Graphics&Geometric Computing Lab
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Data Acquisition

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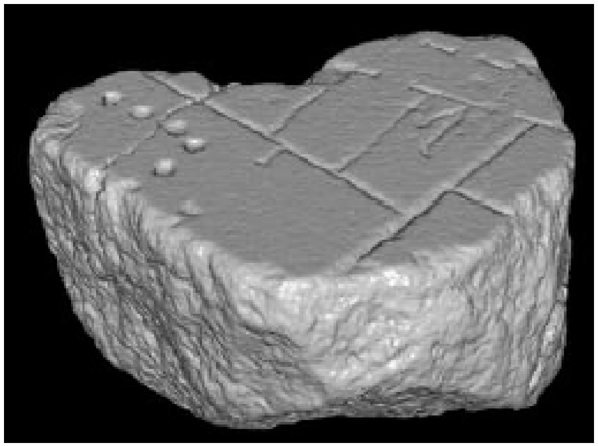
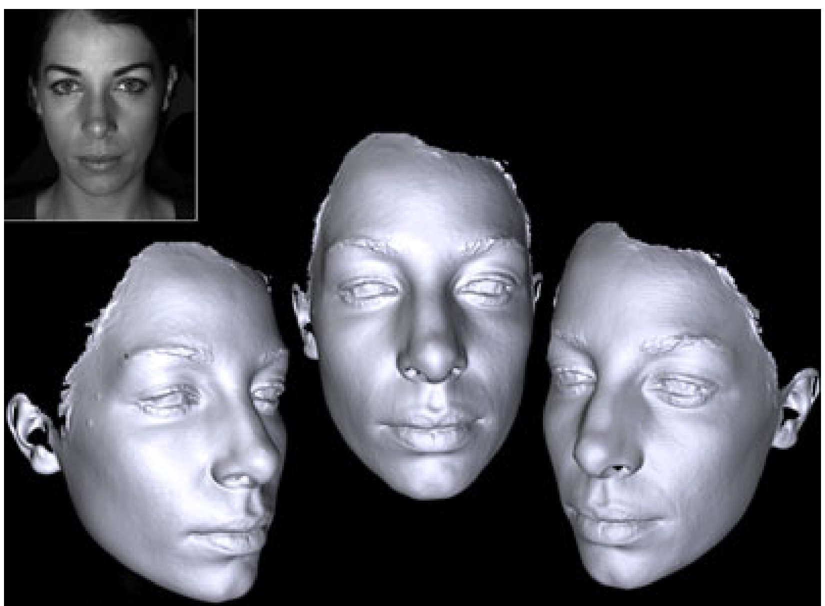
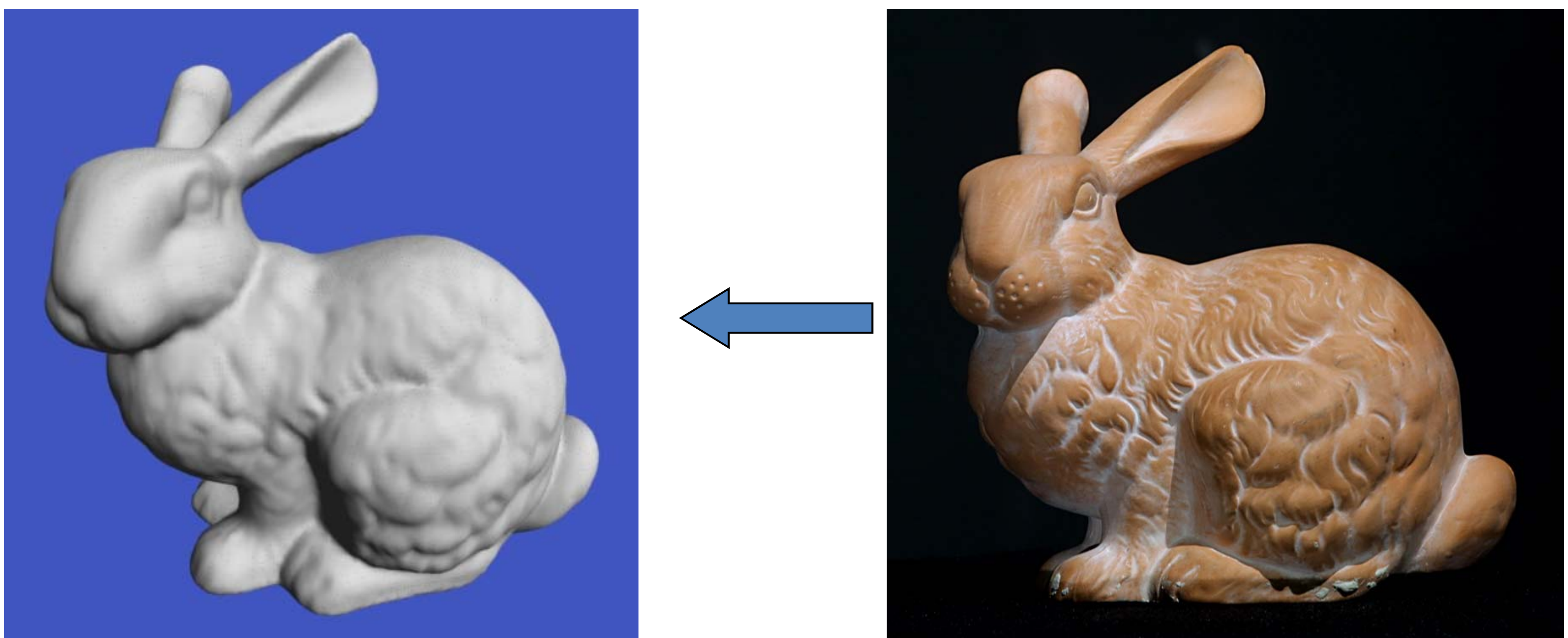
Getting Meshes from Real Objects





Getting Meshes from Real Objects

- Many models used in Graphics are obtained from real objects
  - Well known Stanford bunny model



Reverse Engineering

Real Object

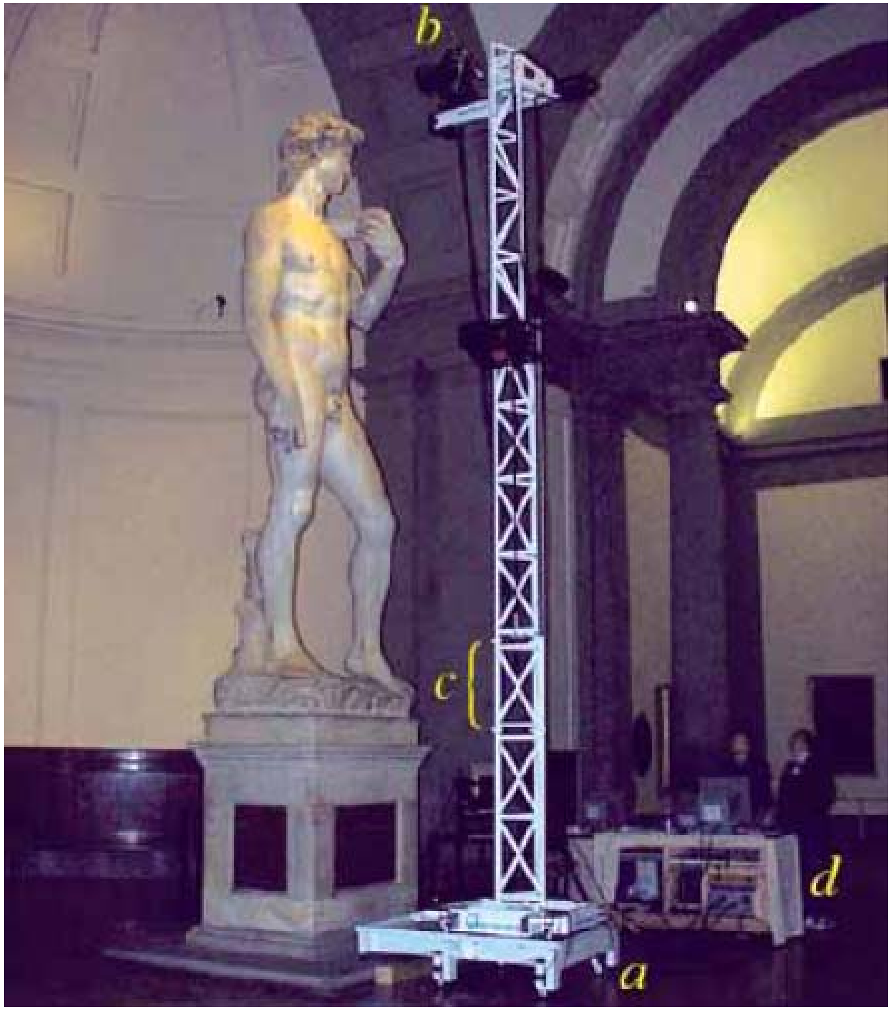
↓

CAD/Graphics Model

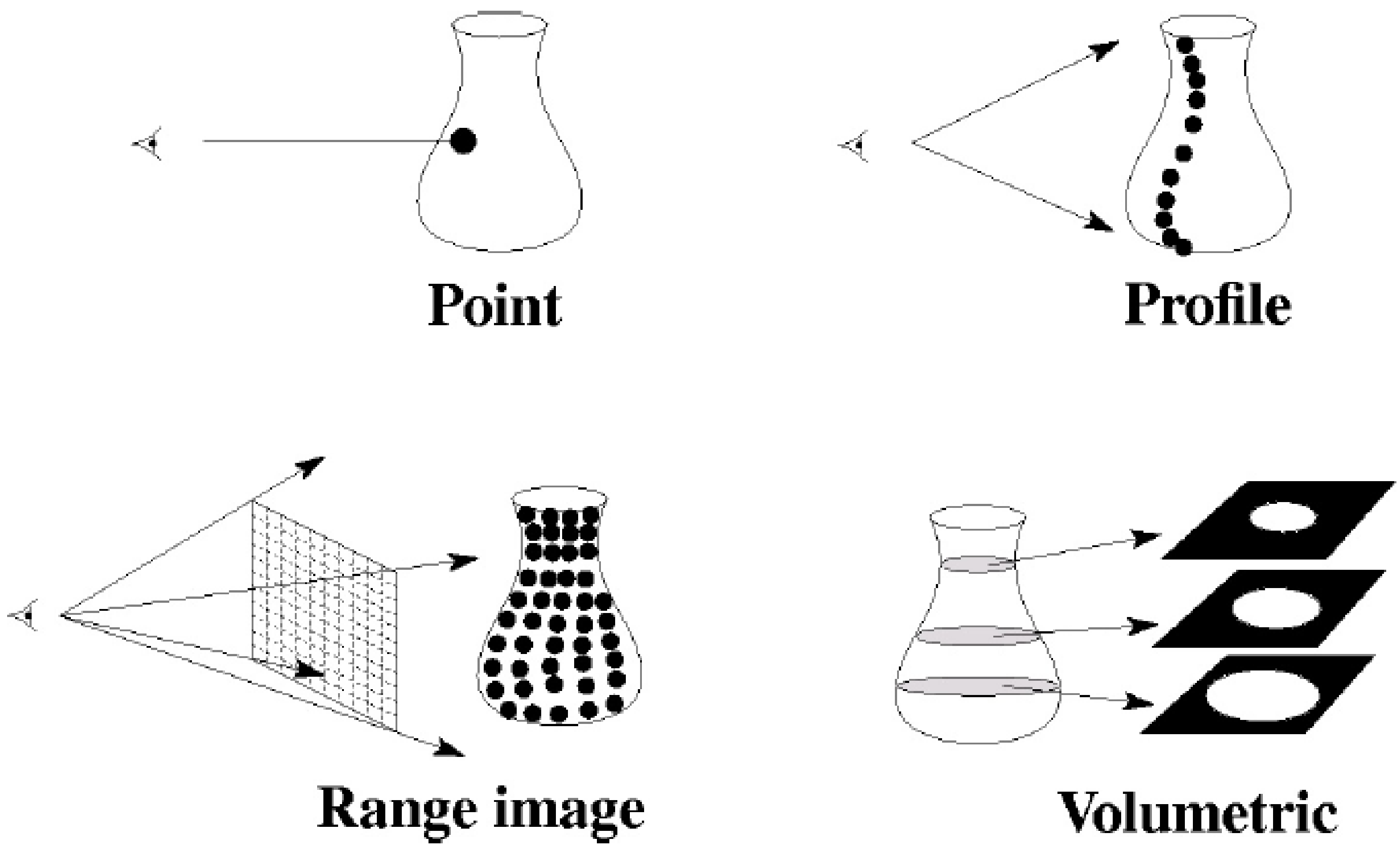
↓

Build new object

Data Acquisition

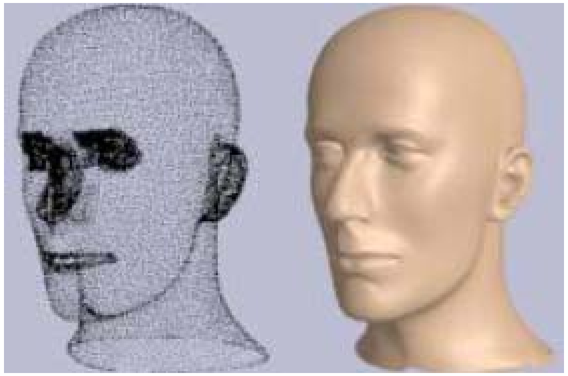


Structure of Data

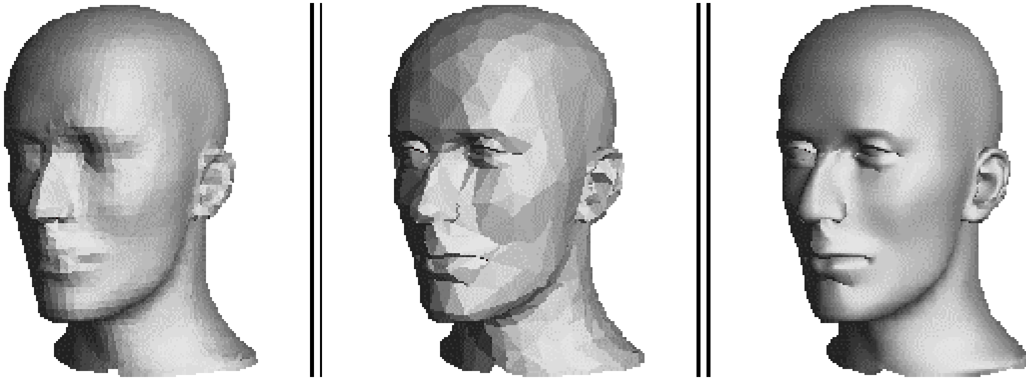


Scan Conversion

- Main phases
  - Sensing - capture raw data
    - Point set
    - Boundary contours
    - Voxels
  - Conversion to polygonal model



- Followed by
  - Surface reconstruction
  - Mesh improvement
    - Simplification
    - Smoothing



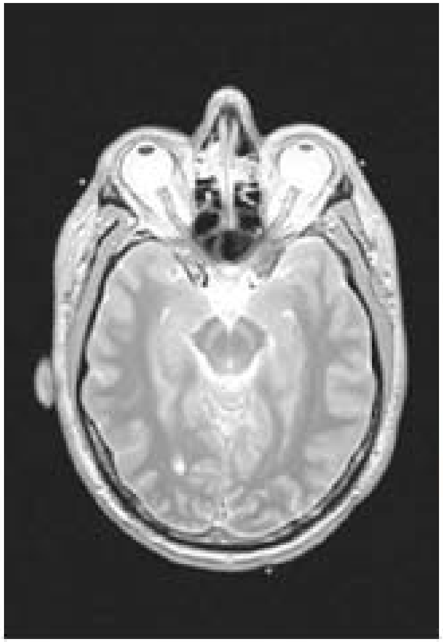
Different Acquisition Systems

- Volumetric scanning
- Photogrammetry
- Range scanning

2.1 Volume Scanning

- Build voxel structure by scanning slices

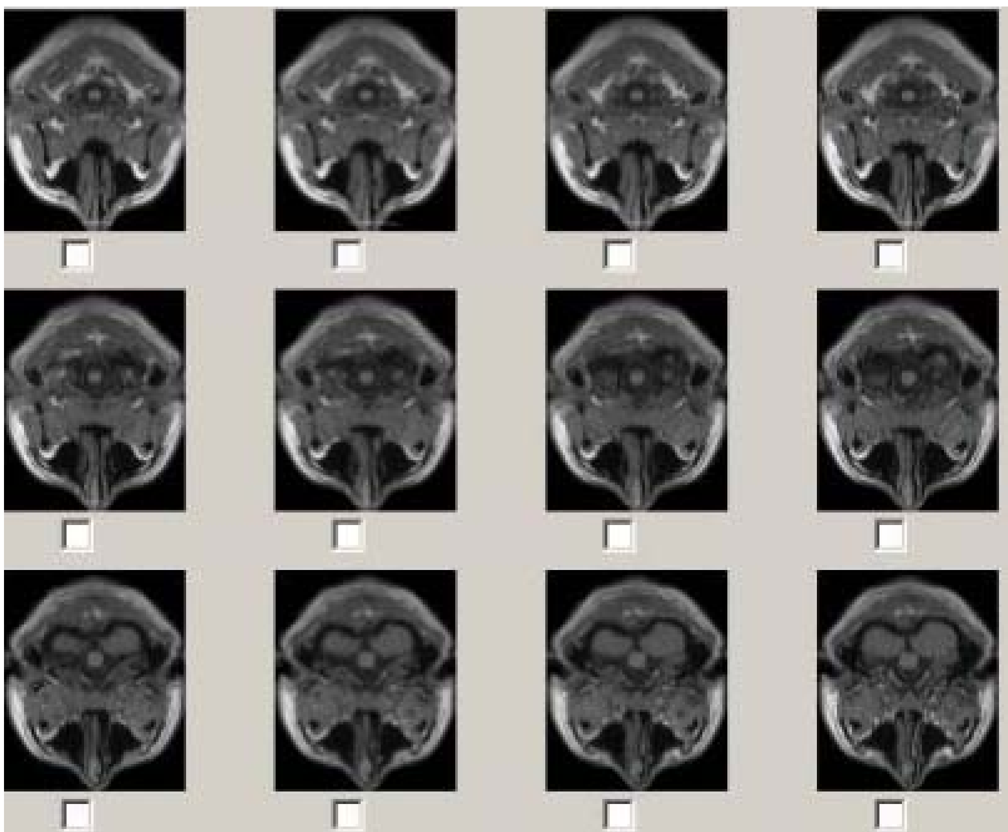
CT

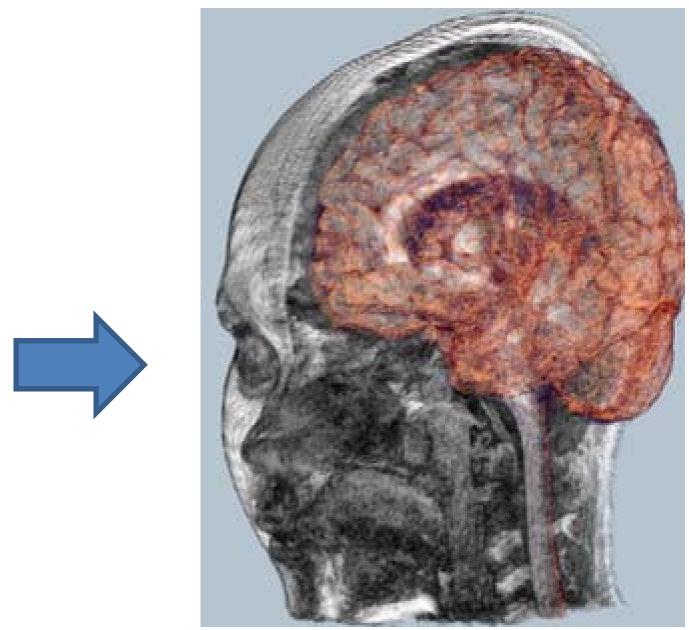


MRI

Volume Scanning

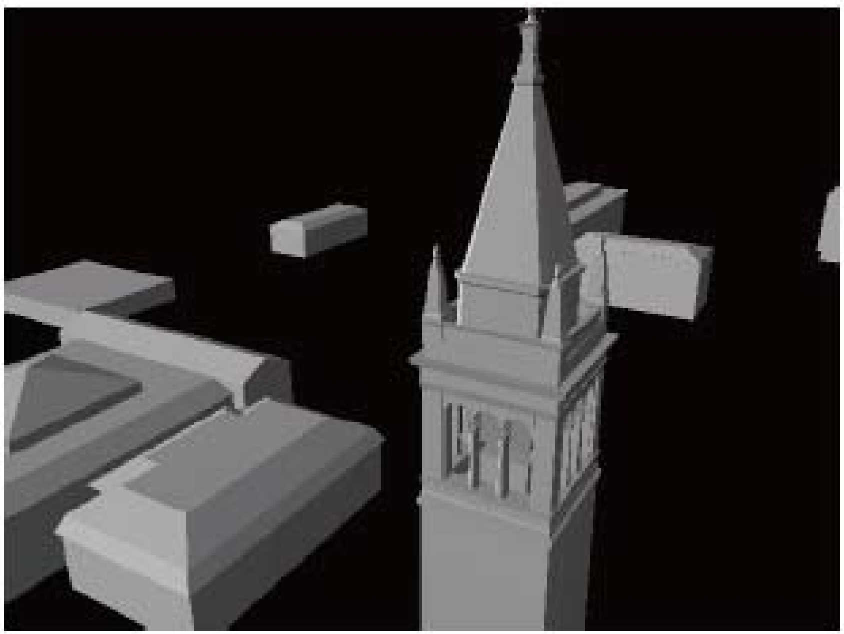
- Build voxel structure by scanning slices





2.2 Photogrammetry

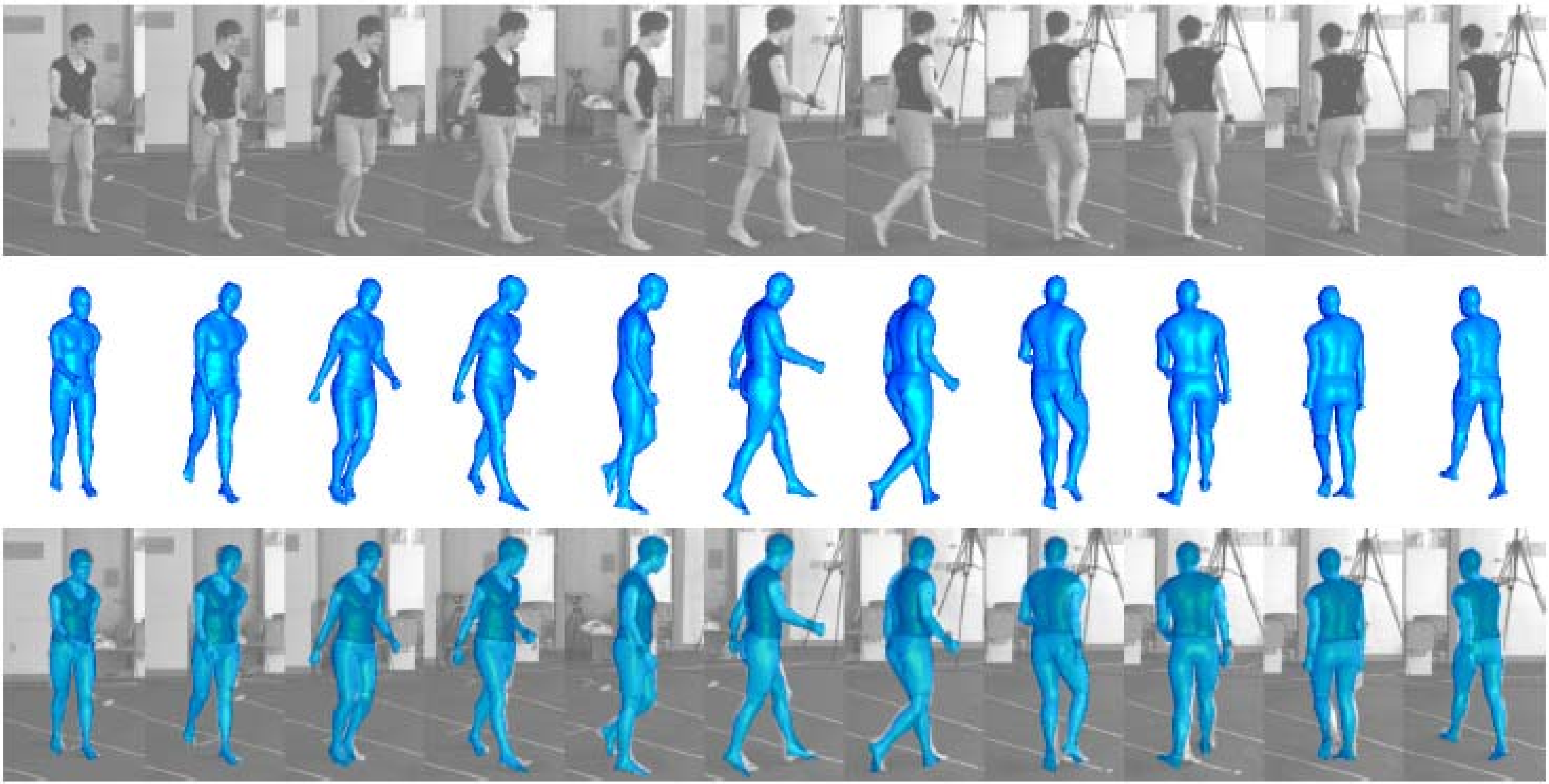
- Reconstruction from photographs



http://www.debevec.org/campanile

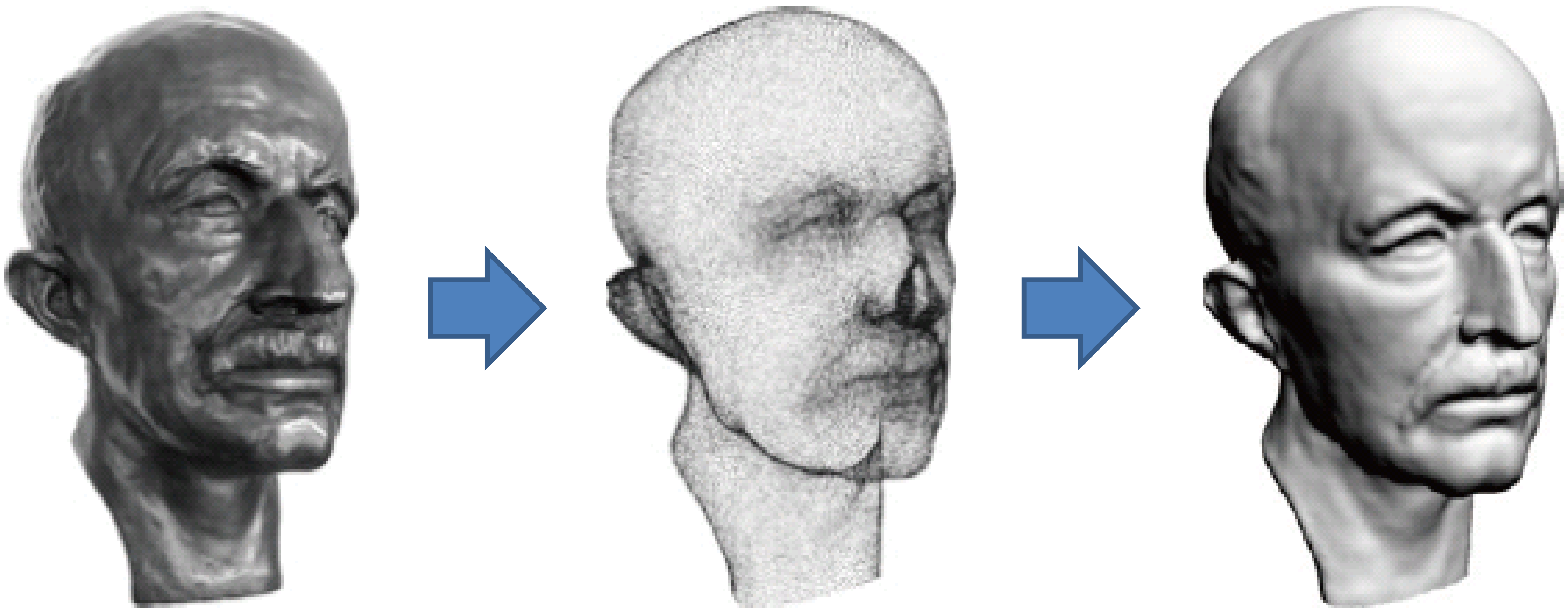
Photogrammetry

- Reconstruction from a series of photos (video)



2.3 Range Scanning

- Reconstruction from point cloud



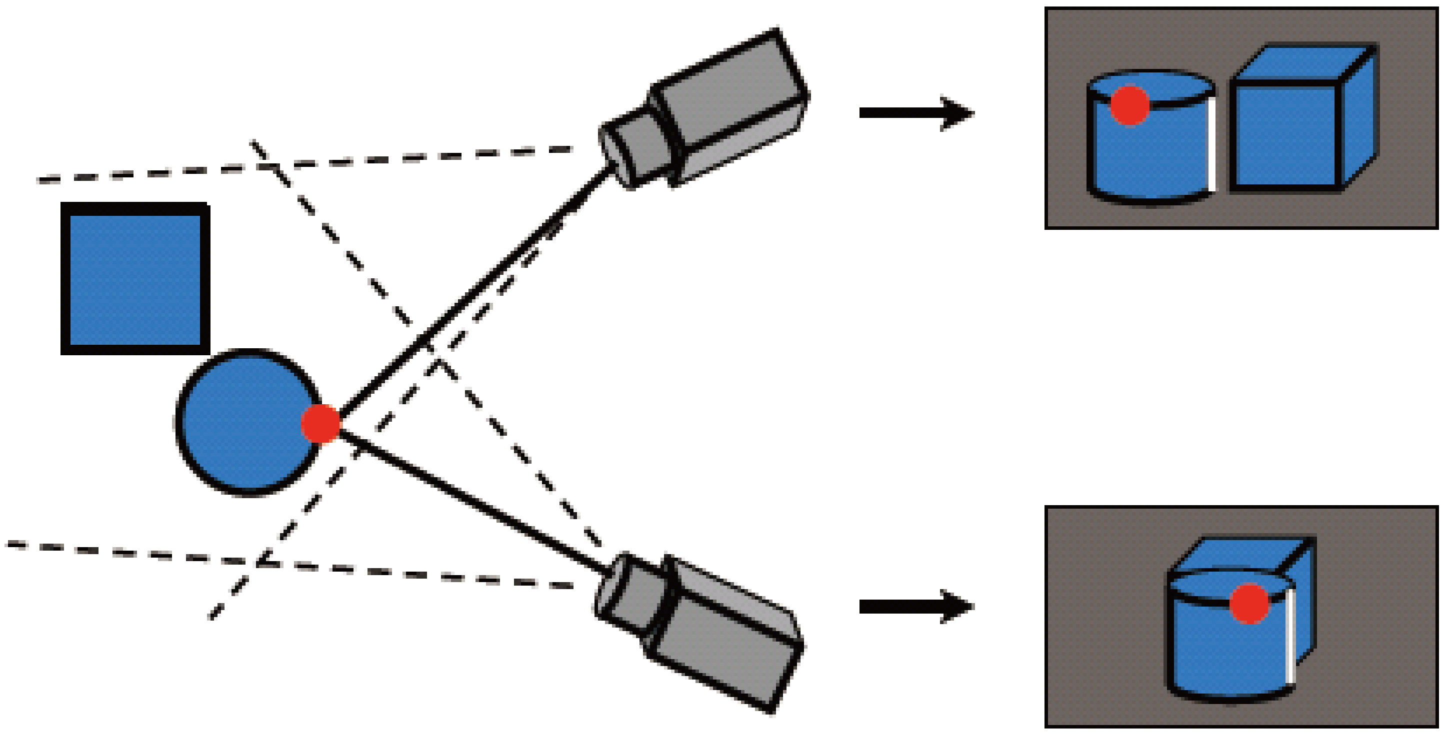
Physical real model

Acquired point cloud

Reconstructed model

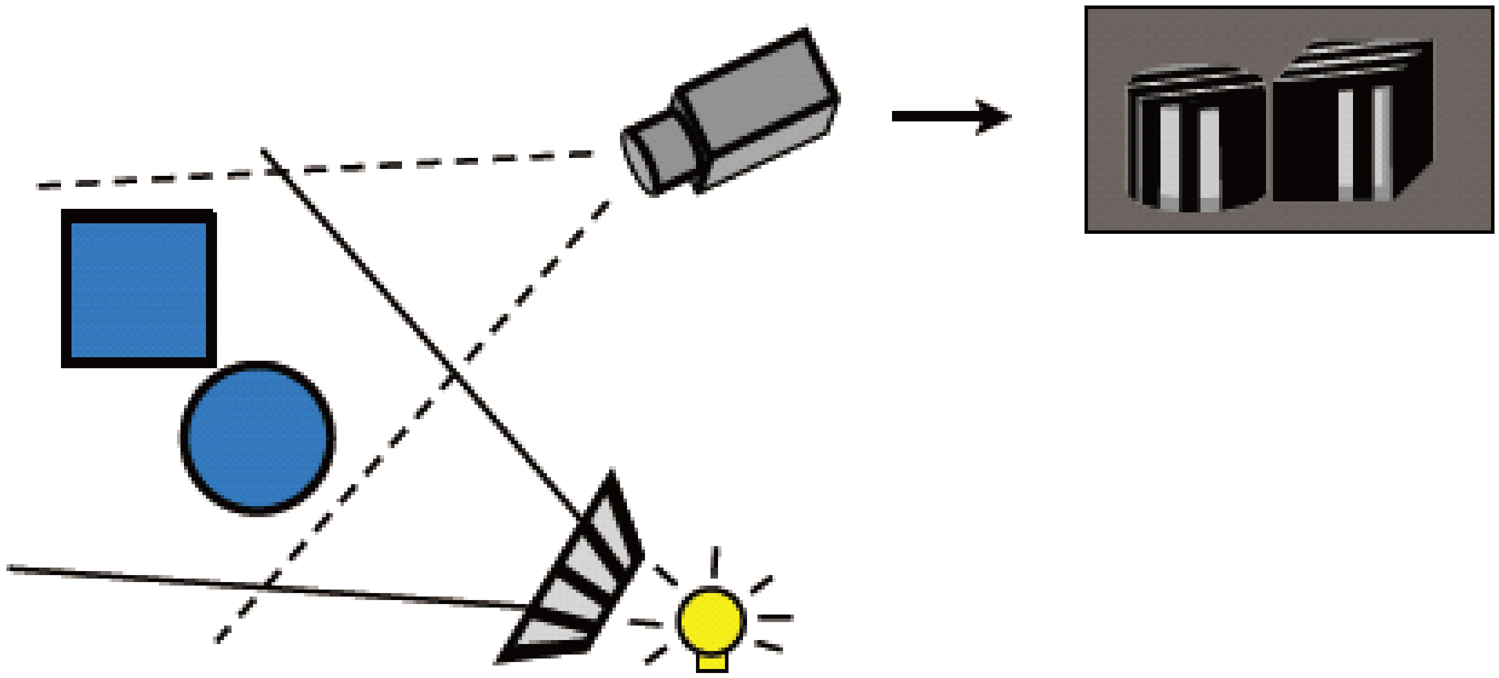
Range Scanning Systems

- Passive: stereo matching



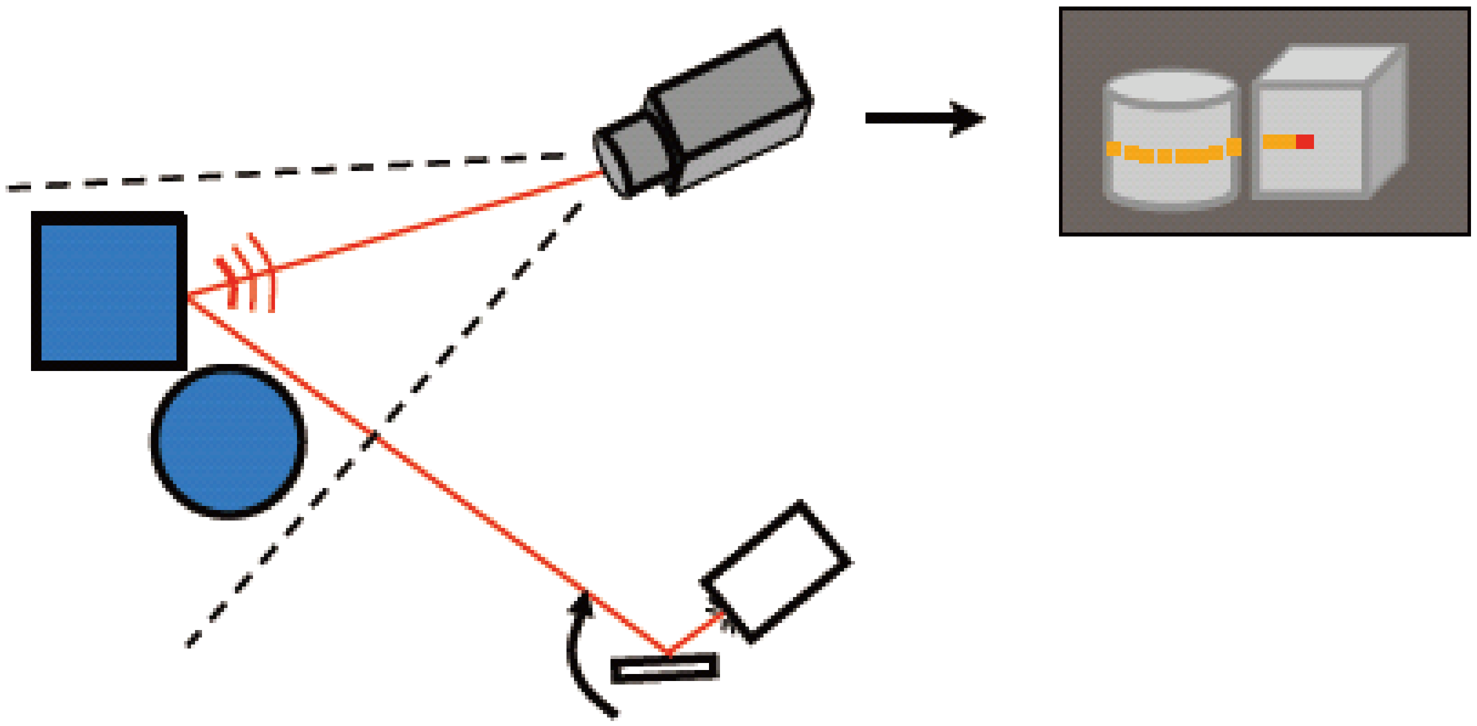
Range Scanning Systems

- Active: structured light acquisition

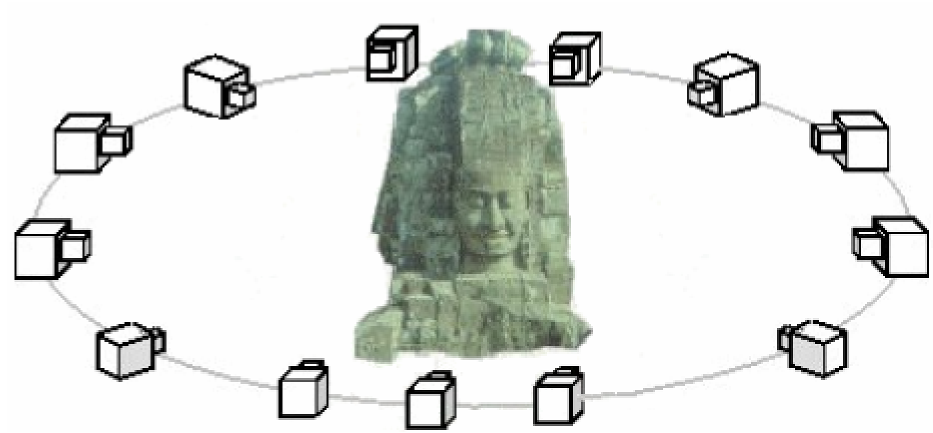


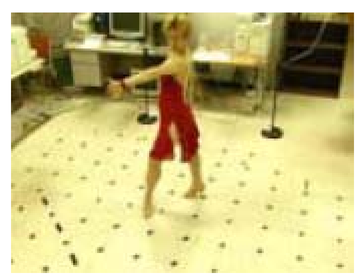
Range Scanning Systems

- Active: laser scanning



Examples of Scan Systems

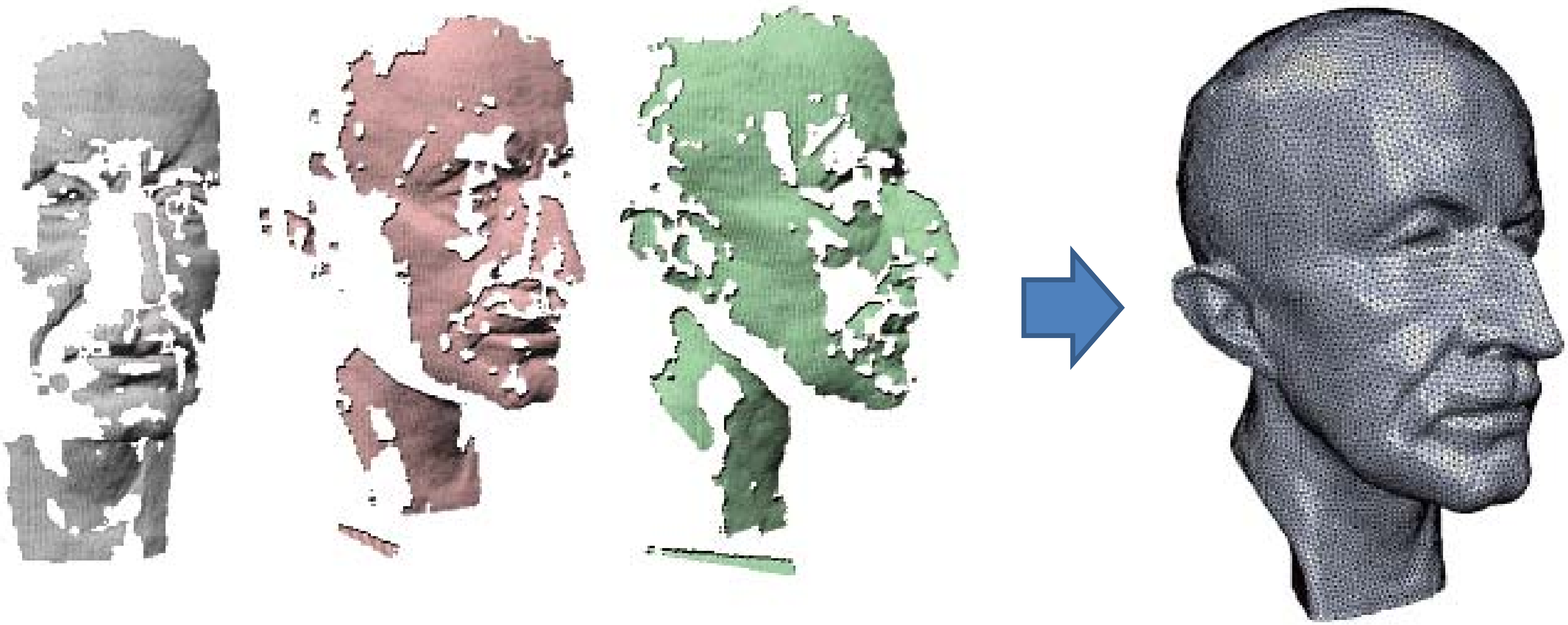




Range Scanning

- Active systems are superior
- Accurate calibration is crucial
- Multiple scans required for complex objects
  - scan path planning
  - scan registration
- Scans are incomplete and noisy
  - model repair, hole filling
  - smoothing for noise removal

Range Scanning: Reconstruction

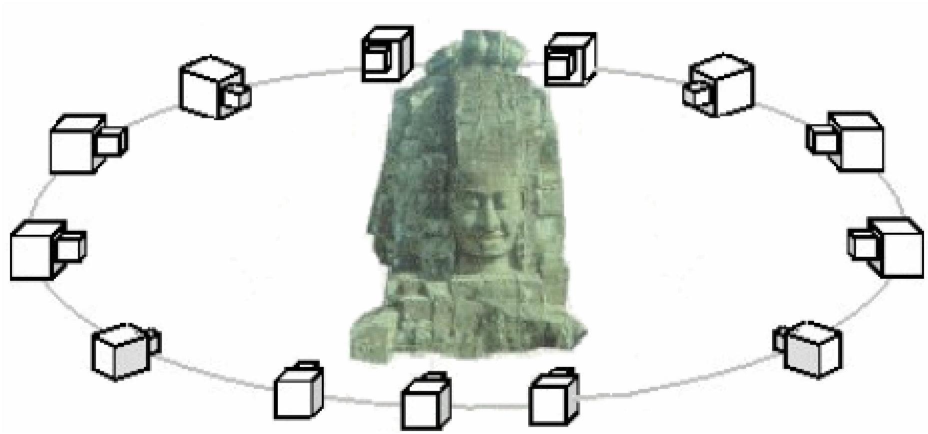


Set of raw scans

Reconstructed model

Sensors

- Scanner types
  - Laser
  - Imaging (2D/3D)
  - Probing
  - Mixed



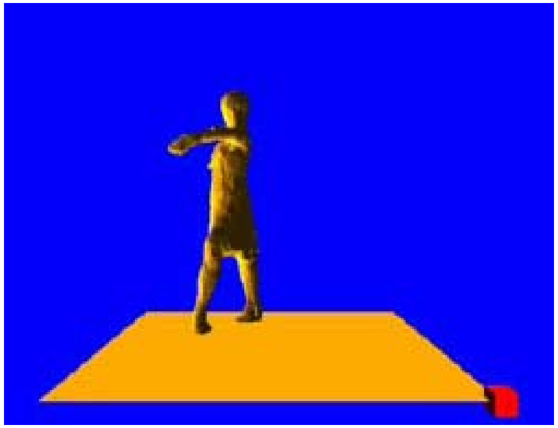
Sensing Technologies - Probing

- Probing
  - position probe on object
  - record the location
- Output
  - point cloud data
- Problematic
  - Labour intensive
  - Error prone

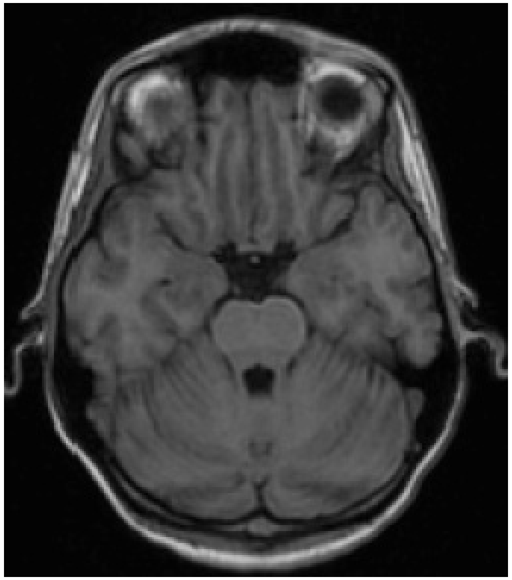
Sensing Technologies - Imaging

- Capture multiple 2D images
- Use image processing tools to create initial geometry data
- Requirements
  - Many cameras
  - Specific locations





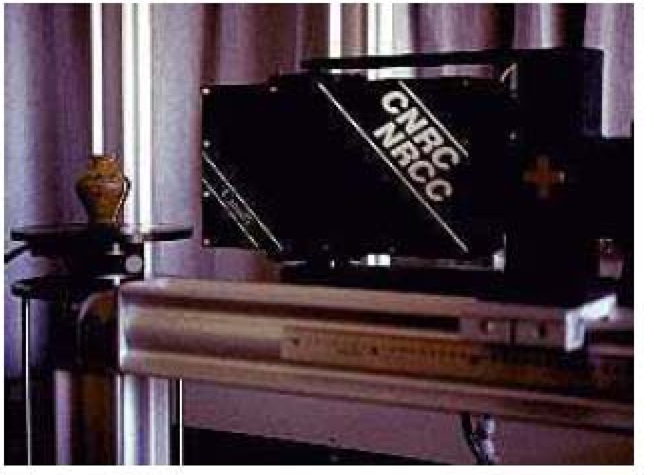
3D Imaging

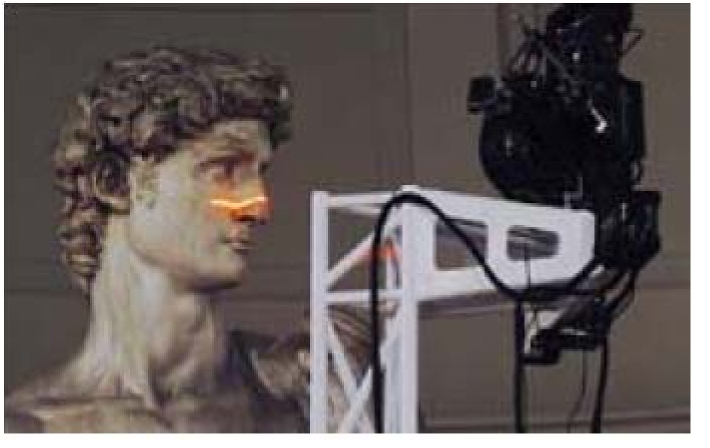


- Wave based sensors
  - Ultrasound
  - Magnetic Resonance Imaging (MRI)
  - X-Ray
  - Computed Tomography (CT)
- Alternative - slice object, take photographs of slices
- Outputs
  - volumetric data (voxels)
  - contour lines (use imaging techniques)

Range Scanners

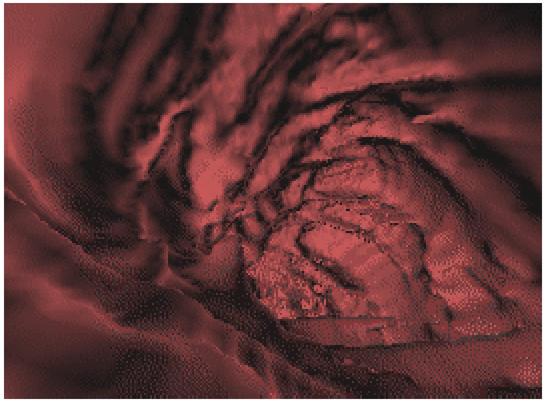
- Laser/Optical range scanner provides 2D array of depth data
- Some capture color (texture)
- Multiple views for complete object scan:
  - Rotate object
  - Rotate sensor
- Output – point set





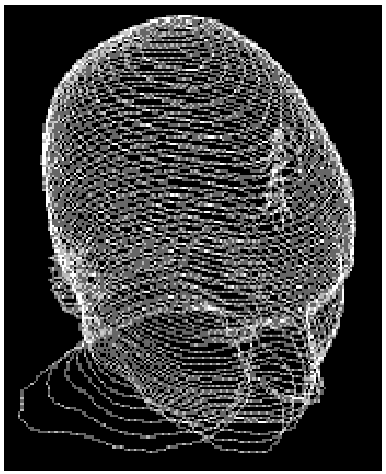
Model Generation

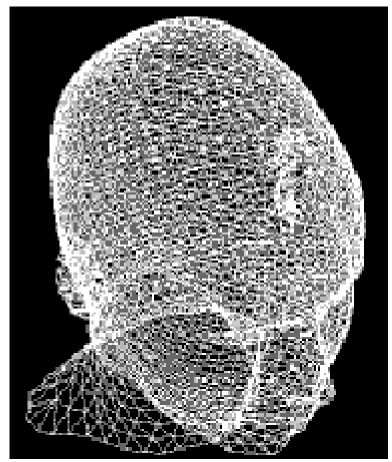
- Generate mesh
  - Point set
    - Graphics
    - CAD
  - Contours
    - Medical Imaging
  - Voxels
    - Medical Imaging
- Direct processing
  - 2D Images
    - Vision
  - Voxels
    - Visualization

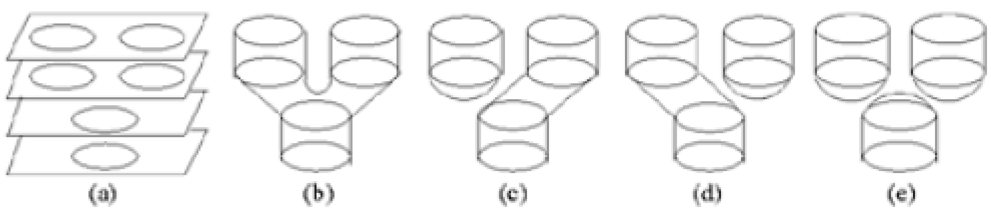


Contours

- Stack contours
- Triangulate "strips" between contours



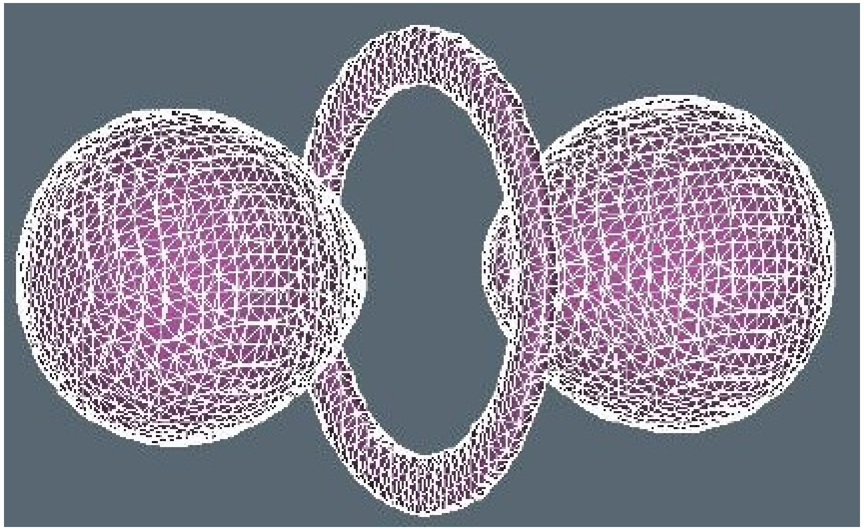


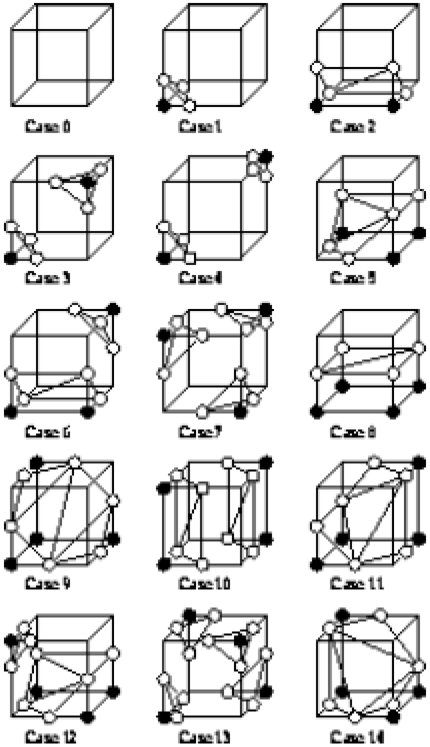


- Note: contour topology can change

Voxels

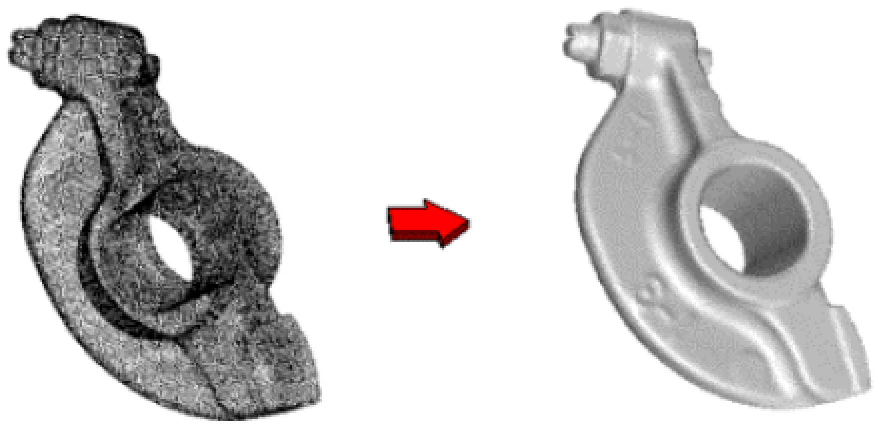
- Define iso-surfaces (between data values)
- Triangulate iso-surface
  - Marching Cubes





Triangulating Point Clouds

- General Idea
  - Connect neighboring points into triangles



Point cloud data　　Reconstructed surface

- Issues
  - Connectivity – manifold? connected?
  - Efficiency – (David 32GIGA)

Surface Reconstruction

- Parametric approaches
  - Neighborhood searching
  - RBF approximation
  - Delaunay triangulation
- Implicit approaches
  - Distance field
  - Level set
  - Marching cube

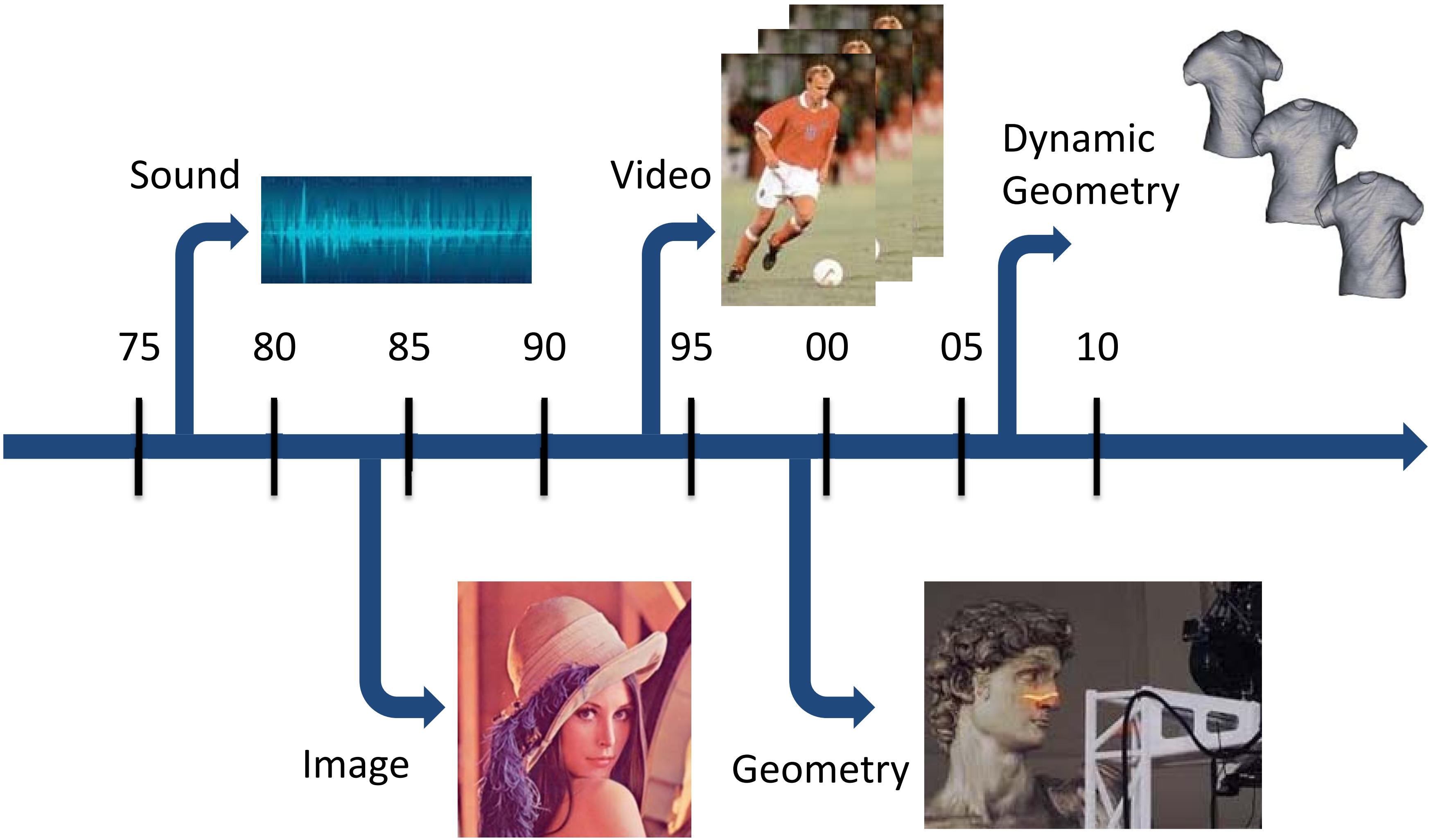
Limitation

- Acquire only visible portions
- Sensitivity to surface properties
- Confused by interreflections

Challenges

- Geometry acquisition
  - Alignment
  - Error controls
- Properties acquisition
  - Texture
  - Color
  - BRDF
  - BTF

Recap: Digital Media



Acquisition of Dynamic Objects

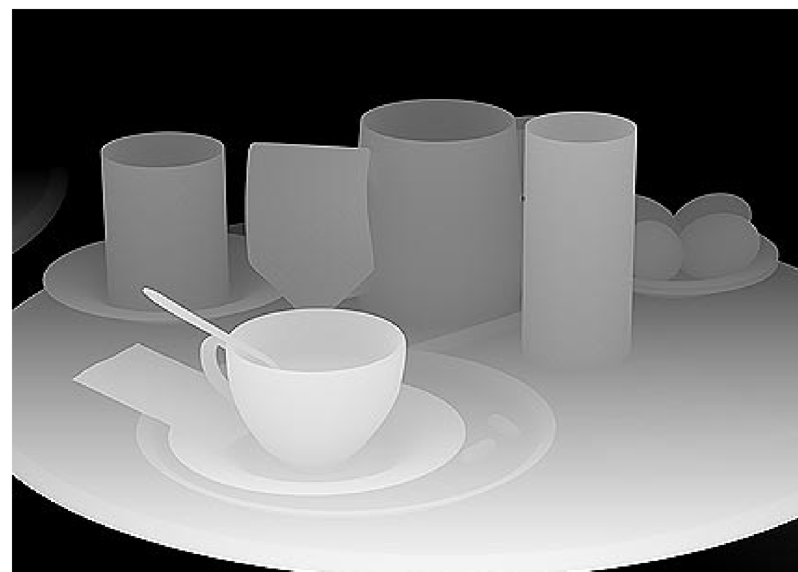
3D Animation Scanner

- New technology
  - Record 3D video
  - Active research area
- Ultimate goal
  - 3D movie making
  - New creative perspectives

Photo: P. Jenke, WSI/GRIS Tübingen

What is Depth Image (DI)?

- A pair of aligned maps
  - a texture map I: gives the color of all visible points
  - a depth map D: gives the distance to each visible point



Time-of-flight (ToF) Camera

- A camera system that creates **distance data** with help of the time-of-flight (TOF) principle
  - Light pulses
  - Can measure depth scans at video rate
- Relatively new devices
  - Become more popular (for everyday users)

FOTONIC-B70 by Fotonic

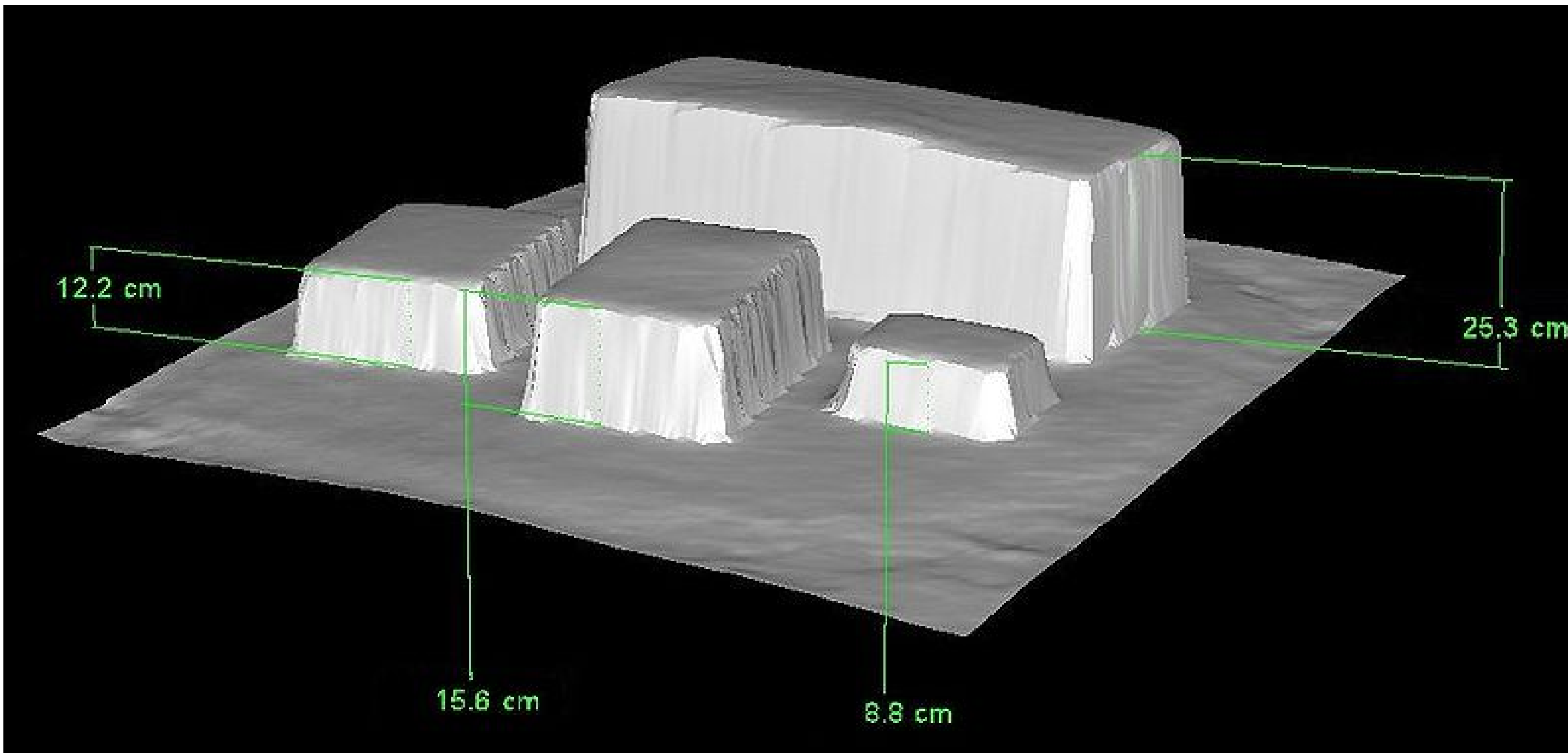
SwissRanger 4000 by MESA Imaging

PMD[vision] CamCube by PMDTechnologies

USB-powered TOF camera out of the European ARTTS project

Range image with height measurements

- Provide 2.5D structure of the scene

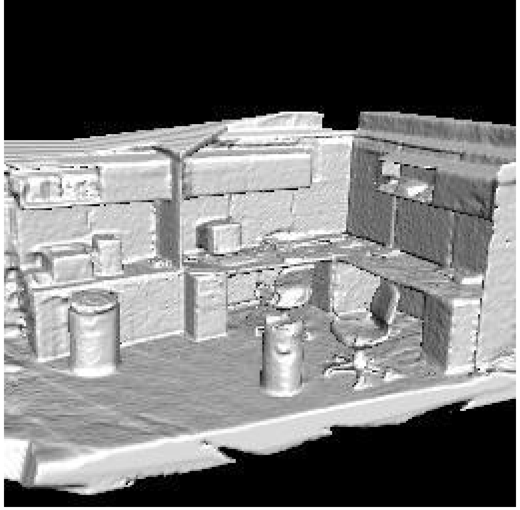


Advantages

- A single depth image
  - Provide 2.5D structure of the scene
- A set of depth images
  - Might provide hole-free 3D scene

Set of Depth Images

- 3D modeling of scene



Problems with Depth Images

- Pros
  - Not only 2D image (2.5D)
  - Easy acquisition
- Cons
  - Substantial sensor level of random noise
    - low quality data
  - Non-trivial systematic bias

New Trends: Dynamic Geometry Data

- Time-of-flight (ToF) Camera
- Microsoft Kinects

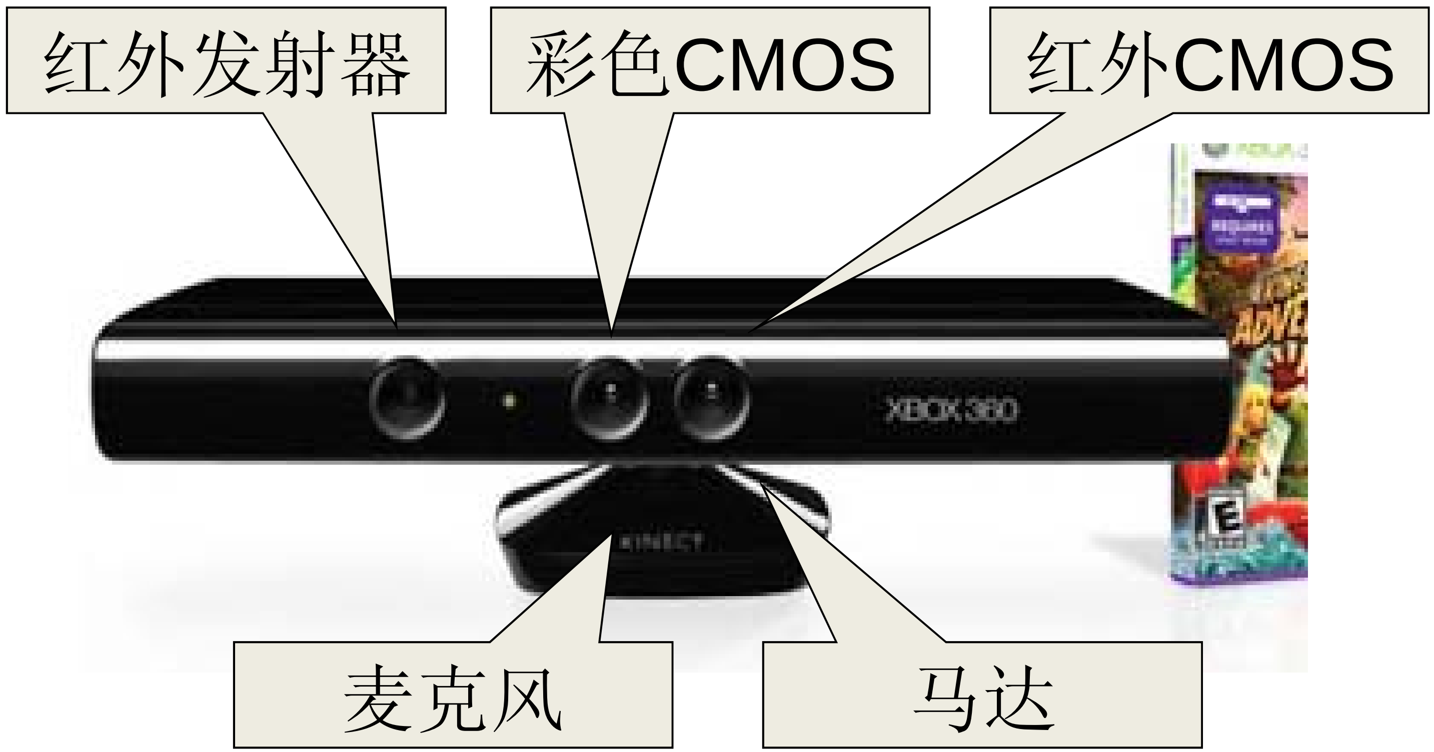
Introduction to Kinect

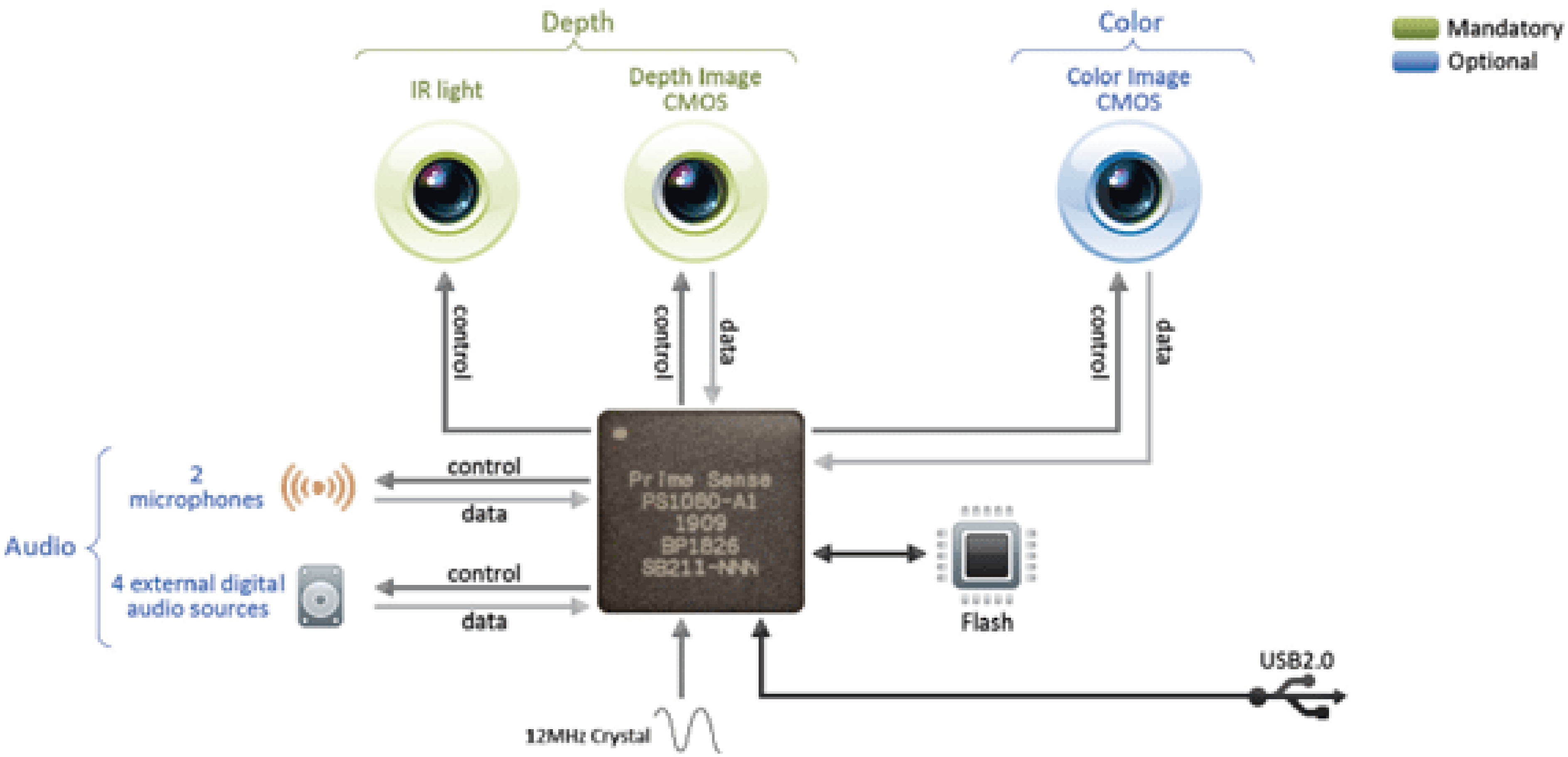
Project Natal

- Play game without controller
  - Use your body!
- Proposed in 2009

Microsoft Kinect + XBOX 360

- Released in Nov. 4, 2010
  - Cheap: only 150 USD
- A controller-free gaming system
- Sales 8 million in its first 60 days
  - Breaks Guinness World Records


红外发射器
彩色CMOS
红外CMOS
XBOX 360
KINECT
麦克风
马达


Depth
Color
Mandatory
Optional
IR light
Depth Image CMOS
Color Image CMOS
control
control
data
control
data
2 microphones
control
data
Audio
4 external digital audio sources
control
data
Prime Sense PS1080-A1 1909 BP1826 SB211-NNN
Flash
USB2.0
12MHz Crystal

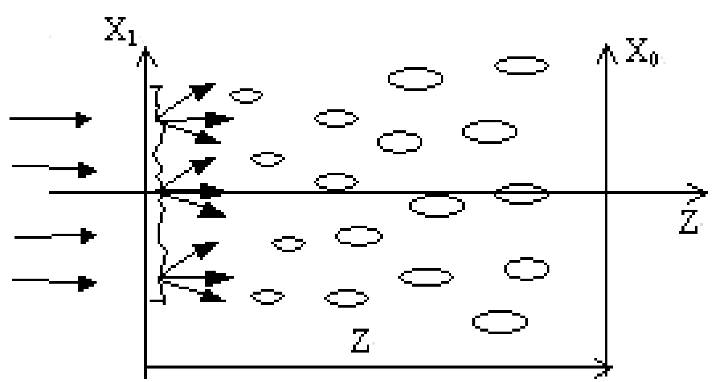
成本仅56美元

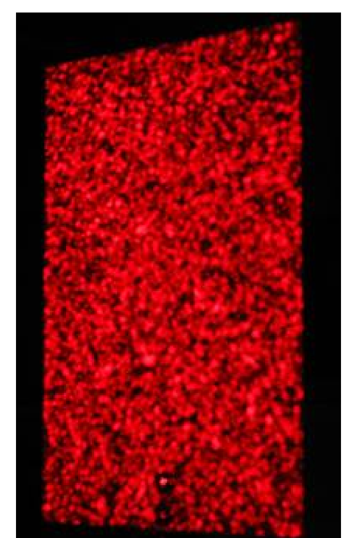
原理

- 2009年微软收购了以色列3DV公司，让人们以为Natal的技术是源自3DV的TOF（time of flight）
- 2010年4月，另一家以色列公司PrimeSense确认为微软提供了其light coding的三维测量技术，并应用于Project Natal
- 不同于TOF或者结构光测量技术，light coding使用连续的照明（而非脉冲），不需要特制的感光芯片，而只需要普通的CMOS感光芯片，这让方案的成本大大降低

原理

- 当激光穿透毛玻璃后形成随机衍射斑点，这些散斑（laser speckle）具有高度的随机性，而且会随着距离的不同变换图案。空间中任意两处散斑图案都不同
- Light coding打出了一个具有三维纵深的“体编码”，只要看物体表面的散斑图案，就可以知道这个物体在什么位置





性能参数

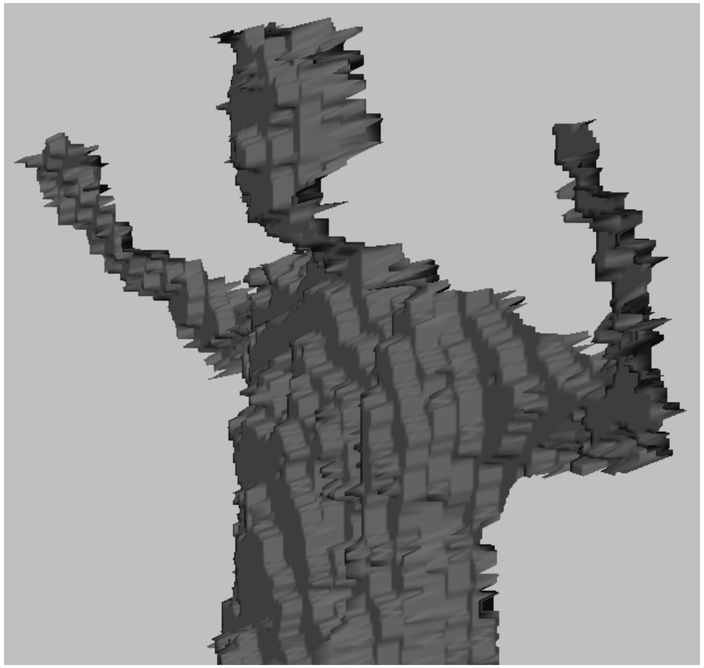
- 水平视角：57度
  垂直视角：43度
  物理倾斜范围：±27度
  景深镜头感应距离：1.2-3.5米（实测0.5-9米）
  Z方向精度：1厘米
- 深度图像分辨率640x480；16位色深；30fps
  彩色图像分辨率640x480；32位色深；30fps
- 骨骼跟踪系统最多识别6人
  可同时动作捕捉2人
  每个动作捕捉对象上有20个捕捉点

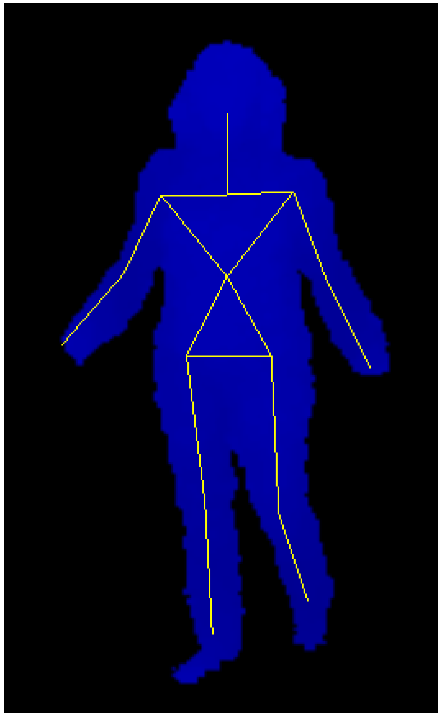
Kinect破解应用

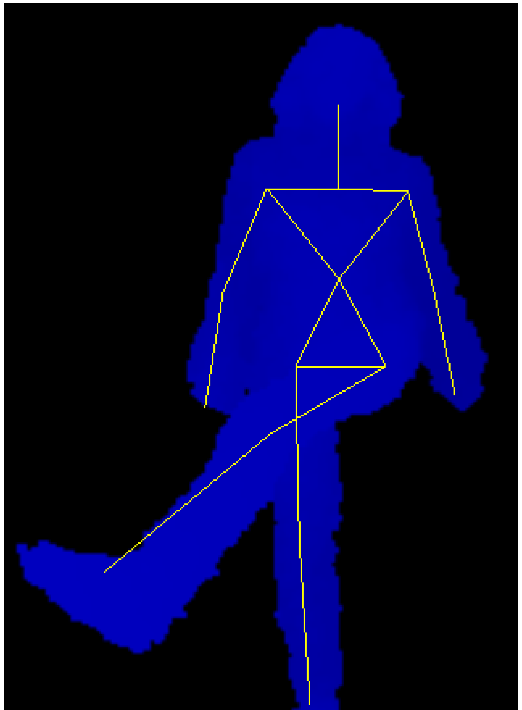
- 游戏（魔兽、体感游戏）
- 人机交互（手势、钢琴）
- 机器人
- 监控
- 运动捕捉（测试、应用）
- 三维重建（场景、人体）
- ……

Kinect Data

- Low resolution 640x480
- Very noisy
- Human skeleton

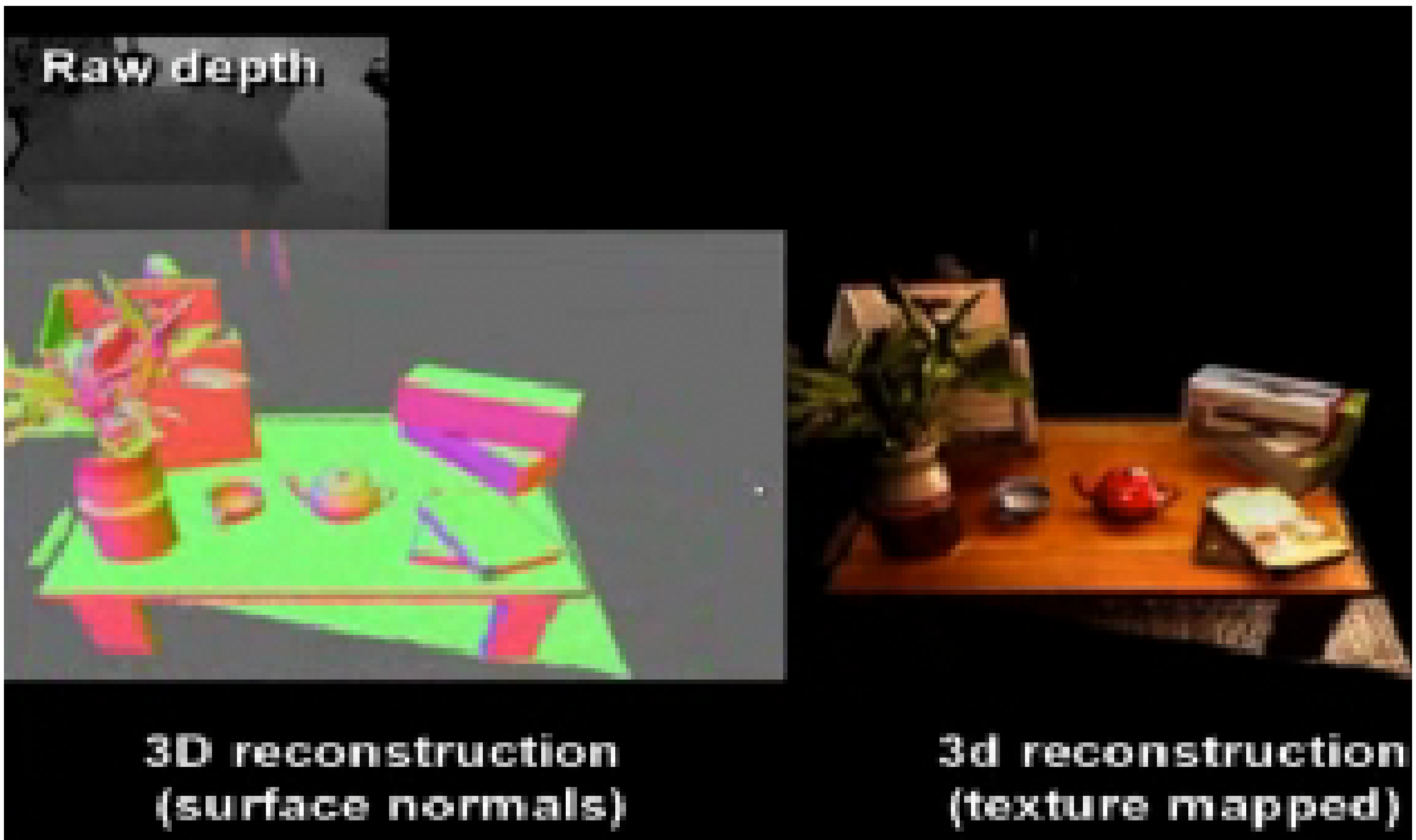






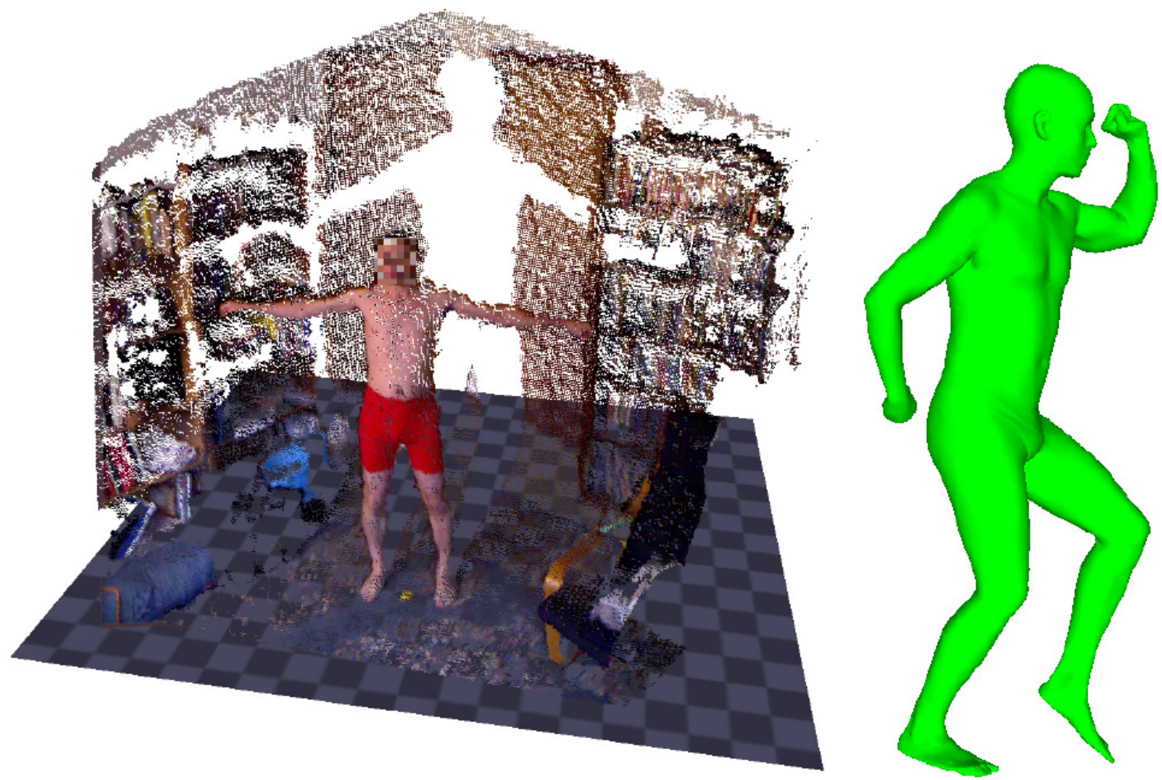
Kinect as Scanners

- Kinect fusion [Siggraph 2011 Sketch]



Scanning Human Bodies

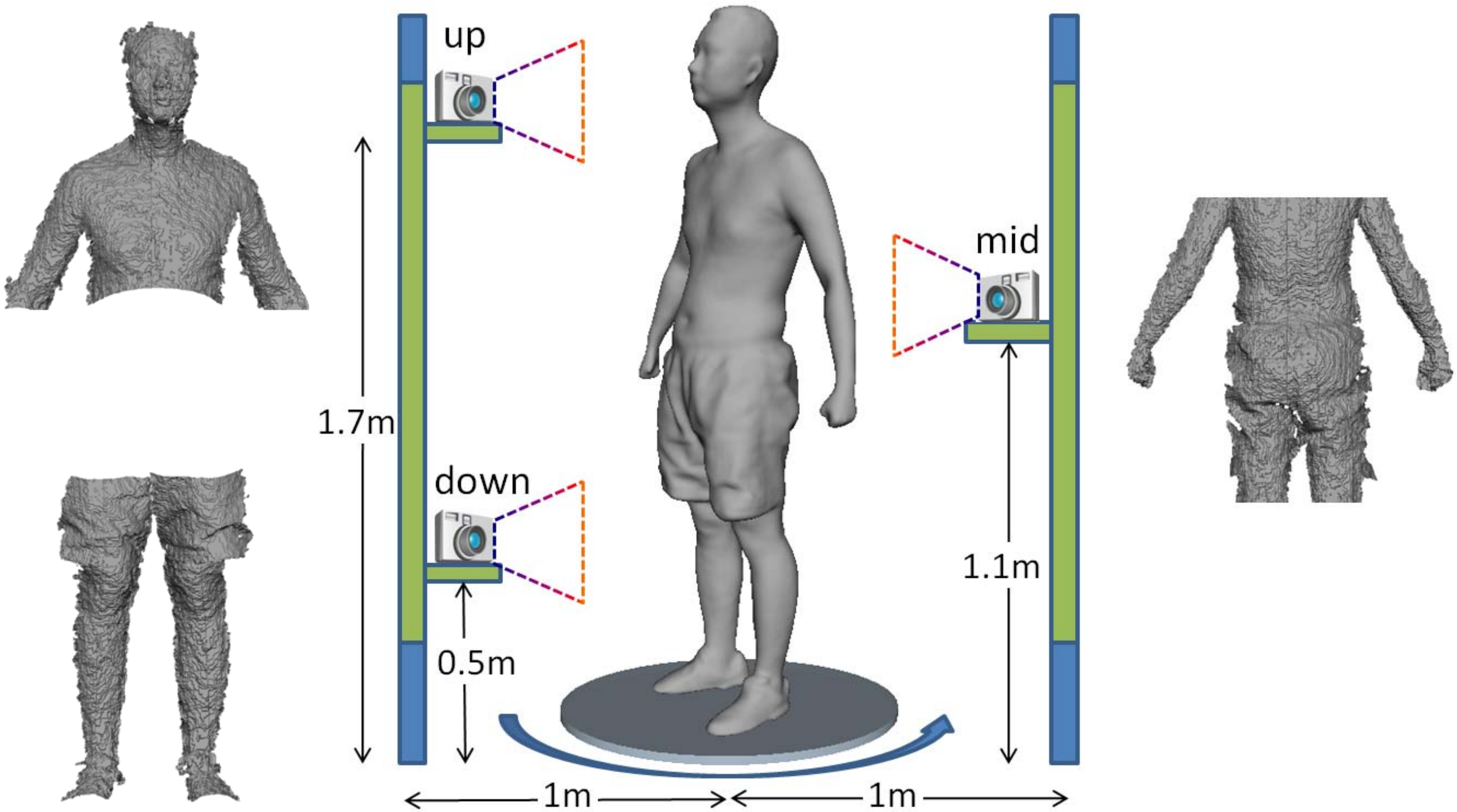
[Cui et al., 2011]



[Anguelov et al., 2011]

Scanning Bodies using Three Kinects

[IEEE VR 2012]



Kinects are popular…

- More applications
- Controller everywhere
- Many opportunities…

Q&A