446.326A CAD/CAM

Reverse Engineering (RE)

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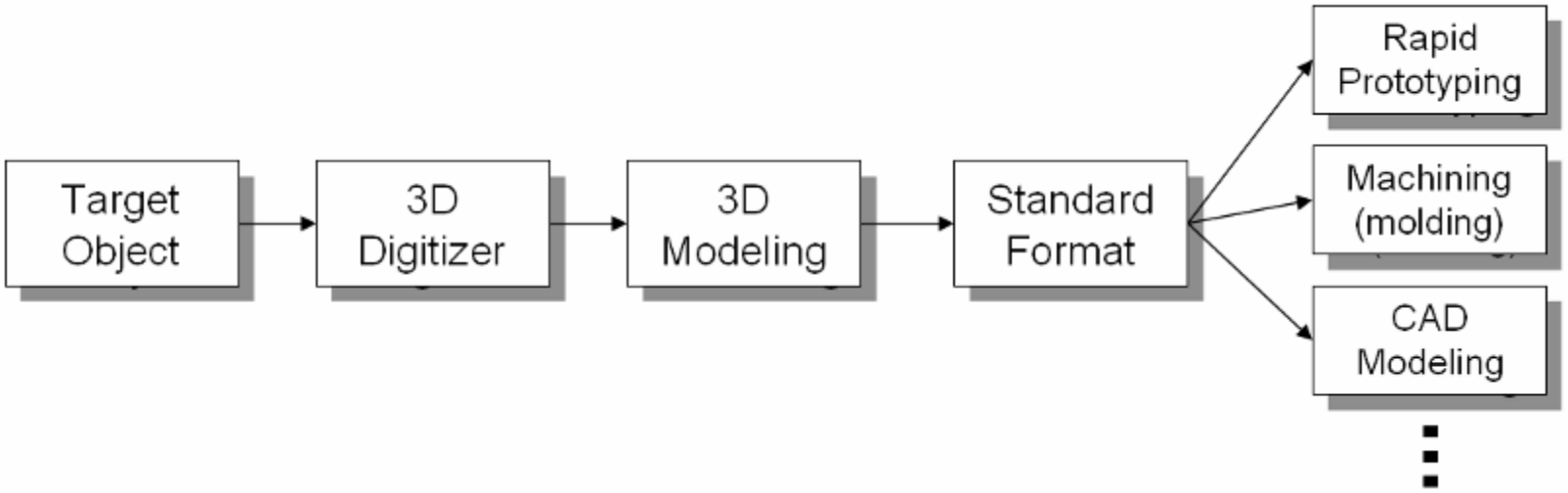
Introduction of RE

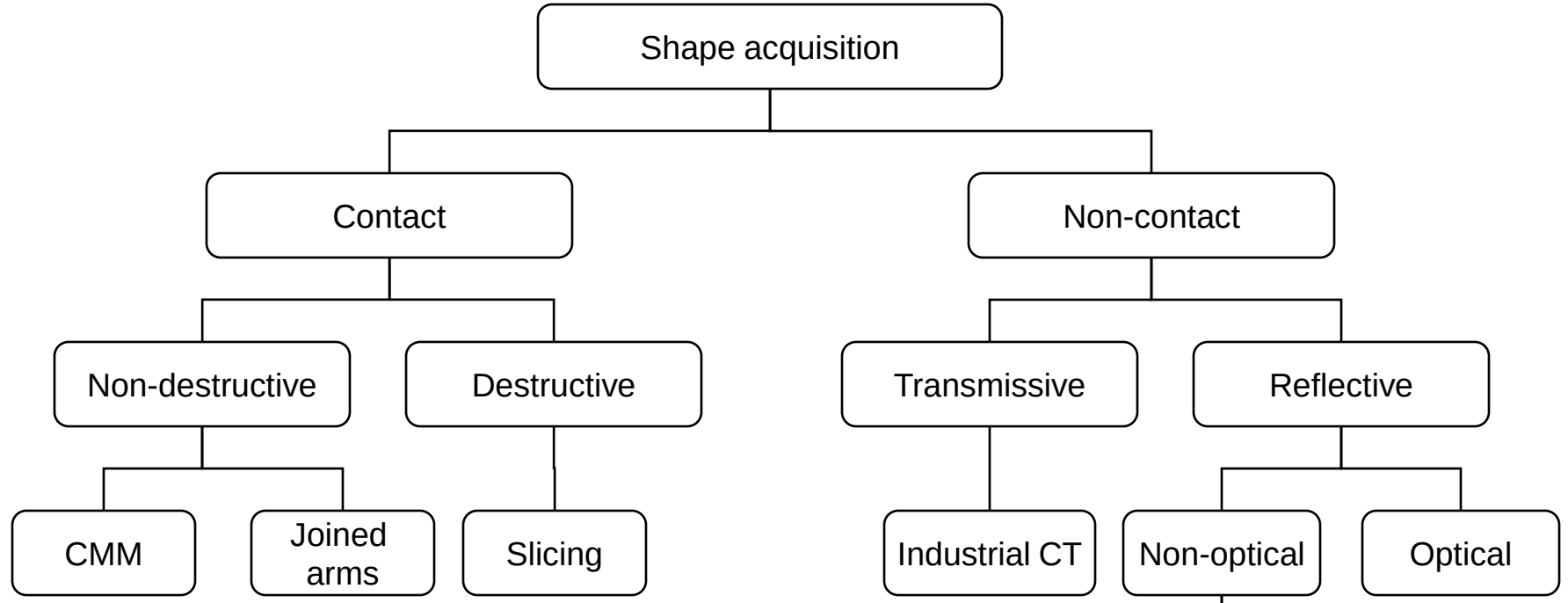
- **Three-dimensional data which is captured in computerized form from physical models or products**

- **Two main phases**
  1. Digitizing or measuring of a part
  2. Three-dimensional modeling of the part from the digitized data



General process of reverse engineering

Digitizing or Measuring Methods



Zeiss

Favo

CGI

Solutionix, 2002 CADCAM Workshop, Korea

Coordinate Measuring Machine (CMM)

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

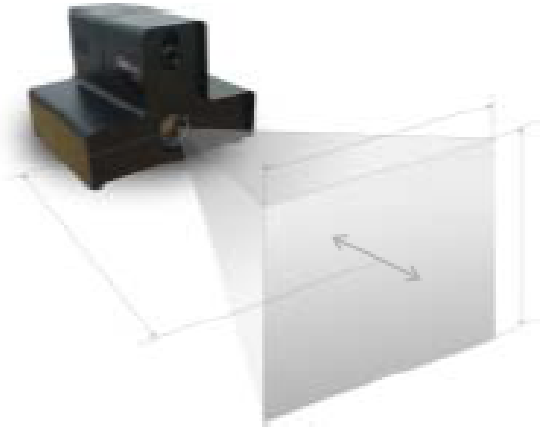
Browne & Sharpe, North Kingstown, Rhode Island

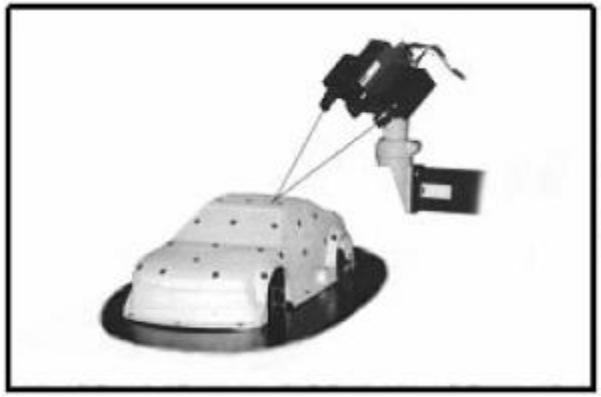
Jointed Arm

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

Scanners

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





Scanning Methods

- Optical
  - Passive
    - Stereo
    - Shape from Shading/focus
  - Active
    - Inteferometry
      - Moire
      - Holography
    - Triangulation

PointGrey

Geometrics

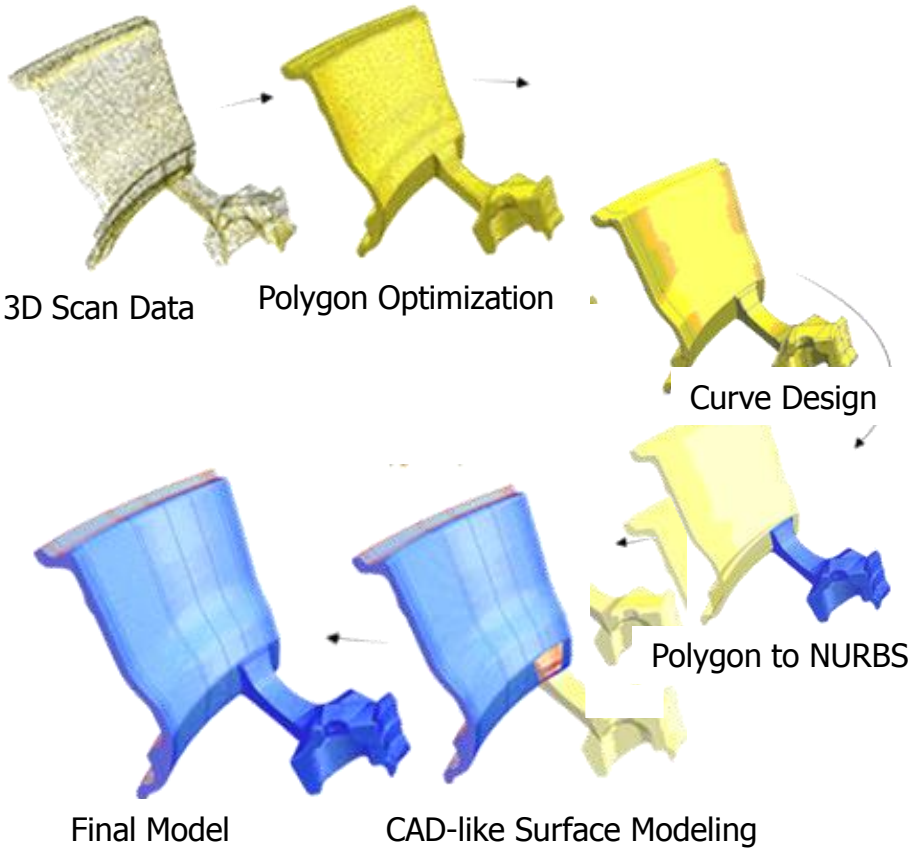
Intekplus

Solutionix, 2002 CADCAM Workshop, Korea

Scanners (cont.)

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

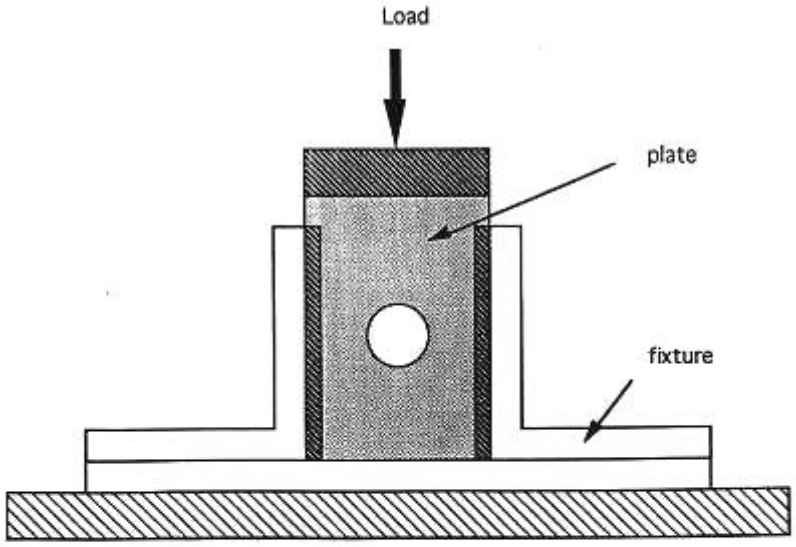
- **Cons**
  - Partial acquisition
  - Sensitive to surface roughness, transparency, shininess, color, variations, darkness, inter-reflections



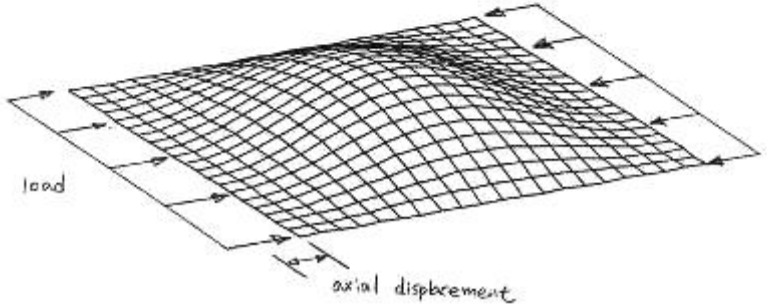
RapidForm, INUS

Moire interferometry

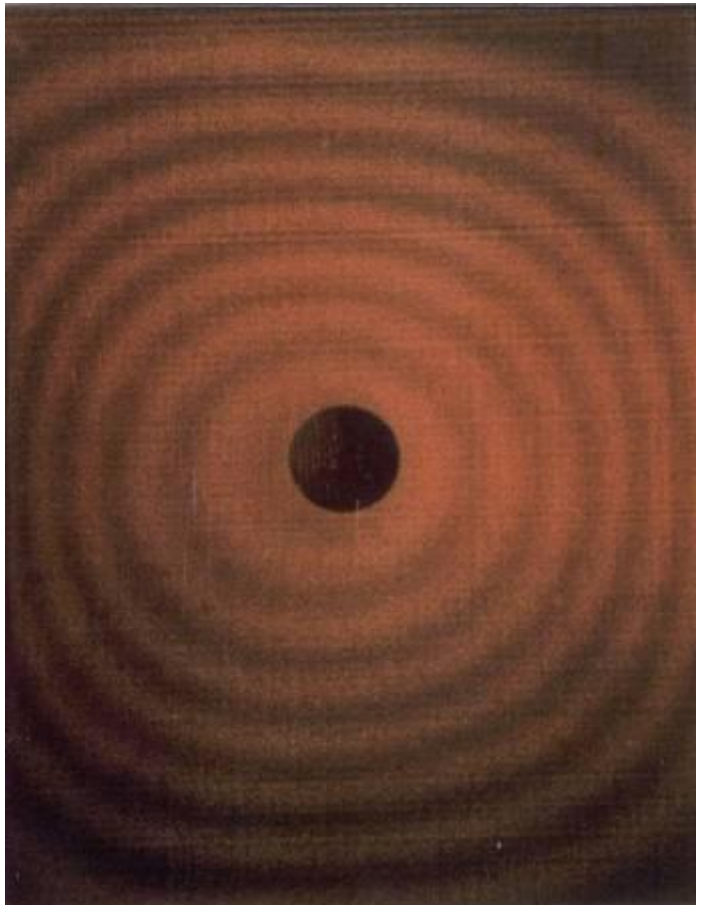
- **Example of buckled plate**



Specimen and fixture



Out-of-plane displacement of buckled plate

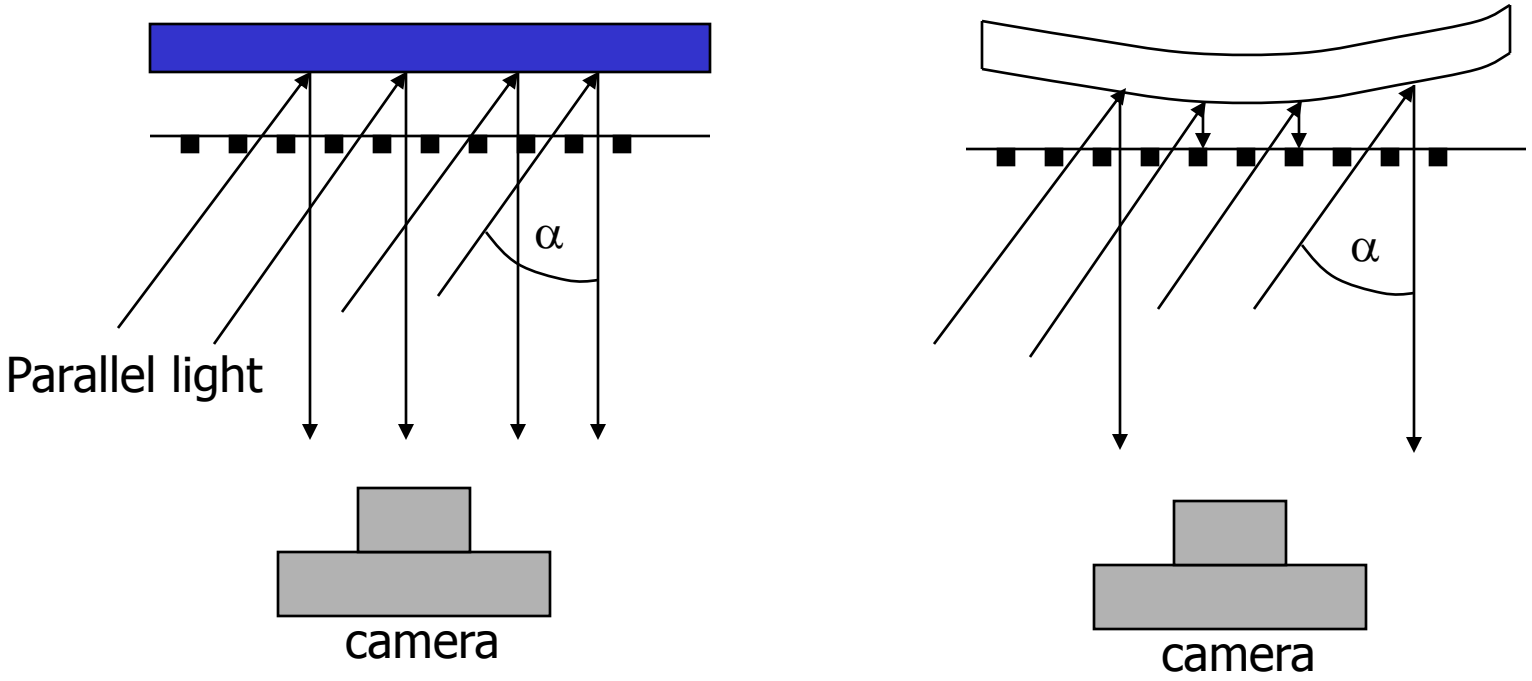


D=0.5 in at 900 lb

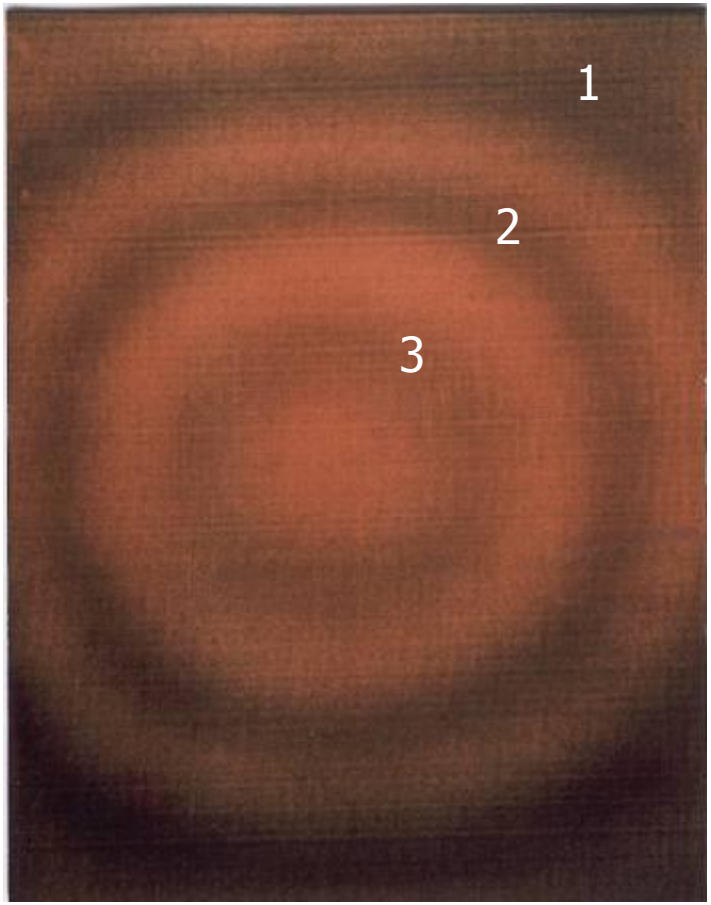
Shadow Moire interferometer

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

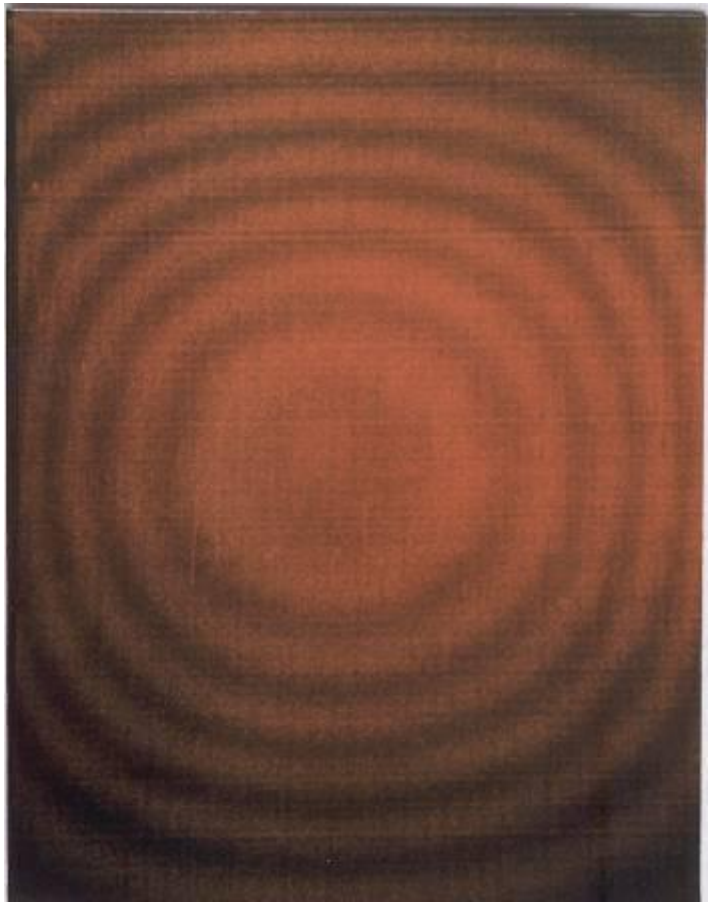
where d = grid density eg. 1mm gap



Out-of-plane deformation by fringes



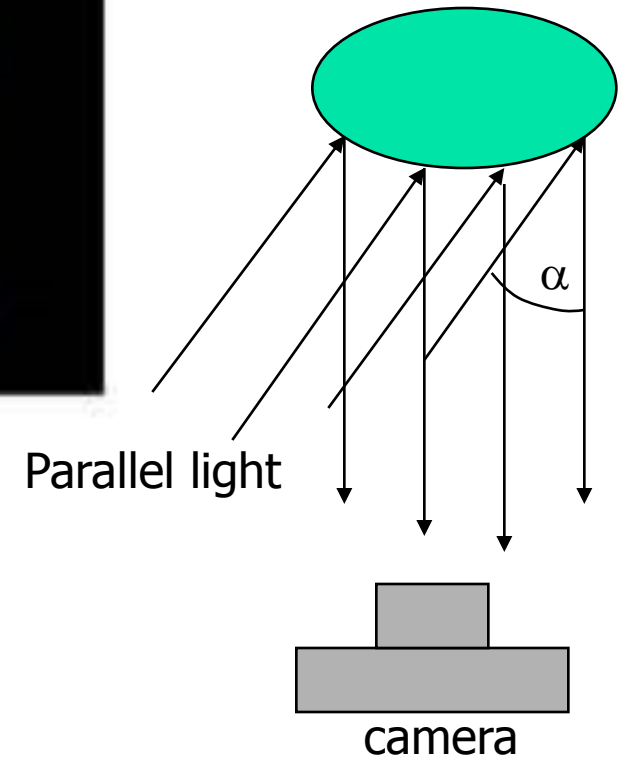
D=0 in at 700 lb



D=0 in at 900 lb

Moire type 3D scanner

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



Optical Triangulation Algorithm

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

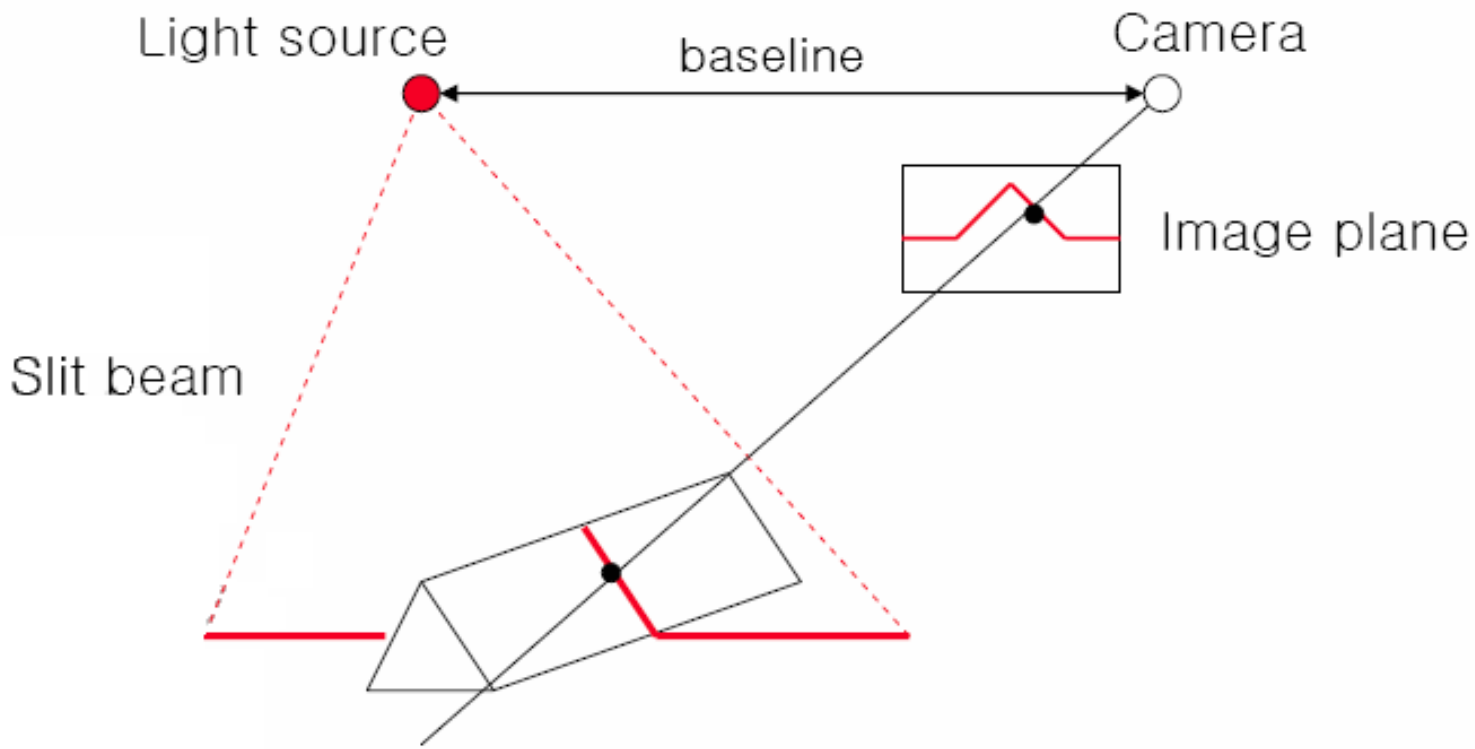
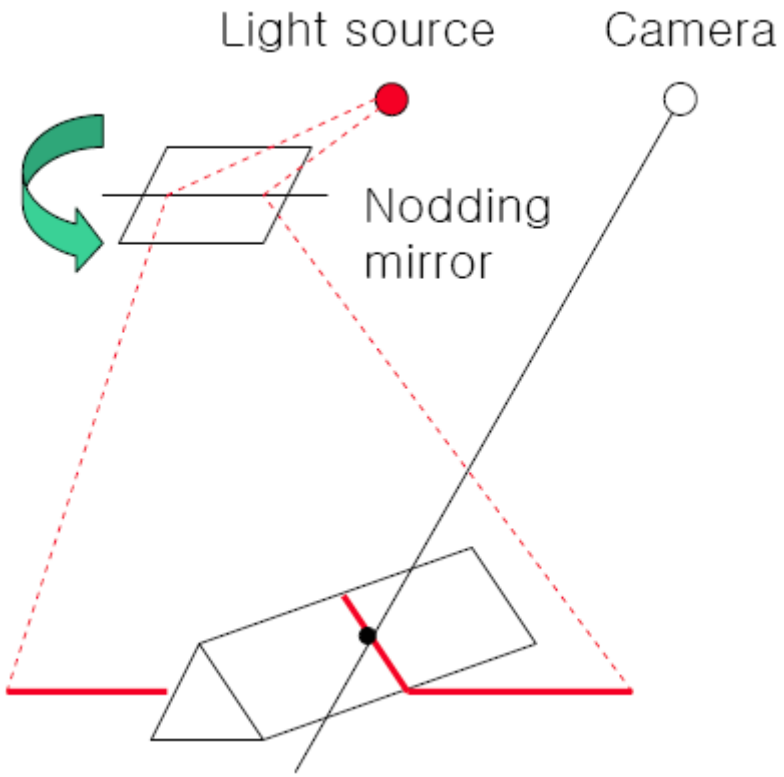


Diagram of triangulation algorithm

Laser Scan – Area

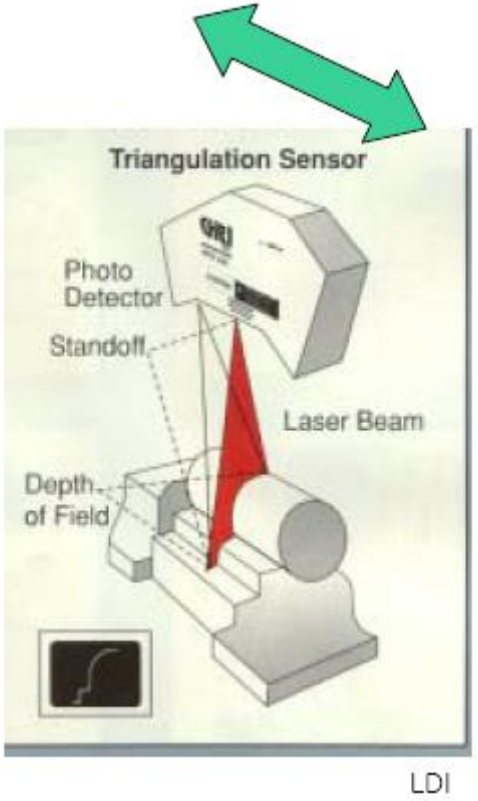
- **Camera is fixed while light source is moving**
- **Simple architecture**
- **Area scanning available**
- **For higher accuracy, accuracy of mechanical device is important**



Laser area scan

Laser Scan – Line

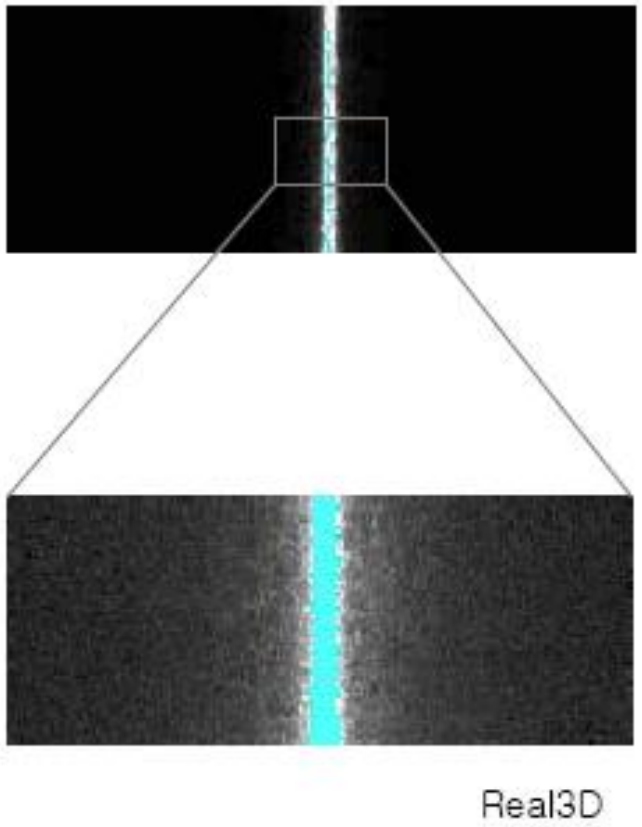
- **Camera and light source are moving simultaneously**
- **Uniform resolution can be achieved**
- **Complex hardware configuration**



Laser area scan

Laser Scan (cont.)

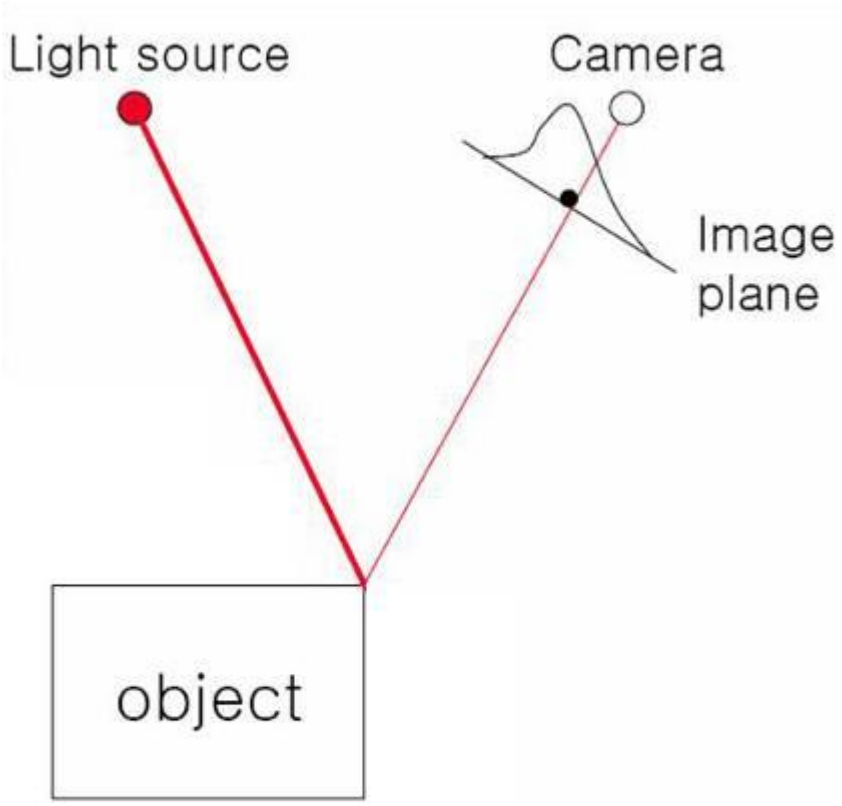
- **Pros**
  - Good depth to various profile
  - Small energy consumption
- **Cons**
  - Hazardous to human eyes
  - Line scan: long scanning time
  - Area scan: difficult to calibrate
  - Shape edge problem

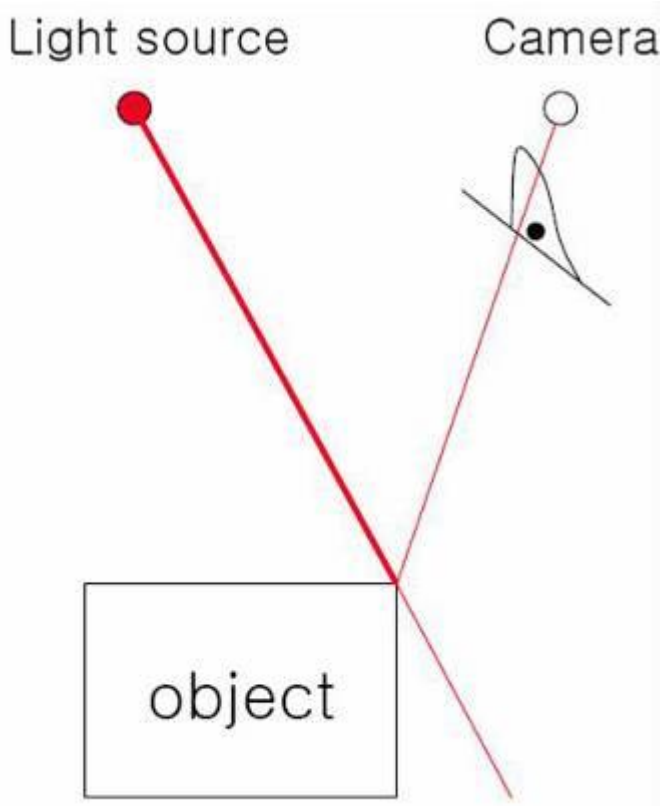


Laser on the object

Shape Edge Problem

- **Slit beam on edges**





Laser Scan – Example

Cyberware

Line laser +
Liner robot

3dscanners

Line laser +
Articulated arm

Steinbichler

Line laser +
Gyroscope

Spatial Encoding

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

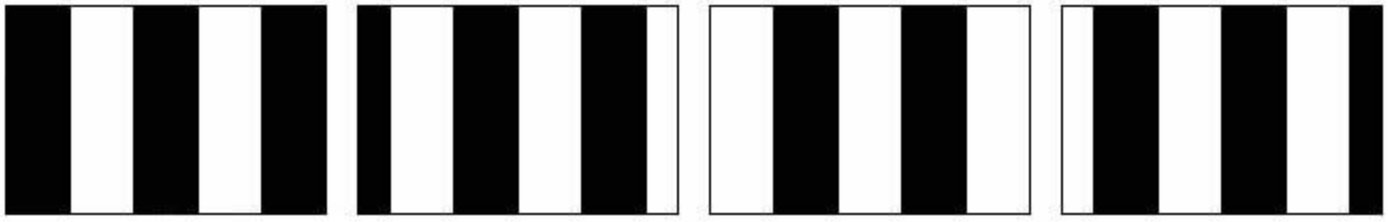
Graycode pattern

부호화한 패턴이 투영된 모습

측정 결과

Spatial Encoding + Phase shifting

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



Phase shifting pattern

Spatial Encoding (cont.)

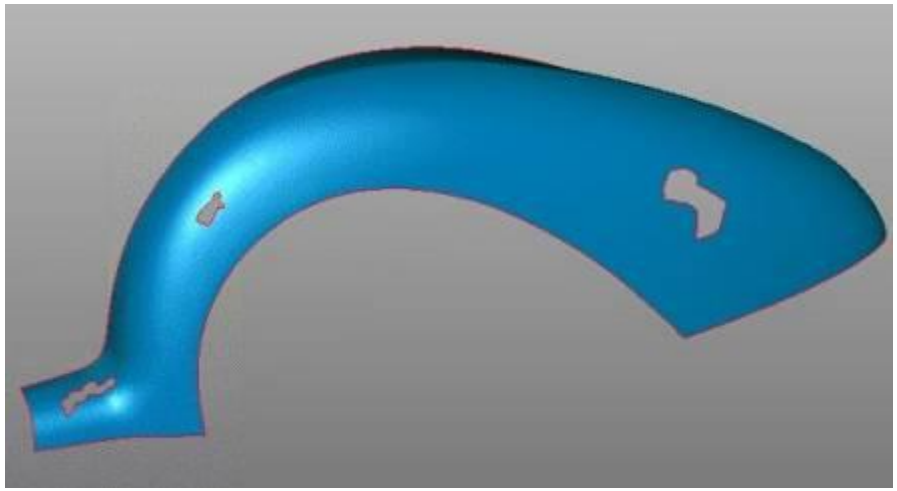
- **Pros**
  - Safe to human eyes
  - Fast scanning
  - High resolution
  - Less shape edge problem than laser scan

- **Cons**
  - Worse depth than laser
  - Large amount of energy consumption

Issues of Using Scanning data

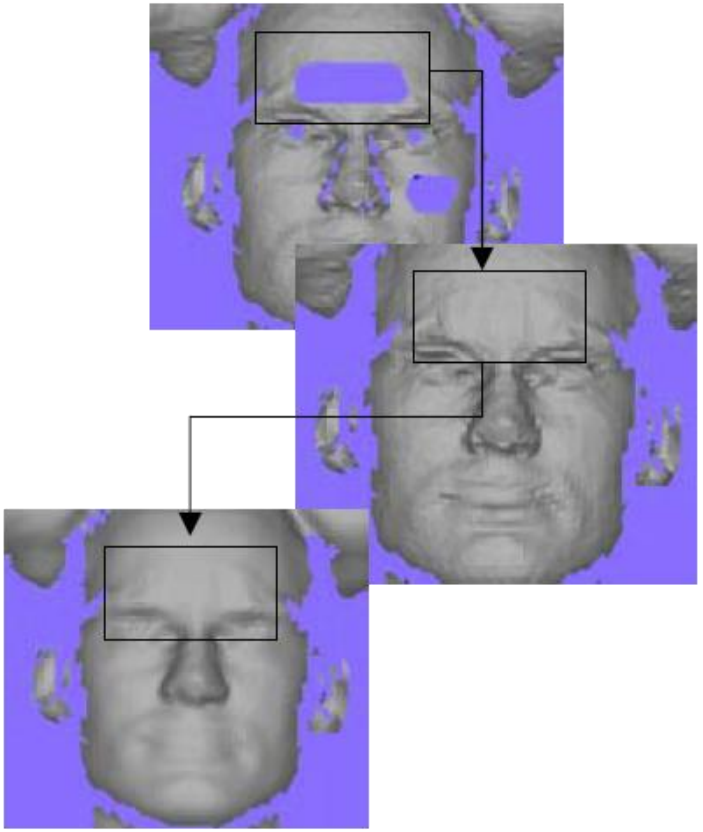
- **Scan data may have some errors such as hole, overlapped area**

- **Filling holes in polygons**



RapidForm, INUS

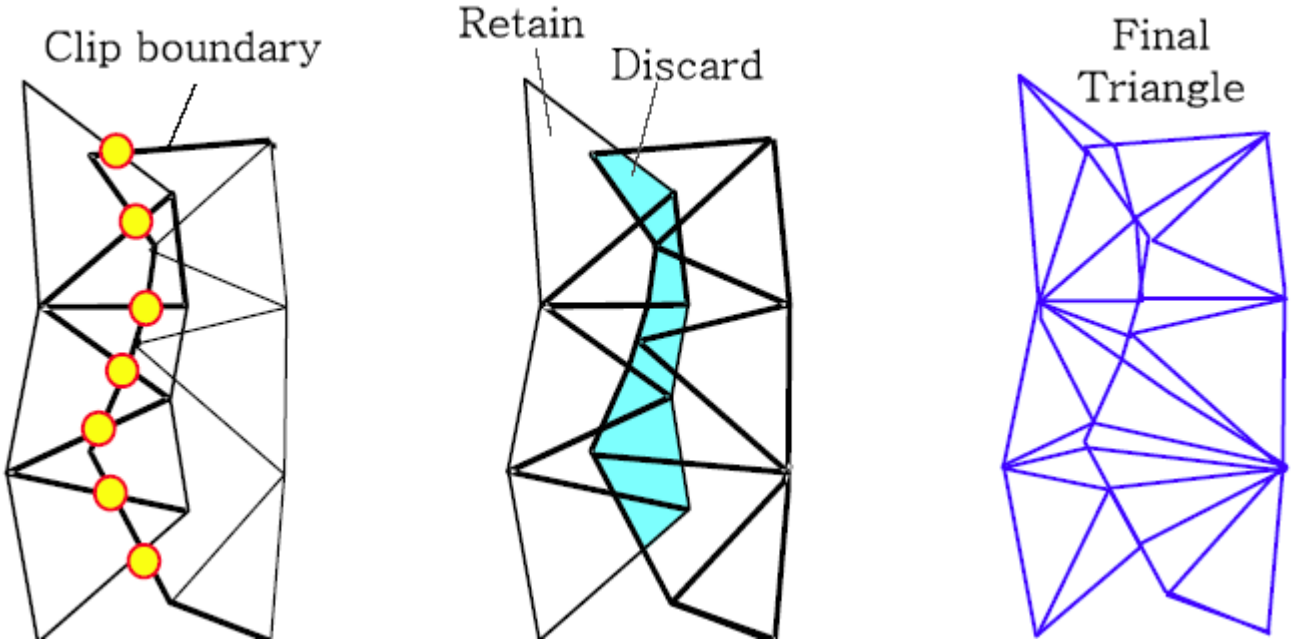
Holes in generated polygon from scan data



Hole filling process

Issues of Using Scanning data (cont.)

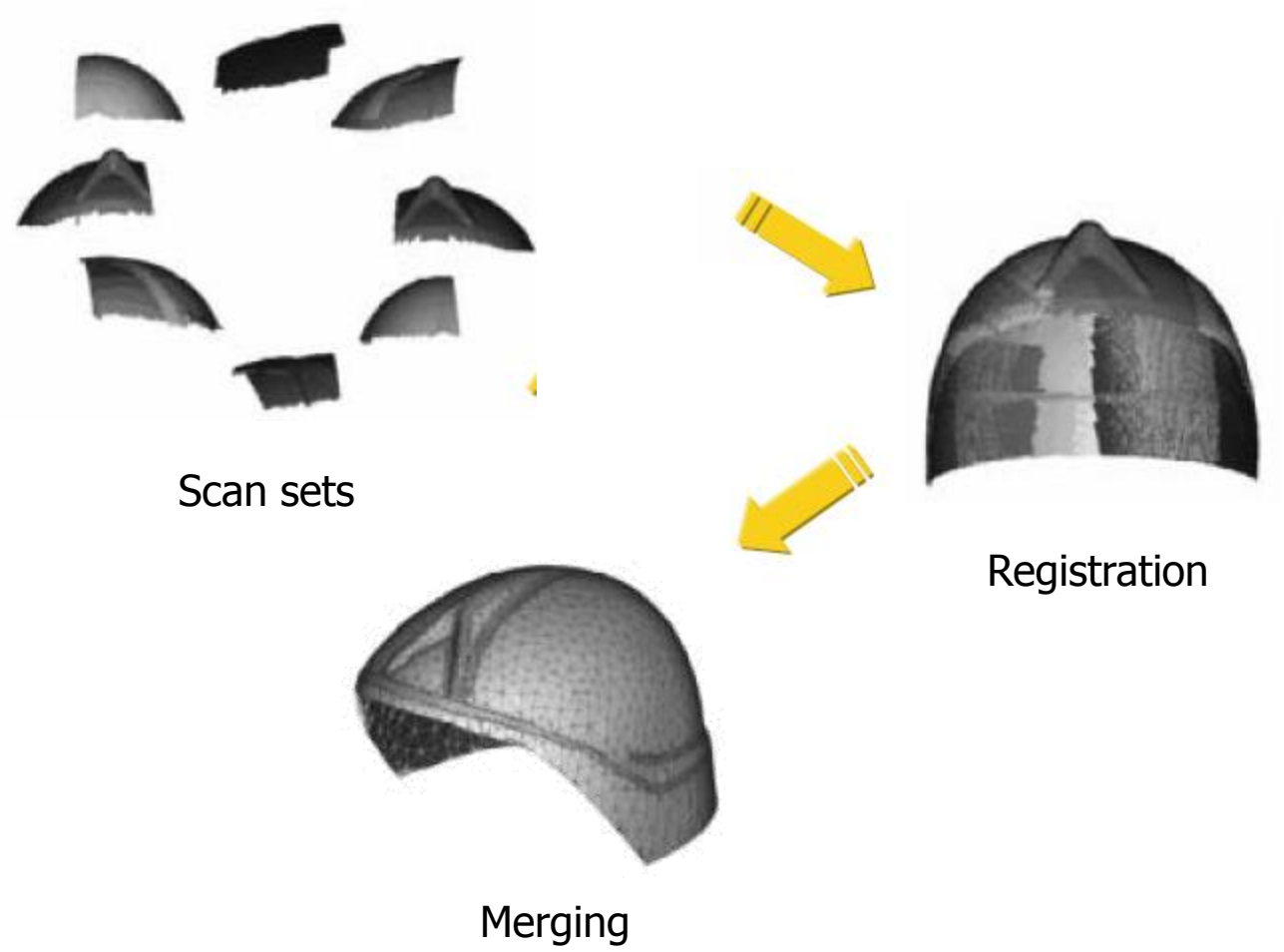
- **Merging overlapped areas**



Merging overlapped area in software

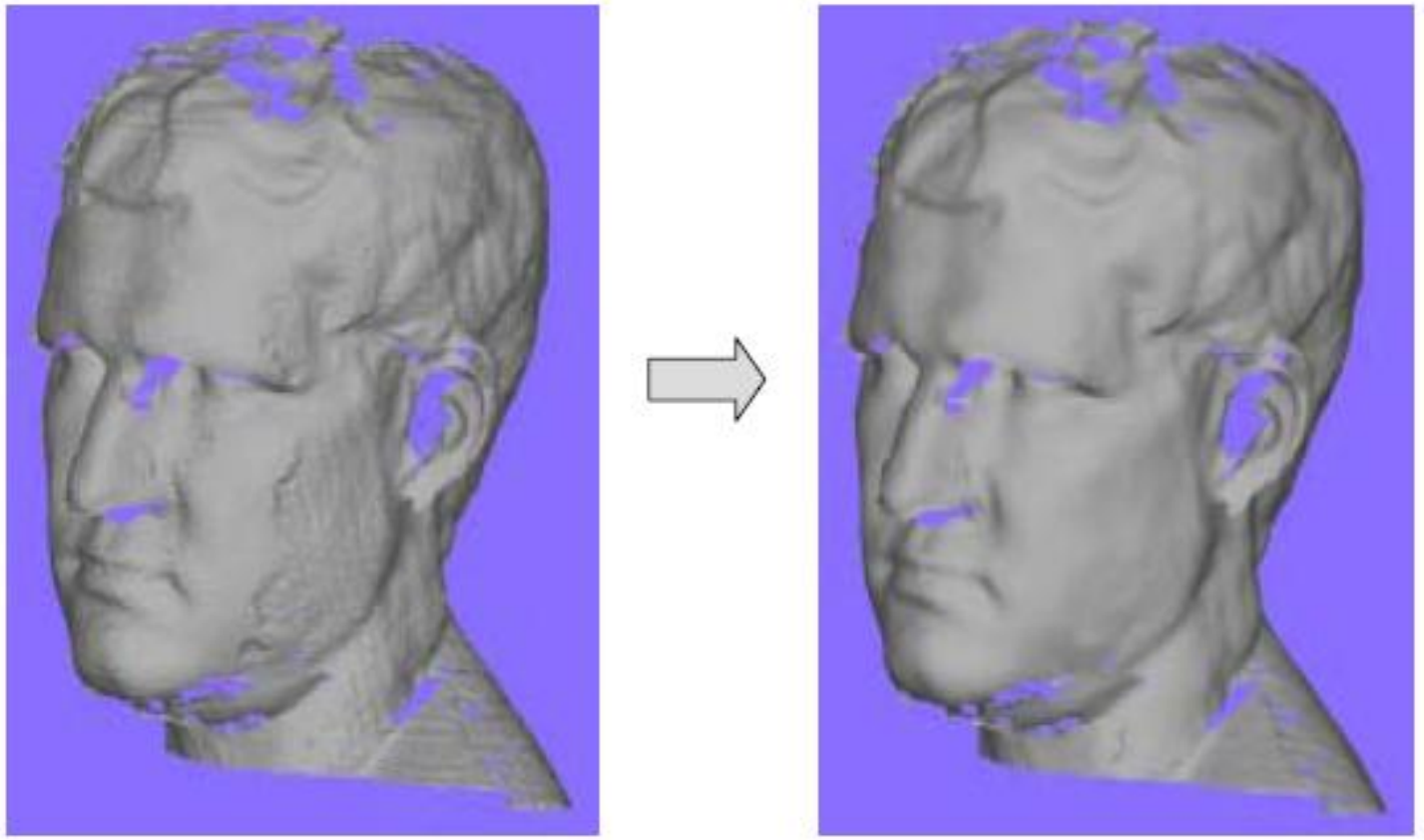
Issues of Using Scanning data (cont.)

- **Registration/Merging**



Issues of Using Scanning data (cont.)

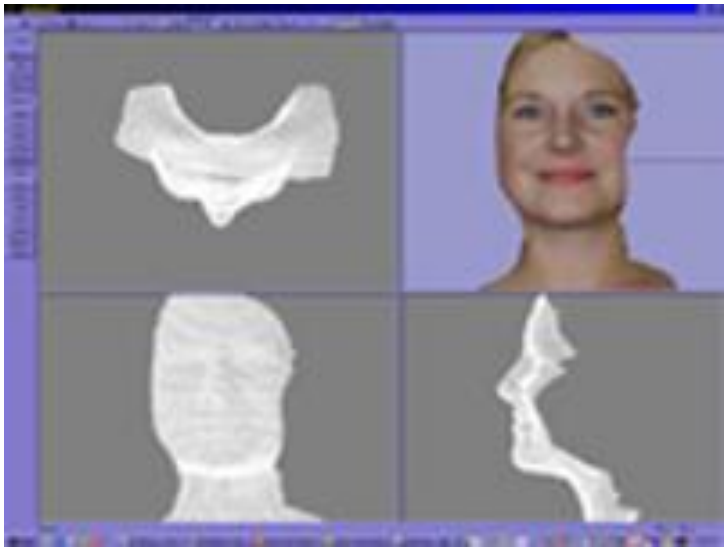
- **Smoothing**



3D Scanner

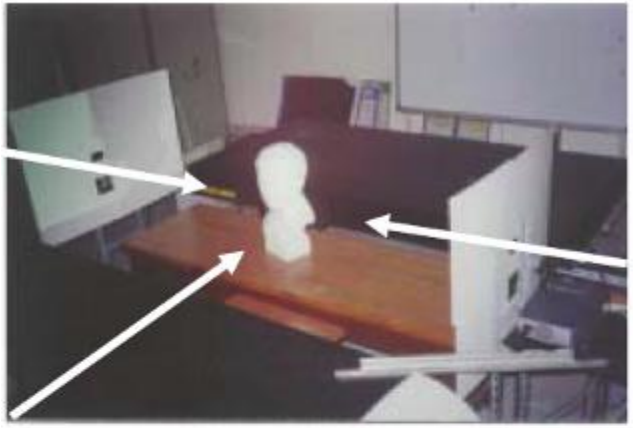
- **Input device to read physical geometry into CAD format**

3D scanning device



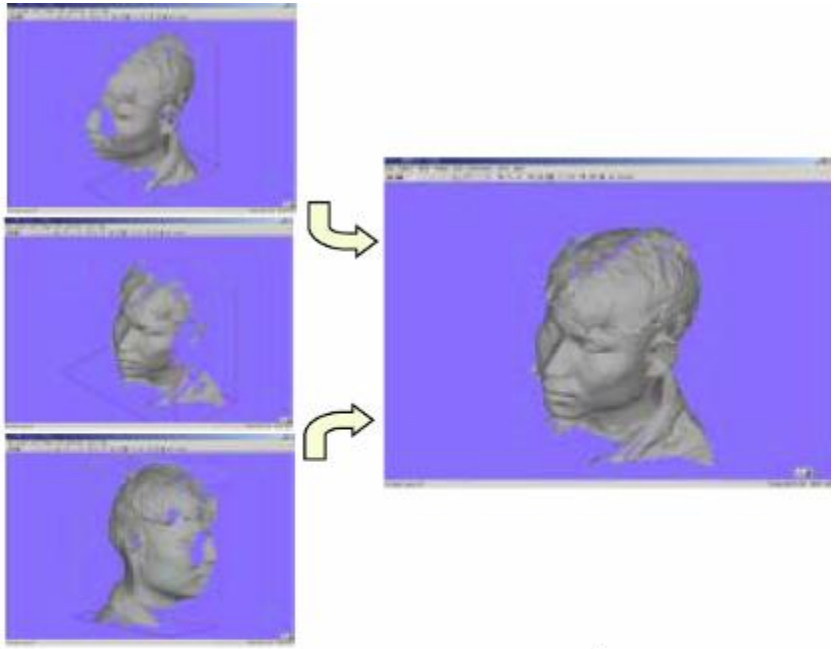
Manipulator software

Replica of Human Face



Scanning

Triangulation

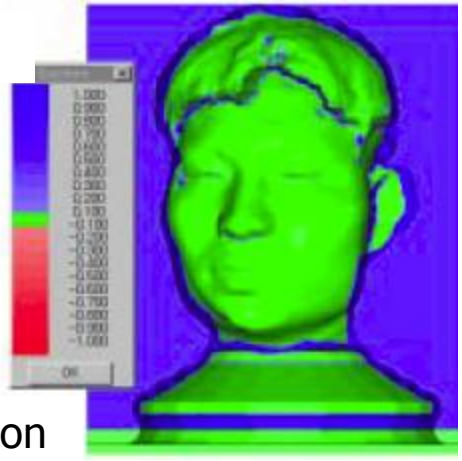


Registering/Merging

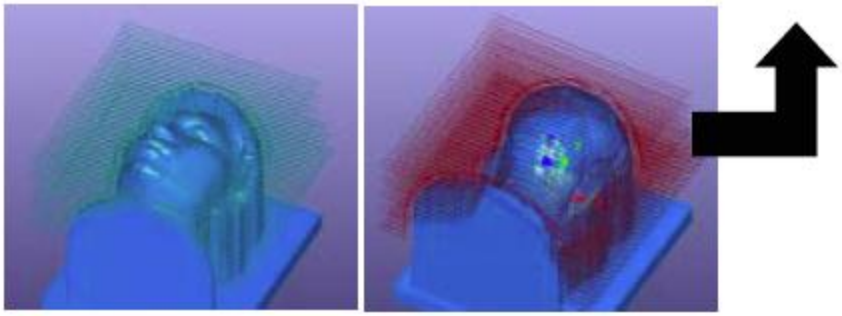
Replica of Human Face (cont.)

Geometry Processing

NC Machining



Error Comparison



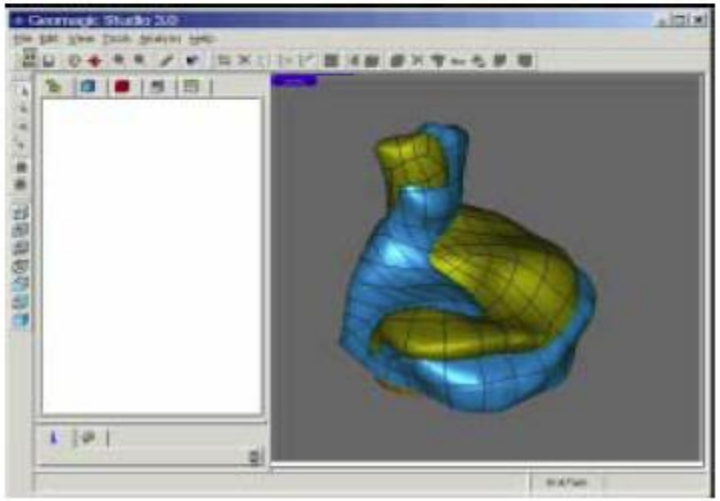
NC Toolpath

3D Scanner (cont.)

- **Demo**

Applications

Scan Geomagic Print



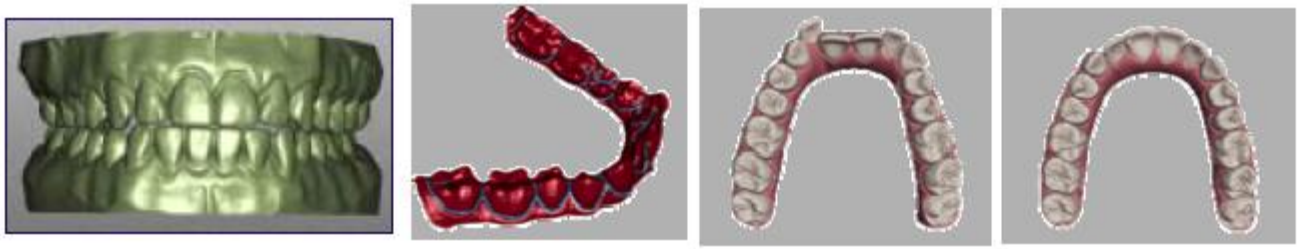
Custom Made Hearing Solution

Applications (cont.)

Orthodontists

Manufacturer

Mass Customization : Orthodontics

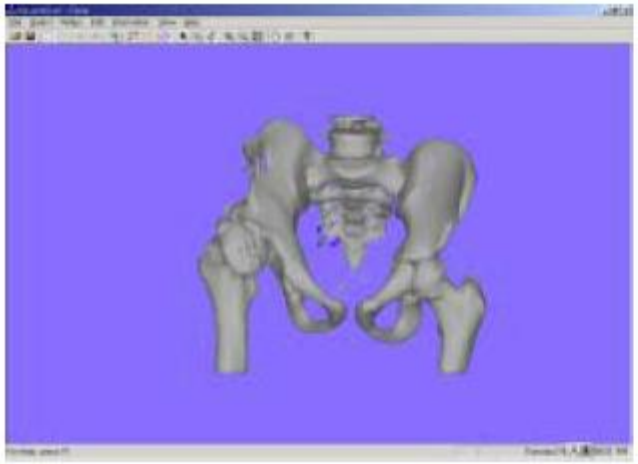


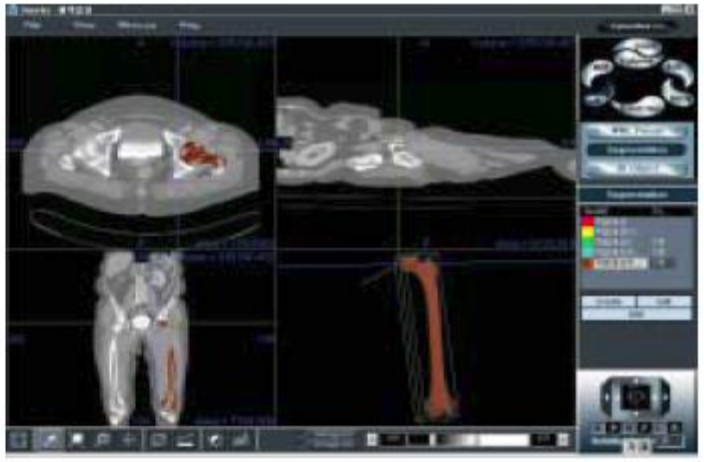
Applications (cont.)

- **Medical**
  - Mechanical Bones
  - Virtual Surgery

Applications (cont.)

- **Medical**





Applications (cont.)

- **3D photography model for e-commerce**