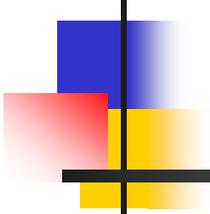


2006-02 CAD/CAM



# Reverse Engineering (RE)

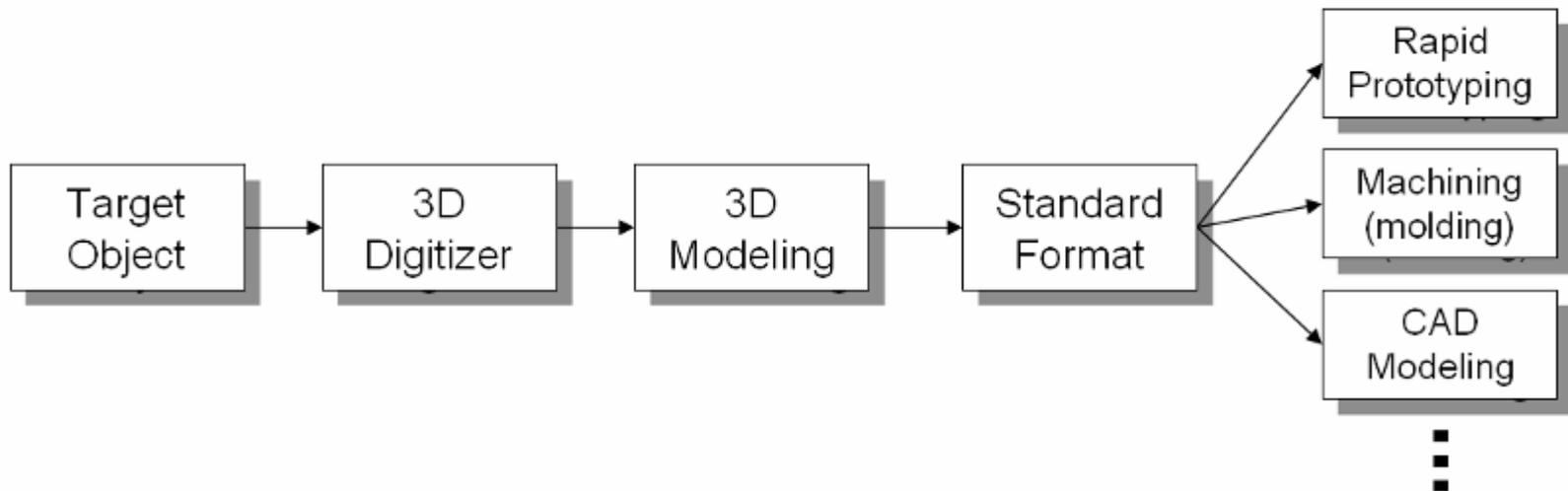
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Prof. Sung-Hoon Ahn

2006-11-13

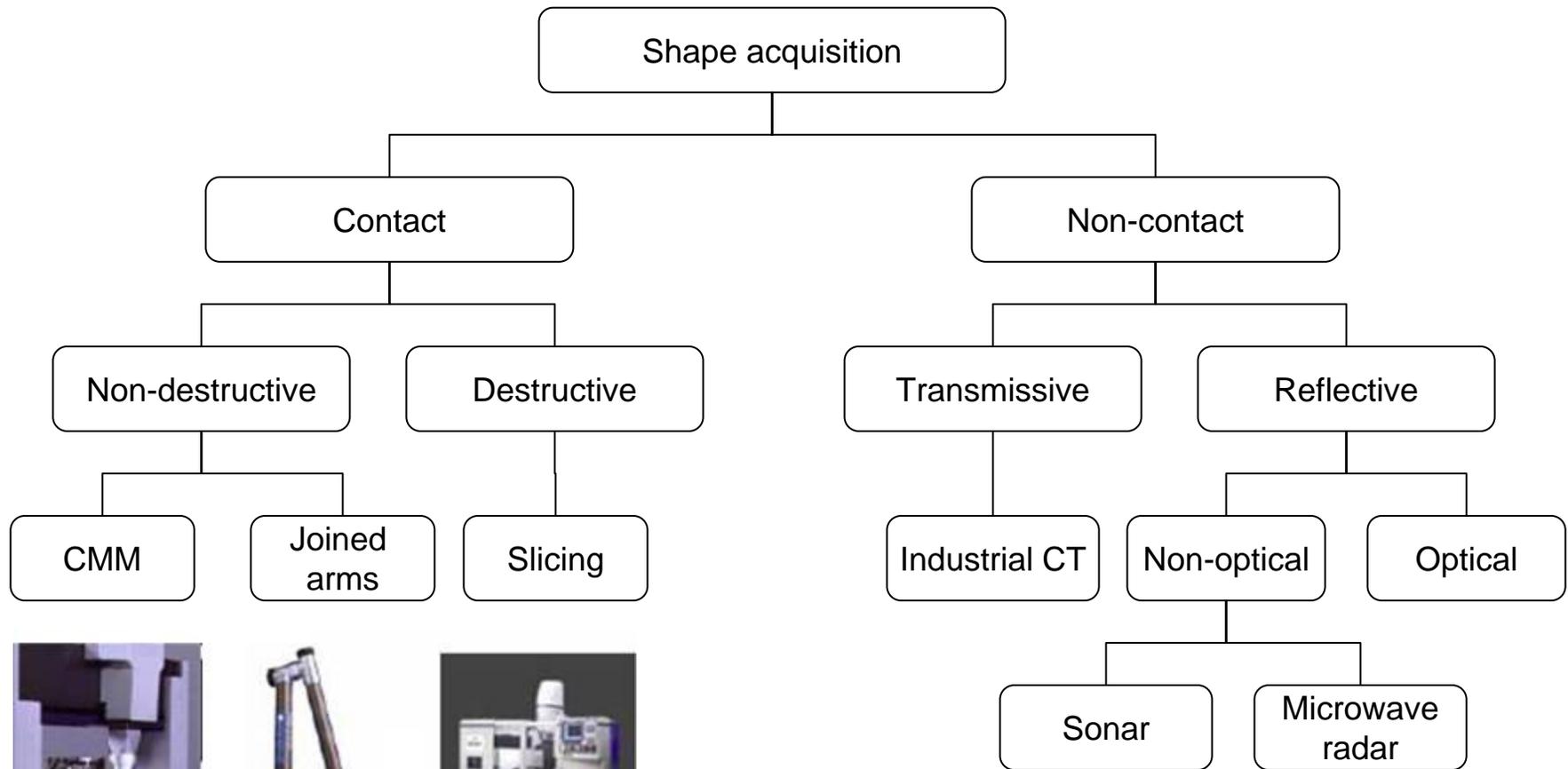
# Introduction of RE

- 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

# 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

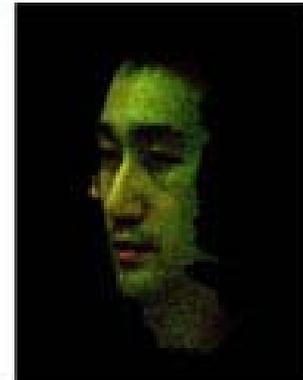
- Phantom Arm haptic finger device
  - Pointing tool on a virtual model.
  - Allows dynamic 3D modification.



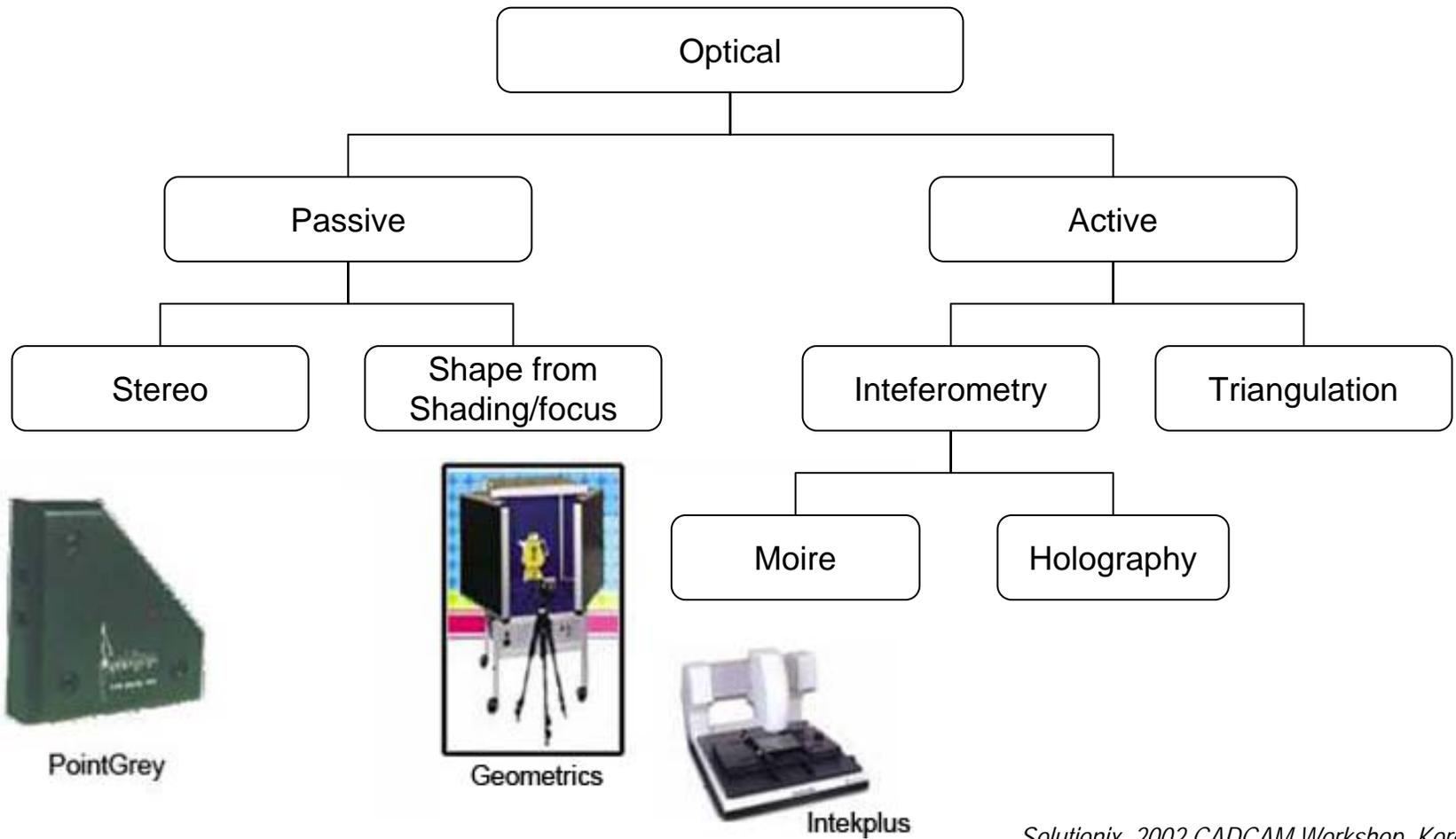
Source: SensAble

# Scanners

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



# Scanning Methods



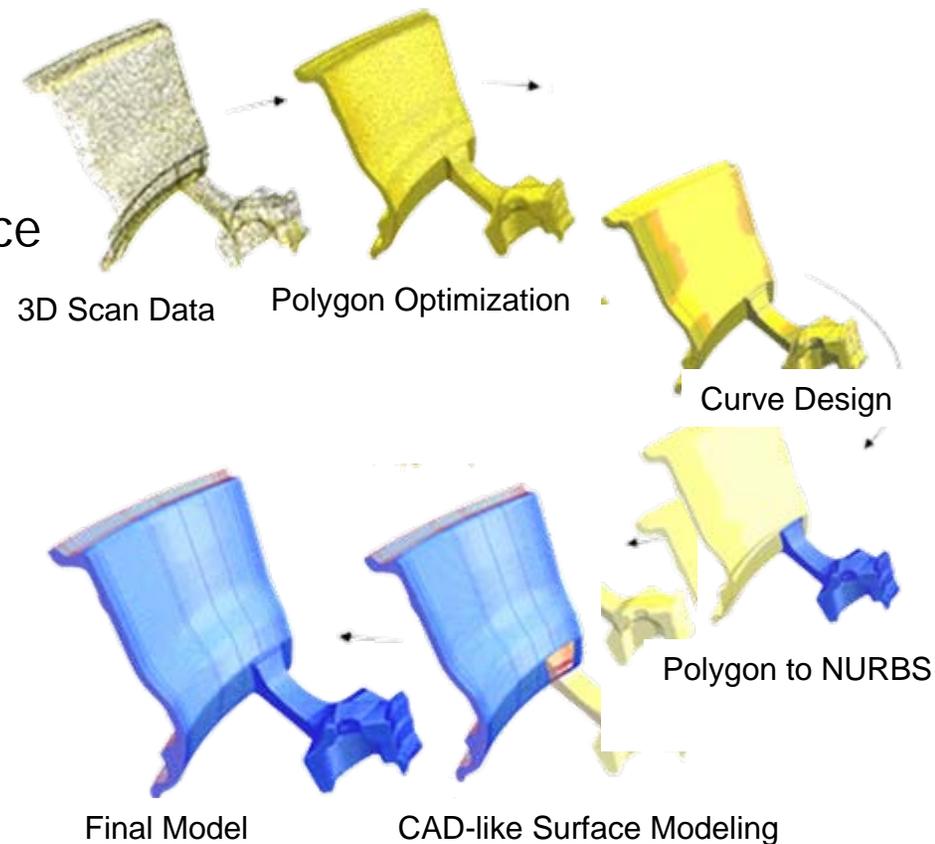
# Scanners (cont.)

## ■ 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



# Moire interferometry

- Example of buckled plate

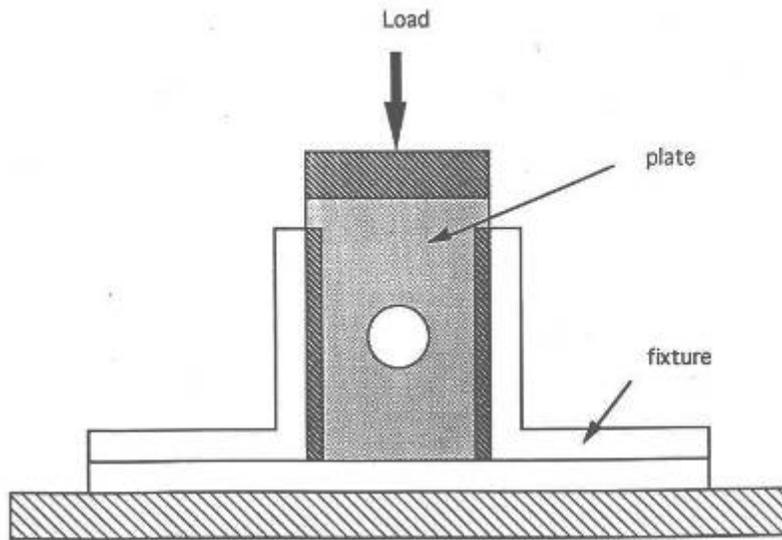


Fig.2.1 Specimen and fixture

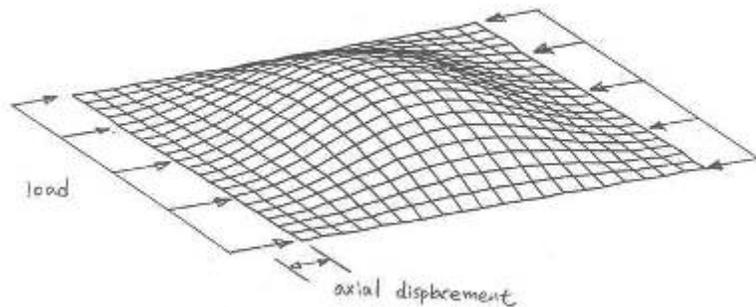


Fig.2.2. Out-of-plane displacement of buckled plate

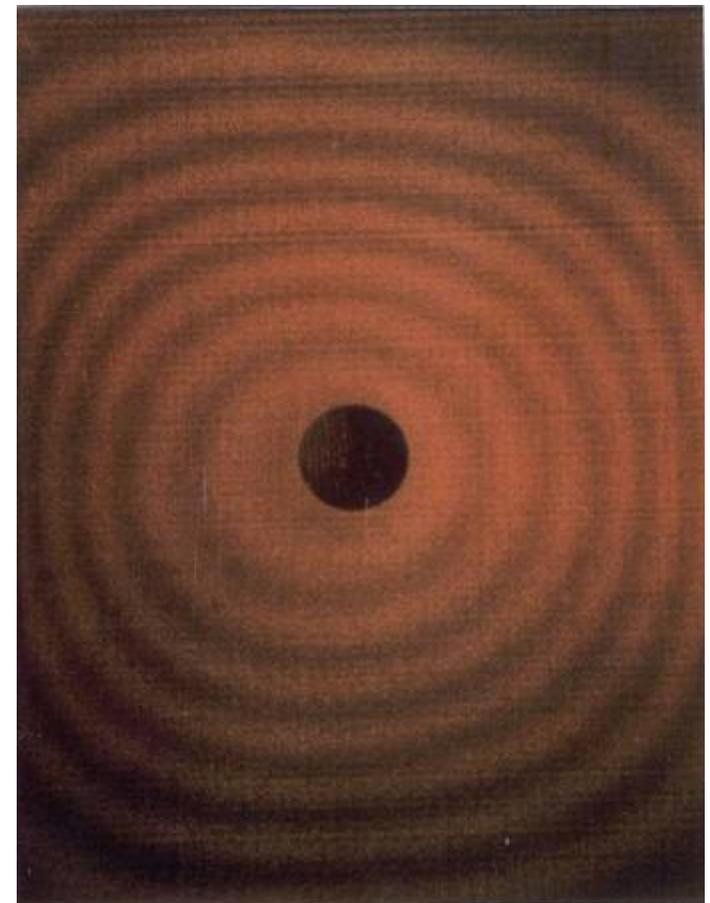
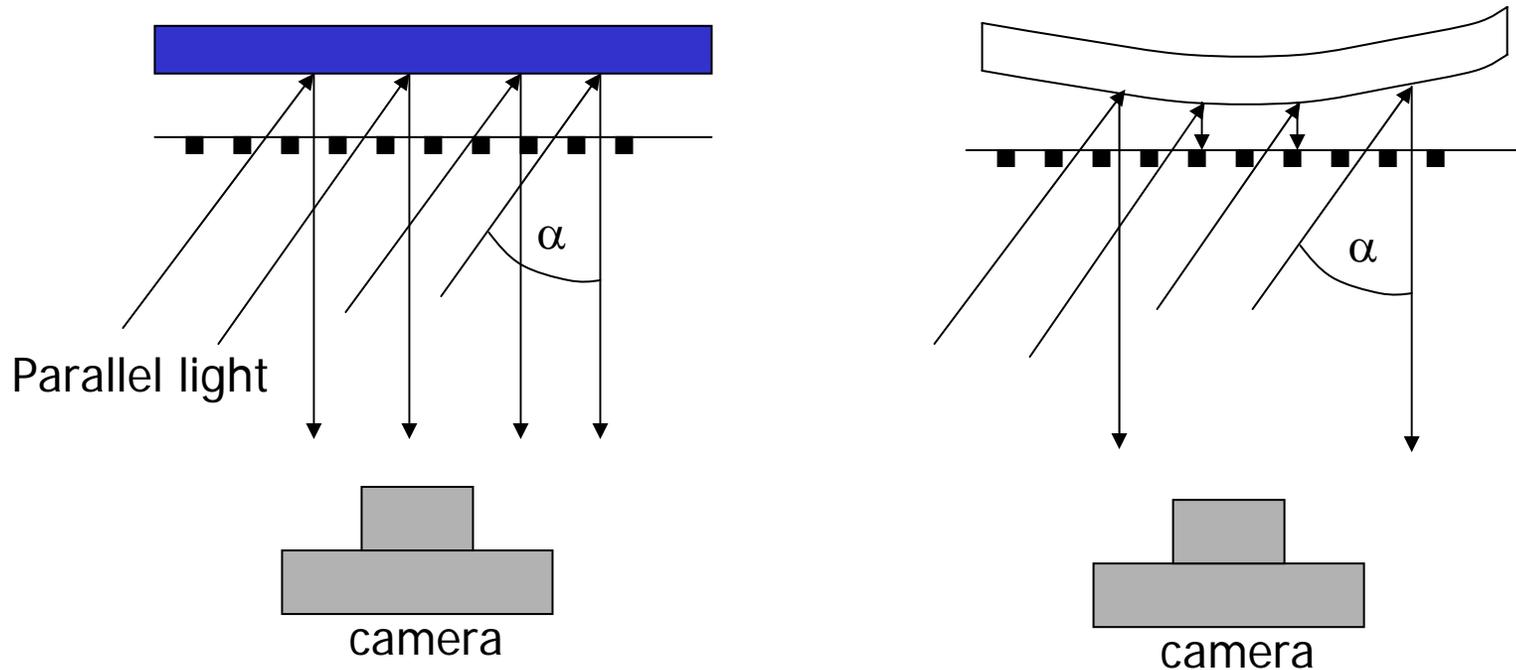


Fig.3.5 D=0.5 in @ 900 lb

# Shadow Moire interferometer

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

where  $d$  = grid density eg. 1mm gap



# Out-of-plane deformation by fringes

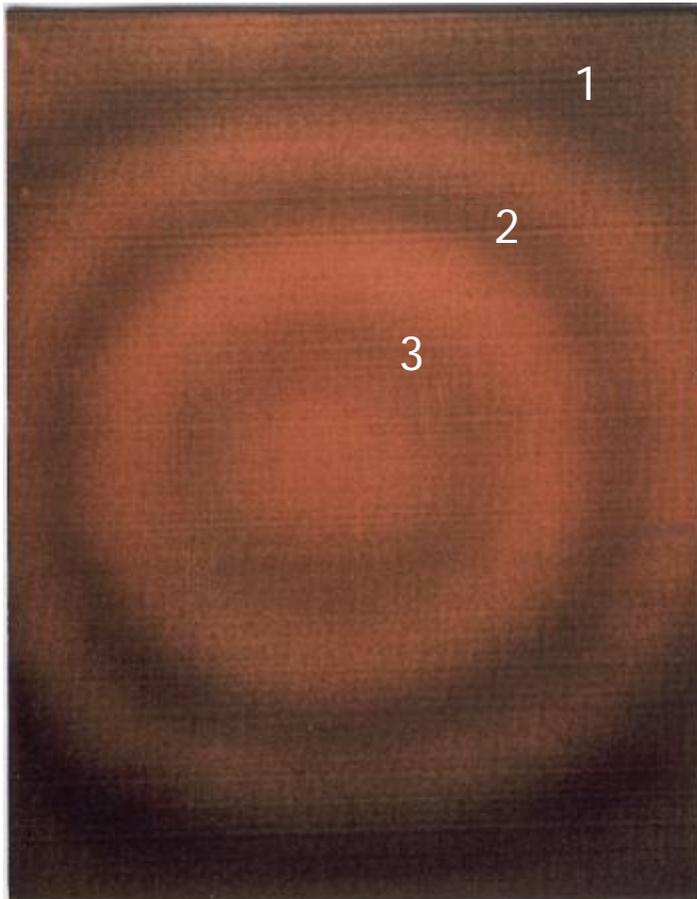


Fig.3.2  $D=0$  in @ 700 lb

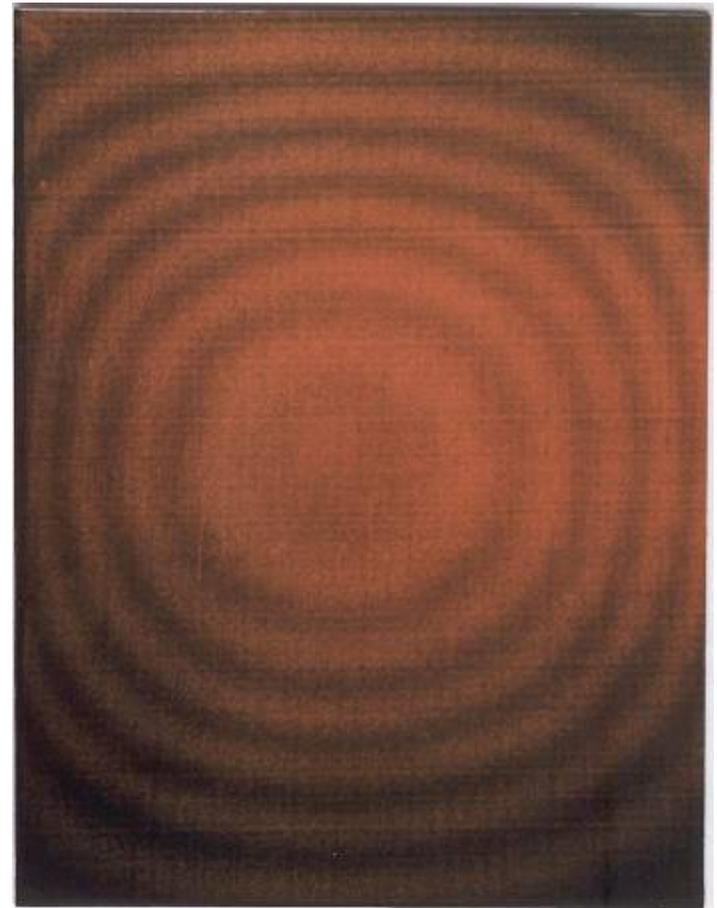
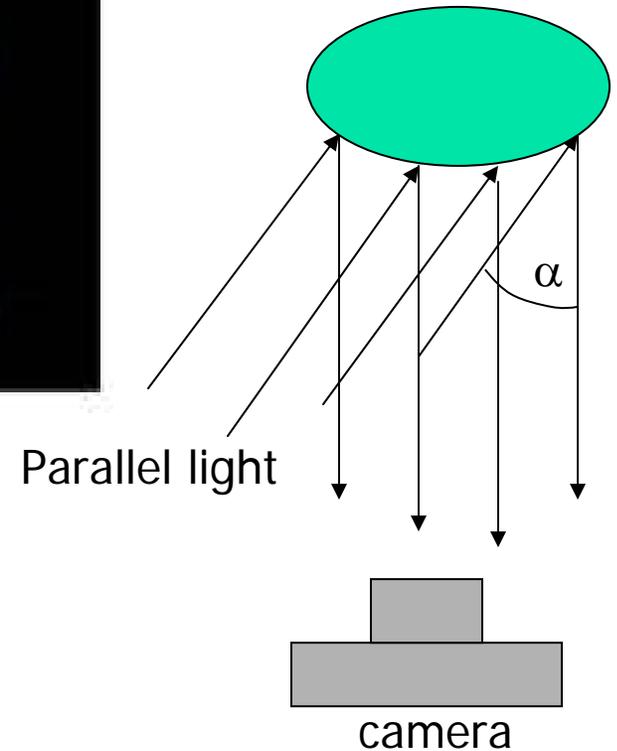


Fig.3.3  $D=0$  in @ 900 lb

# 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

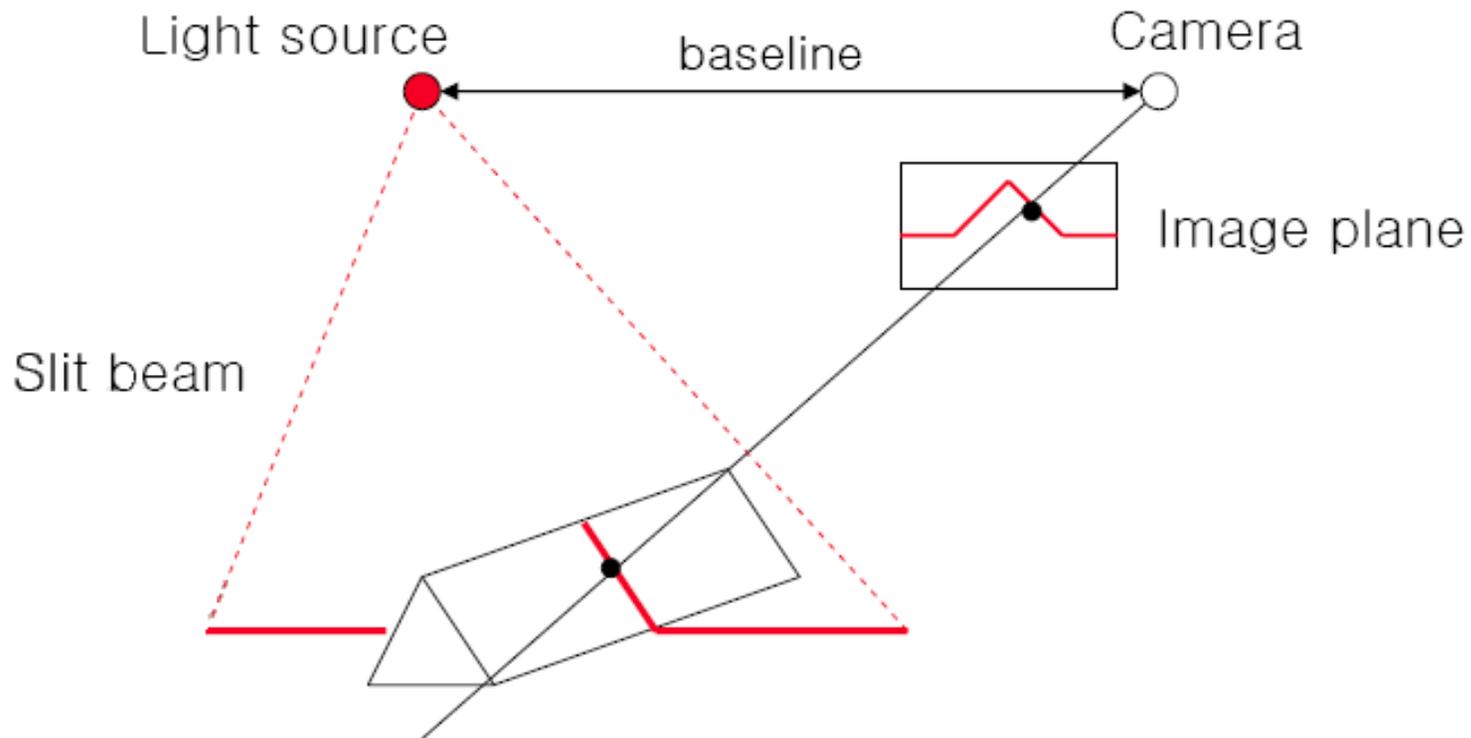
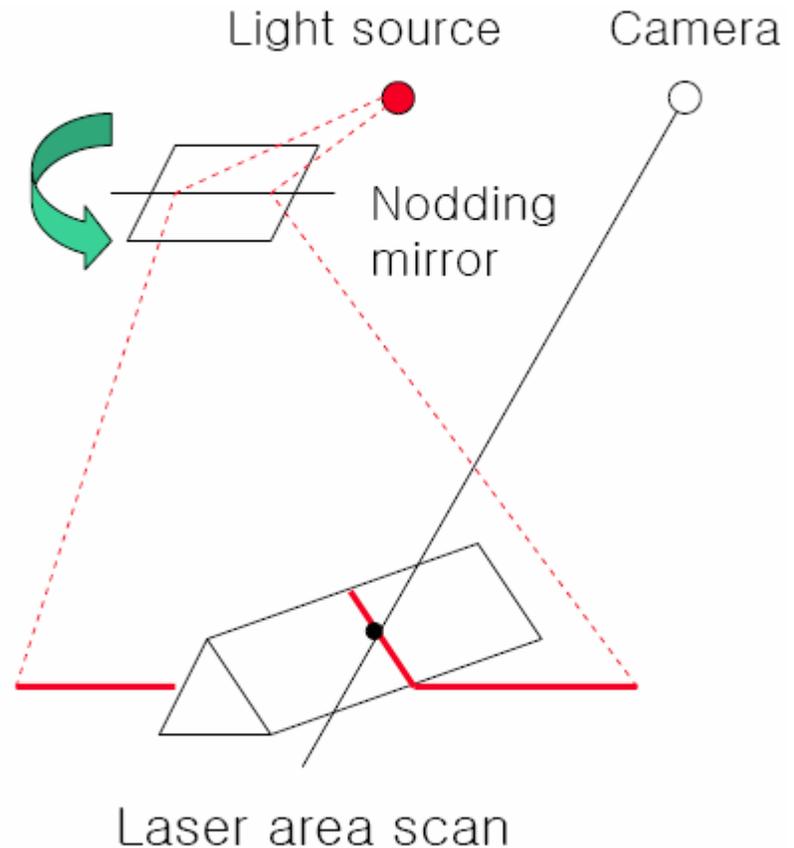


Diagram of triangulation algorithm

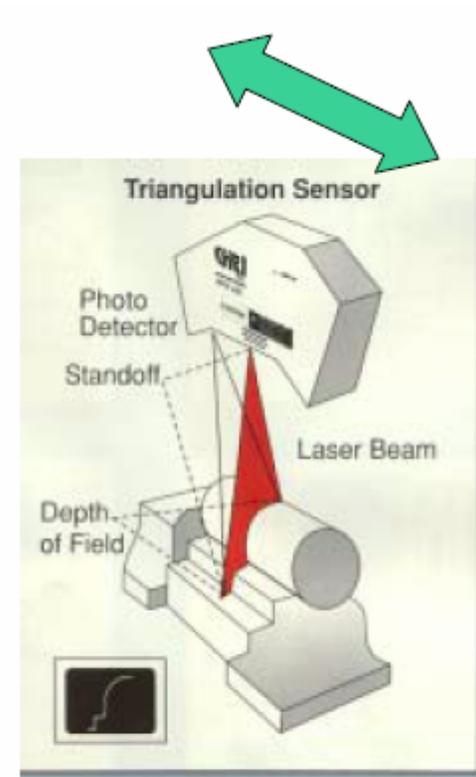
# Laser Scan – Area

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



# Laser Scan – Line

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



LDI

Laser line scan

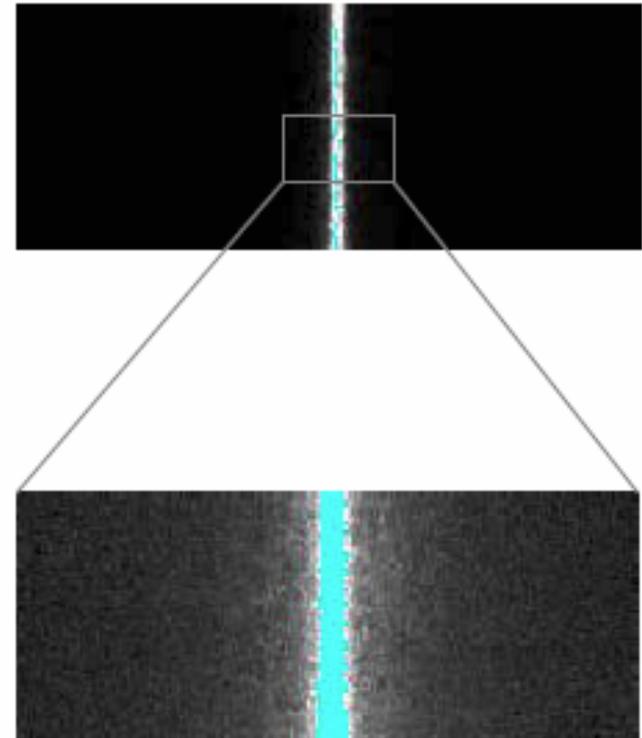
# Laser Scan (cont.)

## ■ 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

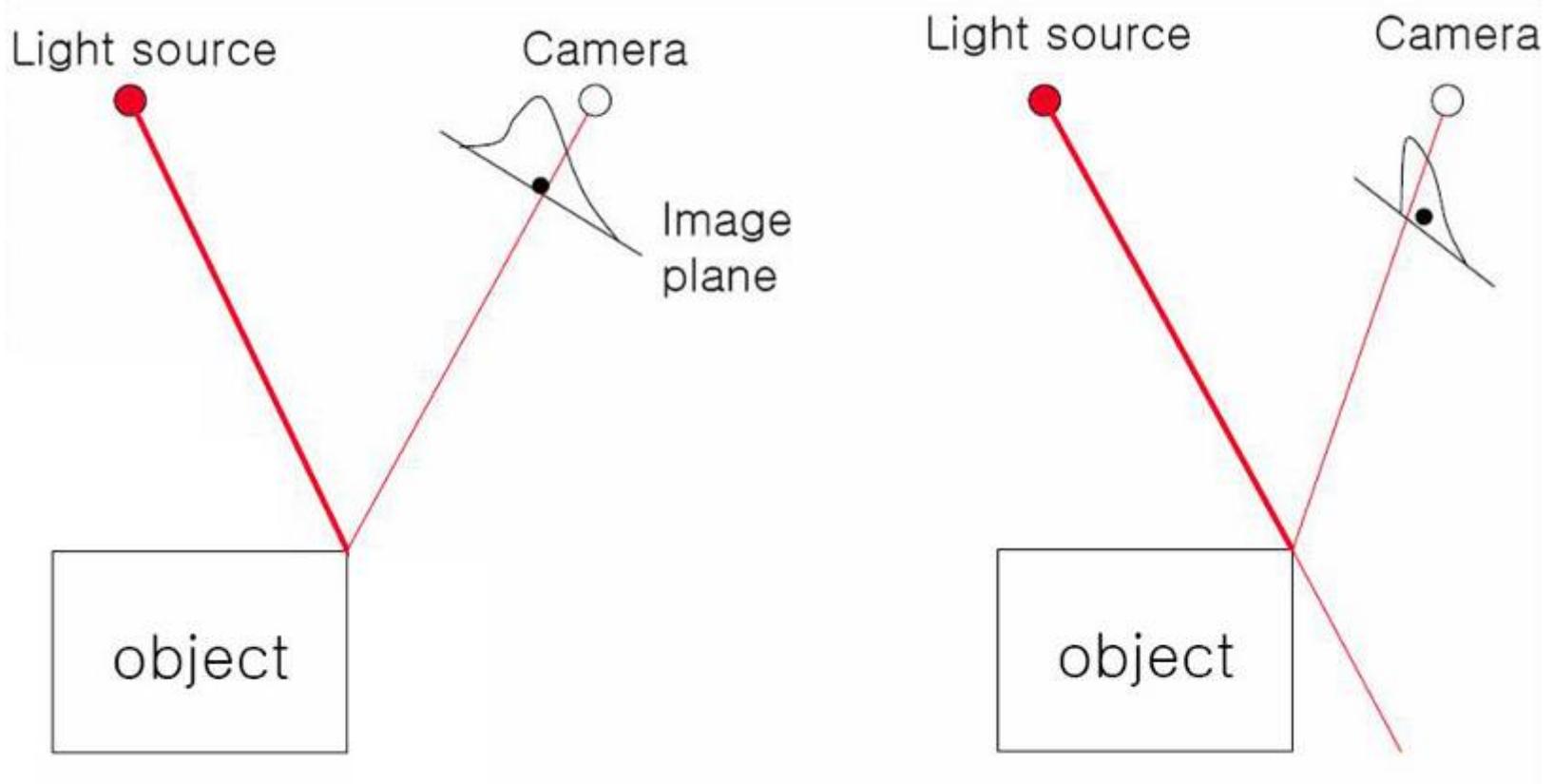


Real3D

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

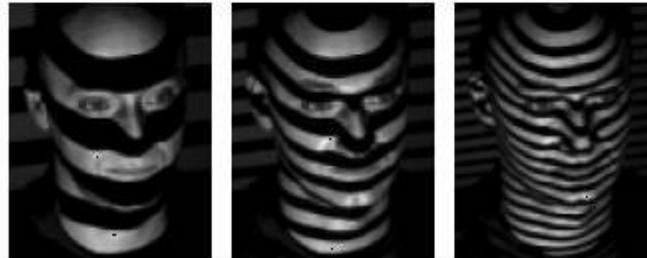
Line laser +  
Gyroscope

# Spatial Encoding

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



Graycode pattern



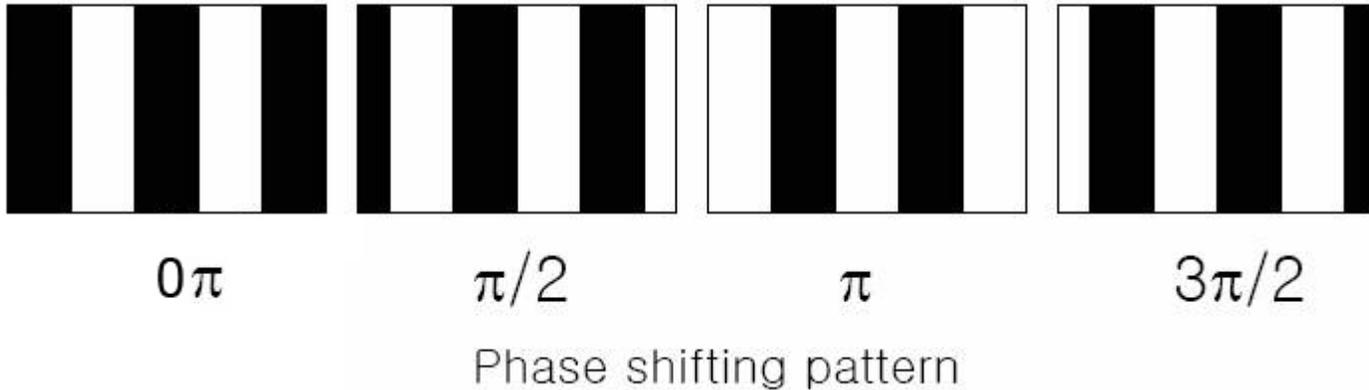
부호화한 패턴이 투영된 모습

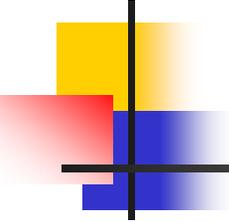


측정 결과

# Spatial Encoding + Phase shifting

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





# Spatial Encoding (cont.)

---

- Pros

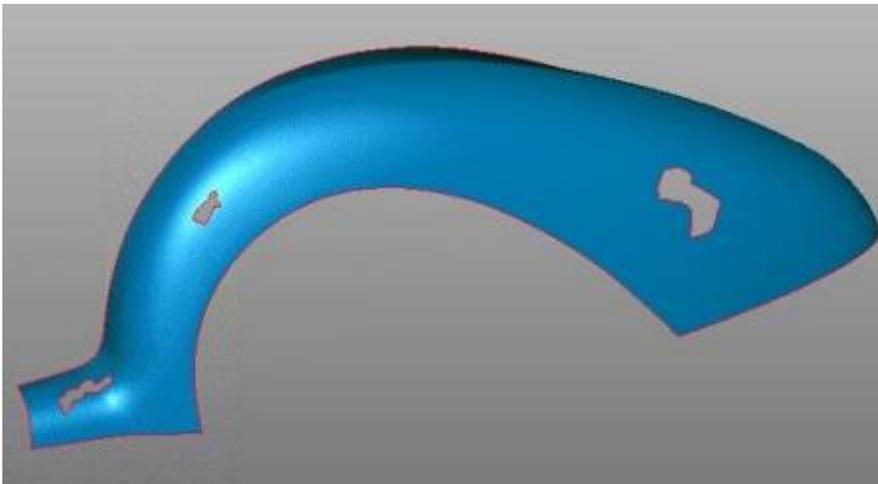
- Safe to human eyes
- Fast scanning
- High resolution
- Less shape edge problem than laser scan

- Cons

- Worse depth than laser
- Large amount of energy consumption

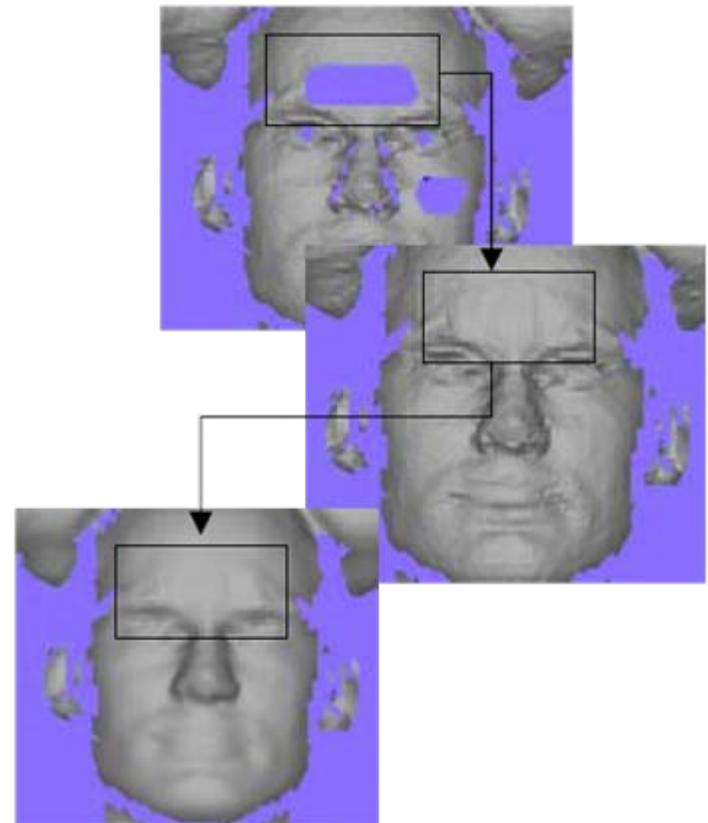
# Issues of Using Scanning data

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



*RapidForm, INUS*

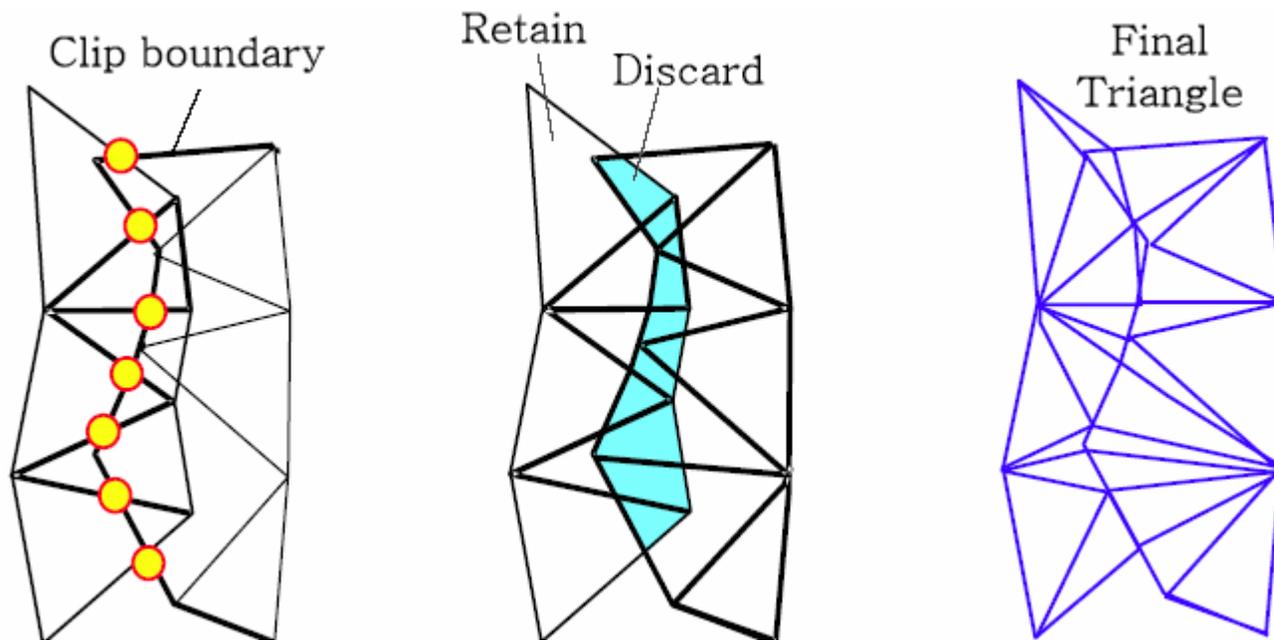
Holes in generated polygon from scan data



Hole filling process

# Issues of Using Scanning data (cont.)

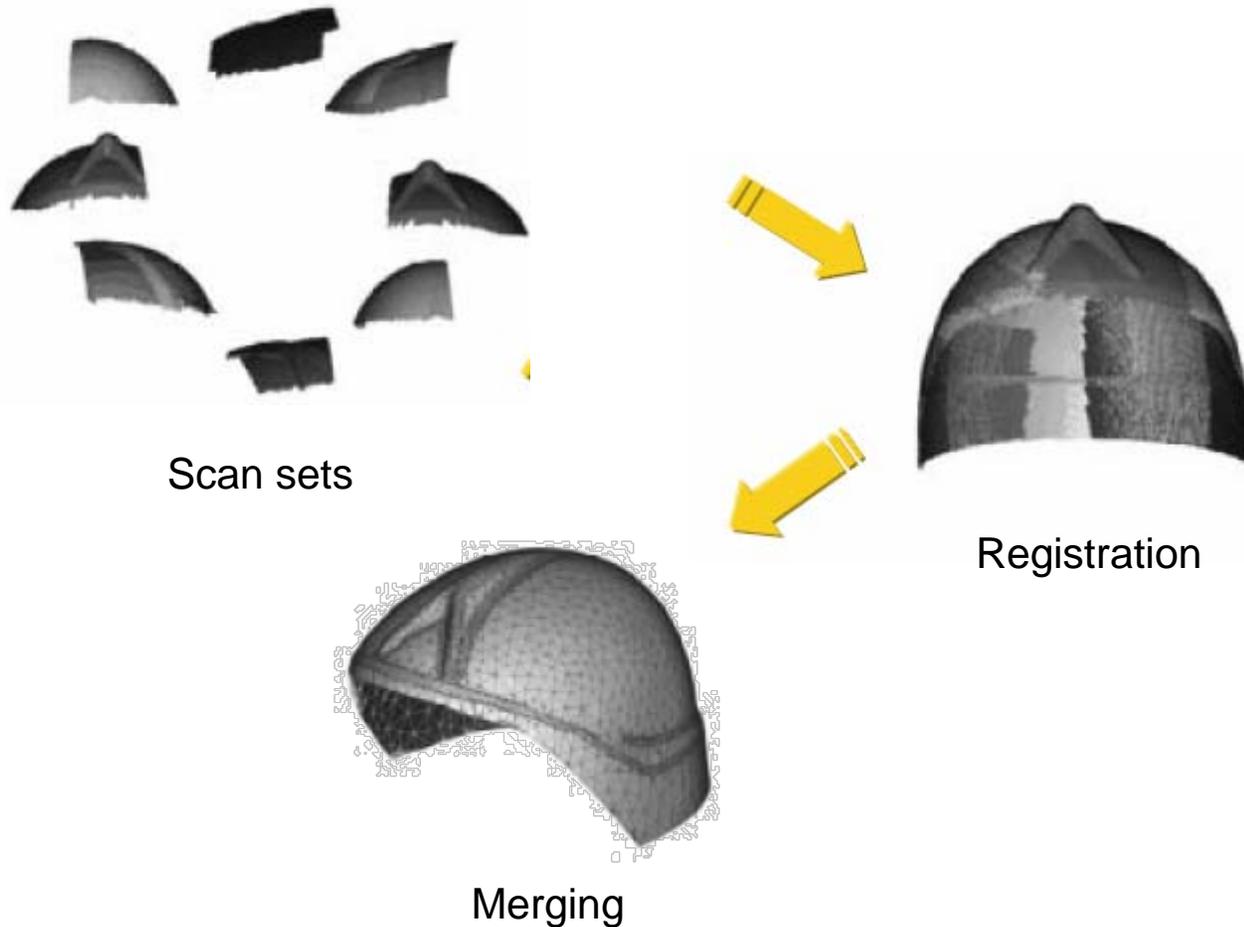
- Merging overlapped areas



Merging overlapped area in software

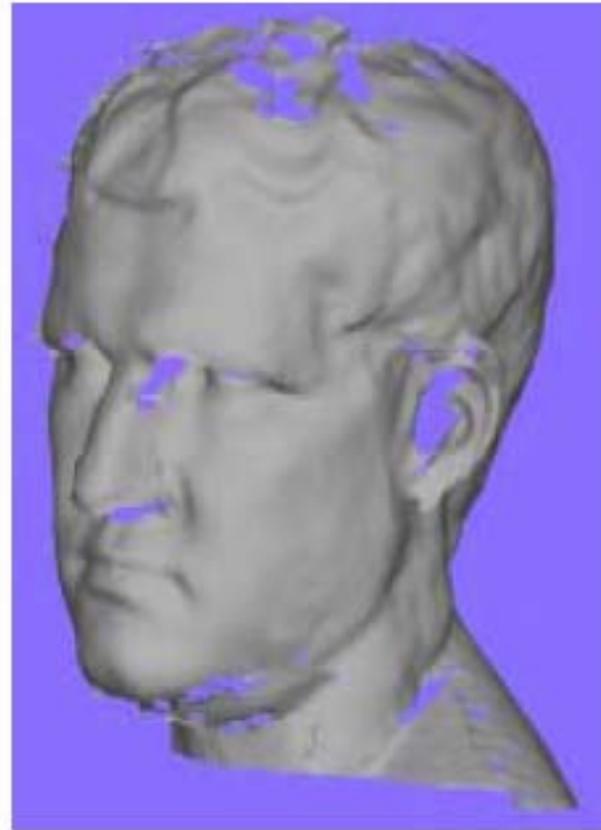
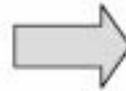
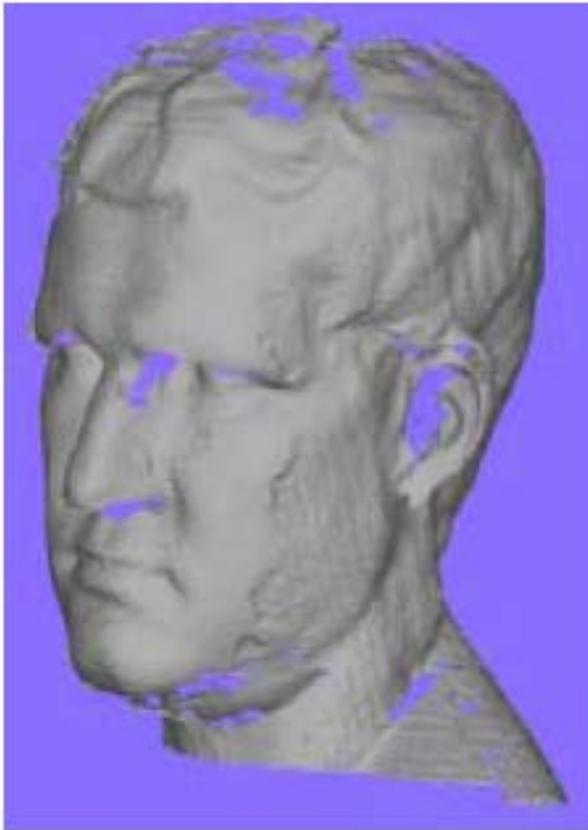
# Issues of Using Scanning data (cont.)

- Registration/Merging



# Issues of Using Scanning data (cont.)

- Smoothing

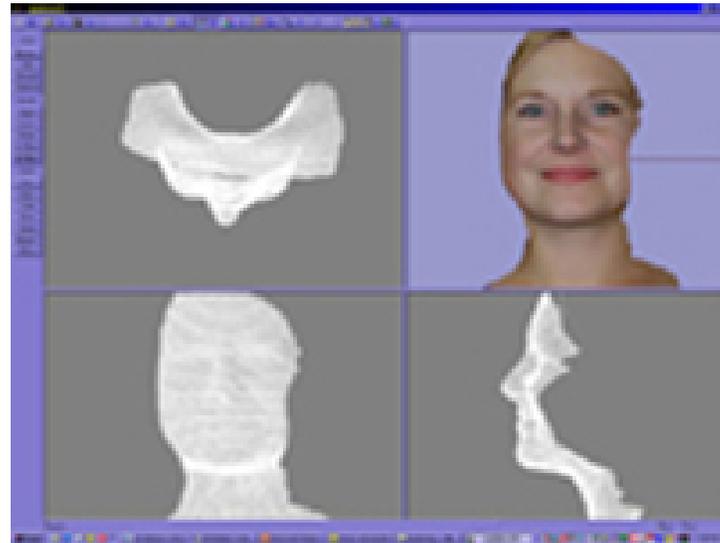


# 3D Scanner

- Input device to read physical geometry into CAD format



3D scanning device

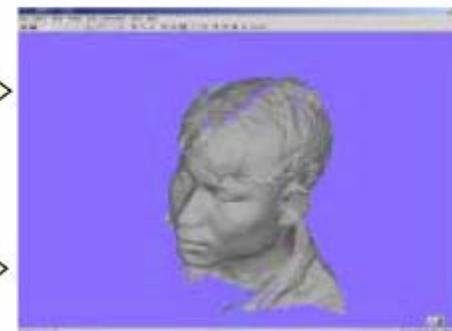


Manipulator software

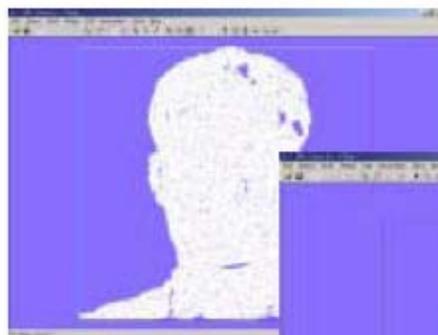
# Replica of Human Face



Scanning



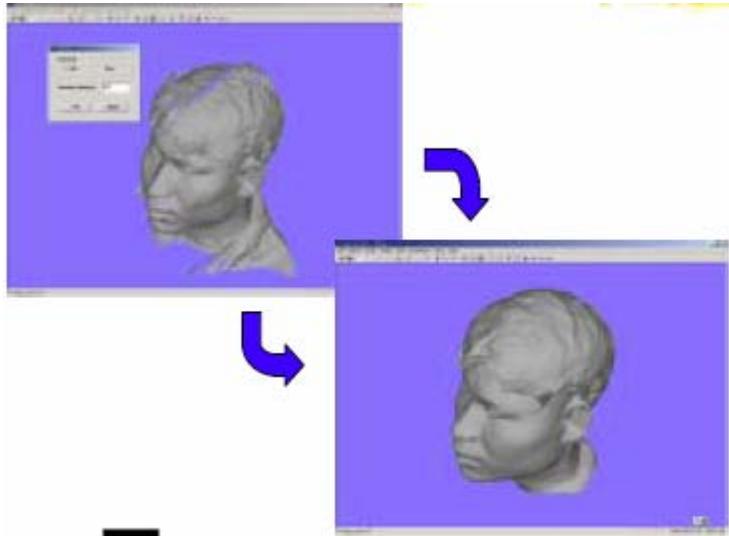
Registering/Merging



Triangulation



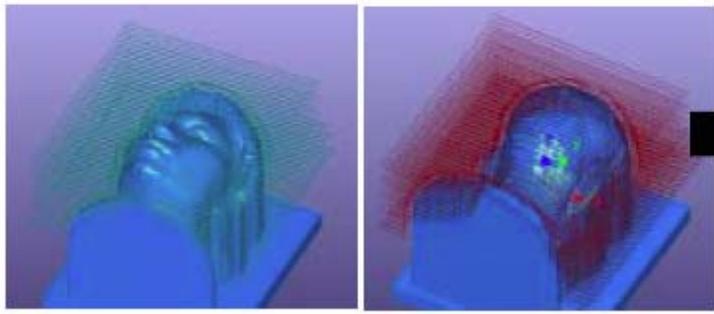
# Replica of Human Face (cont.)



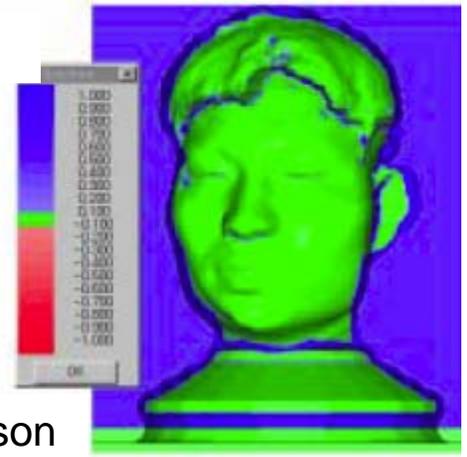
Geometry Processing



NC Machining



NC Toolpath



Error Comparison

# 3D Scanner (cont.)

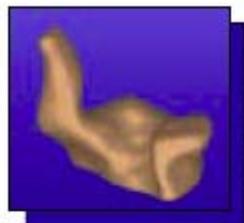
- Demo



# Applications

**PHONAK**  
hearing systems

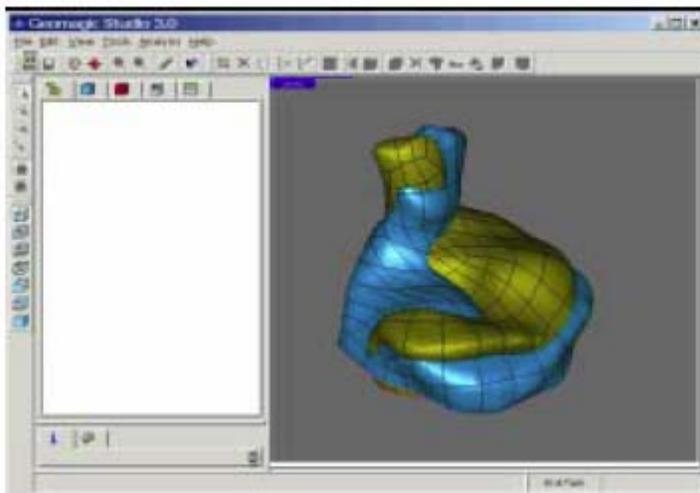
the definition of  
better hearing



Scan

Geomagic

Print



**Custom Made  
Hearing Solution**

# Applications (cont.)

invisalign™

raindropgeomagic®

*The revolution in adult orthodontics is here.*



Patients

Doctors

Media / News

About Align Technology

Orthodontists

Manufacturer



## Mass Customization : Orthodontics



# Applications (cont.)

- 3D photography model for e-commerce

