **Project encoded patterns on the target object**
- **Using Halogen lamp for light source**



20

Spatial Encoding + Phase shifting

- For higher resolution, spatial encoding is used with phase shifting



21

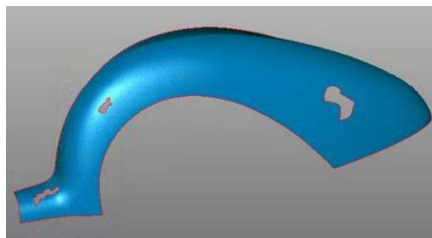
Spatial Encoding (cont.)

- Pros**
 - Safe to human eyes
 - Fast scanning
 - High resolution
 - Less shape edge problem than laser scan
- Cons**
 - Worse depth than laser
 - Large amount of energy consumption

22

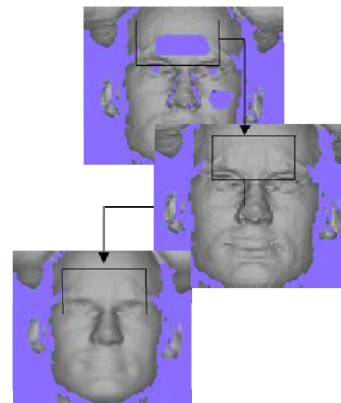
Issues of Using Scanning data

- Scan data may have some errors such as hole, overlapped area
- Filling holes in polygons



RapidForm, INUS

Holes in generated polygon from scan data

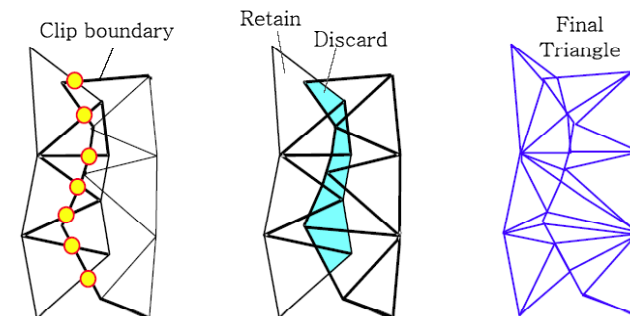


Hole filling process

23

Issues of Using Scanning data (cont.)

- Merging overlapped areas

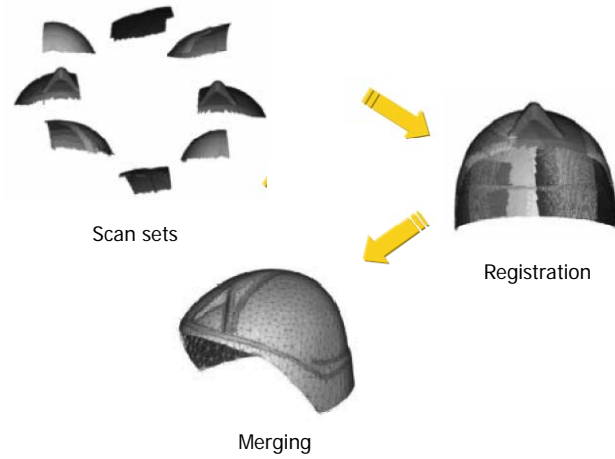


Merging overlapped area in software

24

Issues of Using Scanning data (cont.)

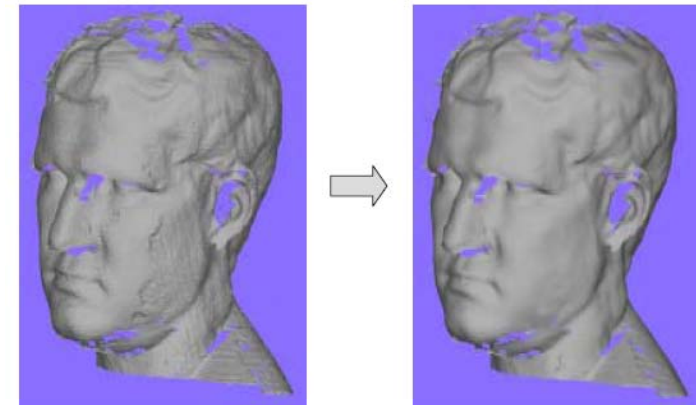
- Registration/Merging



25

Issues of Using Scanning data (cont.)

- Smoothing



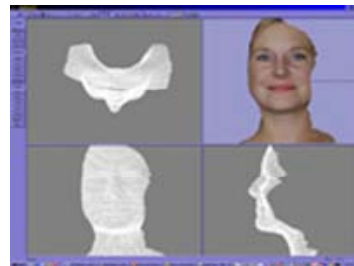
26

3D Scanner

- Input device to read physical geometry into CAD format



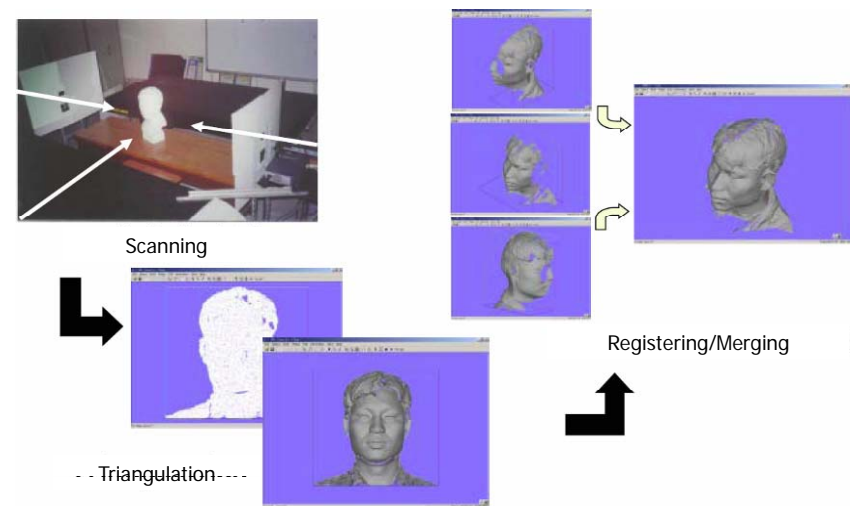
3D scanning device



Manipulator software

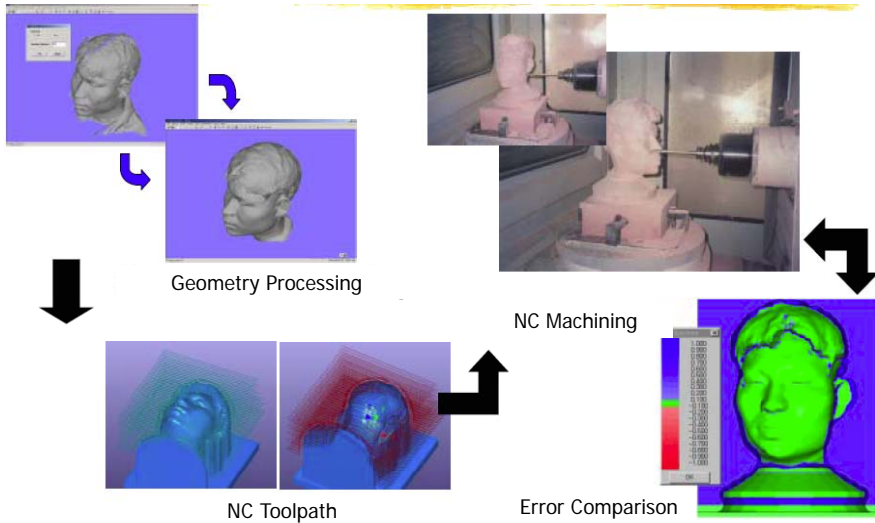
27

Replica of Human Face



28

Replica of Human Face (cont.)



29

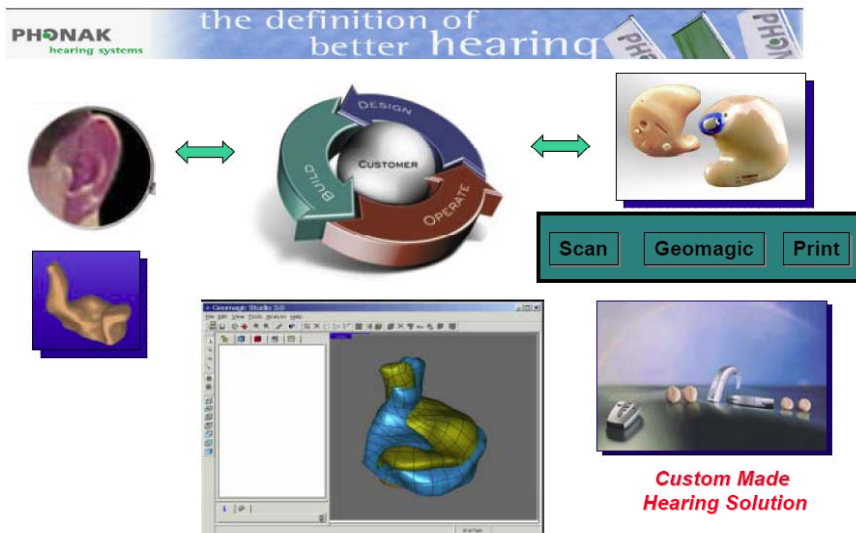
3D Scanner (cont.)

- Demo



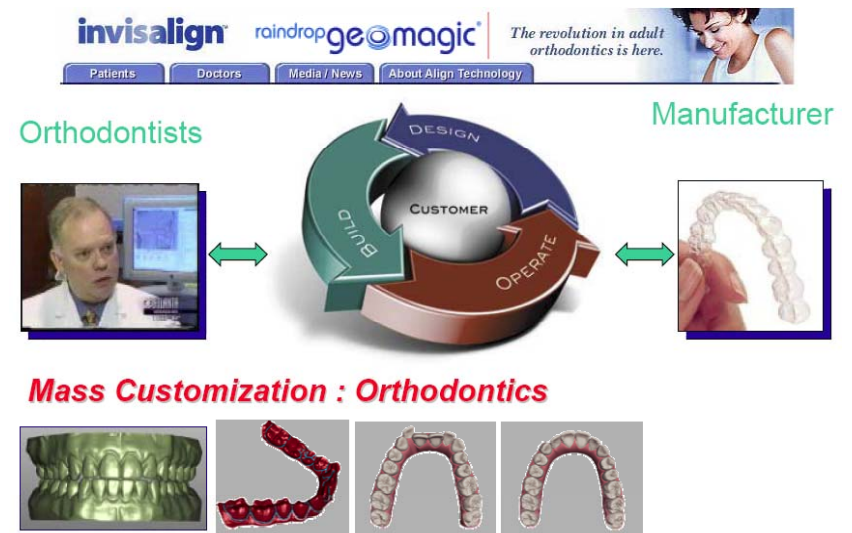
30

Applications



31

Applications (cont.)

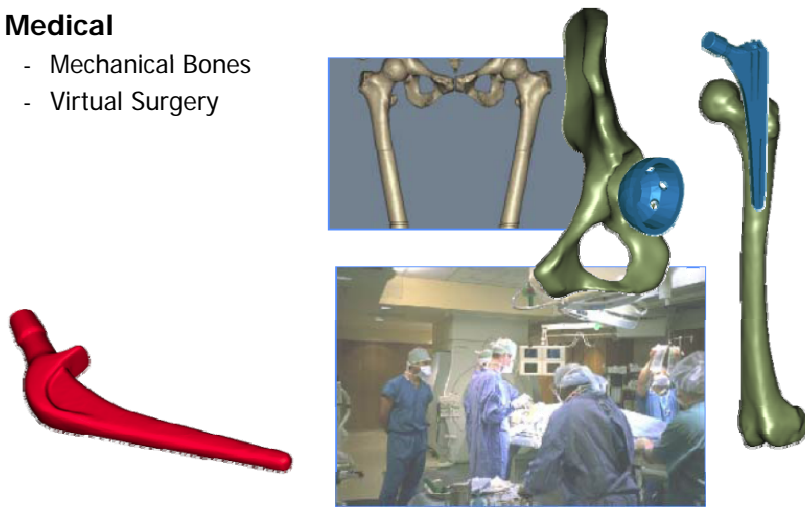


32

Applications (cont.)

Medical

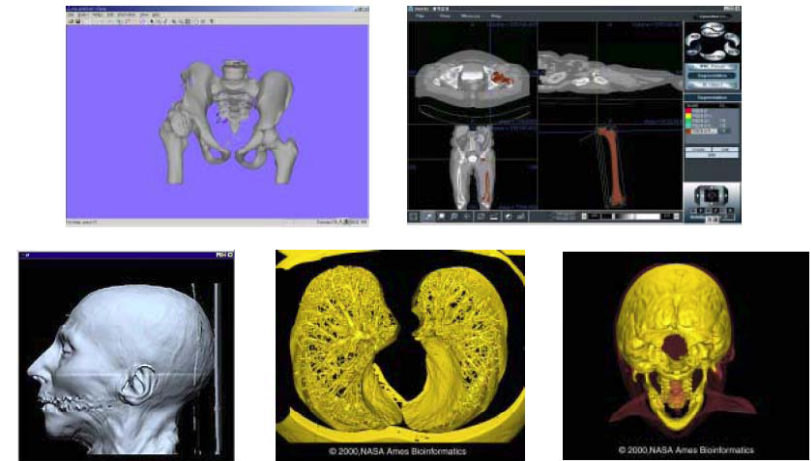
- Mechanical Bones
- Virtual Surgery



33

Applications (cont.)

Medical



34

Applications (cont.)

3D photography model for e-commerce



35



36