User Interface Software Projects: Intro to Depth-Sensing Interfaces

Assoc. Professor Donald J. Patterson
INF 134 Winter 2013

Intro to Kinect and Depth-Sensing Interfaces

http://www.nintendo.com/wii/what-is-wii/#/wii-for-the-whole-far

http://us.playstation.com/ps3/accessories/playstation-eye-camera-ps3.html

Intro to Kinect and Depth-Sensing Interfaces

- What is Kinect?
  - Hardware package for sensors
  - Built for the Microsoft Xbox 360 game console

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Intro to Kinect and Depth-Sensing Interfaces

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- Supports a new interaction mode
  - Natural User Interface
    - Gestures
    - Speech
  - No explicit controller

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Intro to Kinect and Depth-Sensing Interfaces

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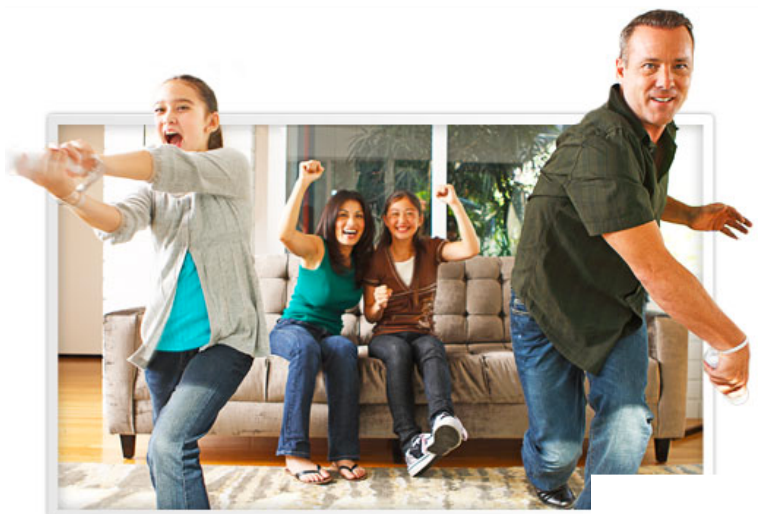
- Supports a new interaction mode
  - Natural User Interface
    - Gestures
    - Speech
  - No explicit controller
- Competitors
  - Wii Remote
  - PlayStation Move
  - LEAP



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Intro to Kinect

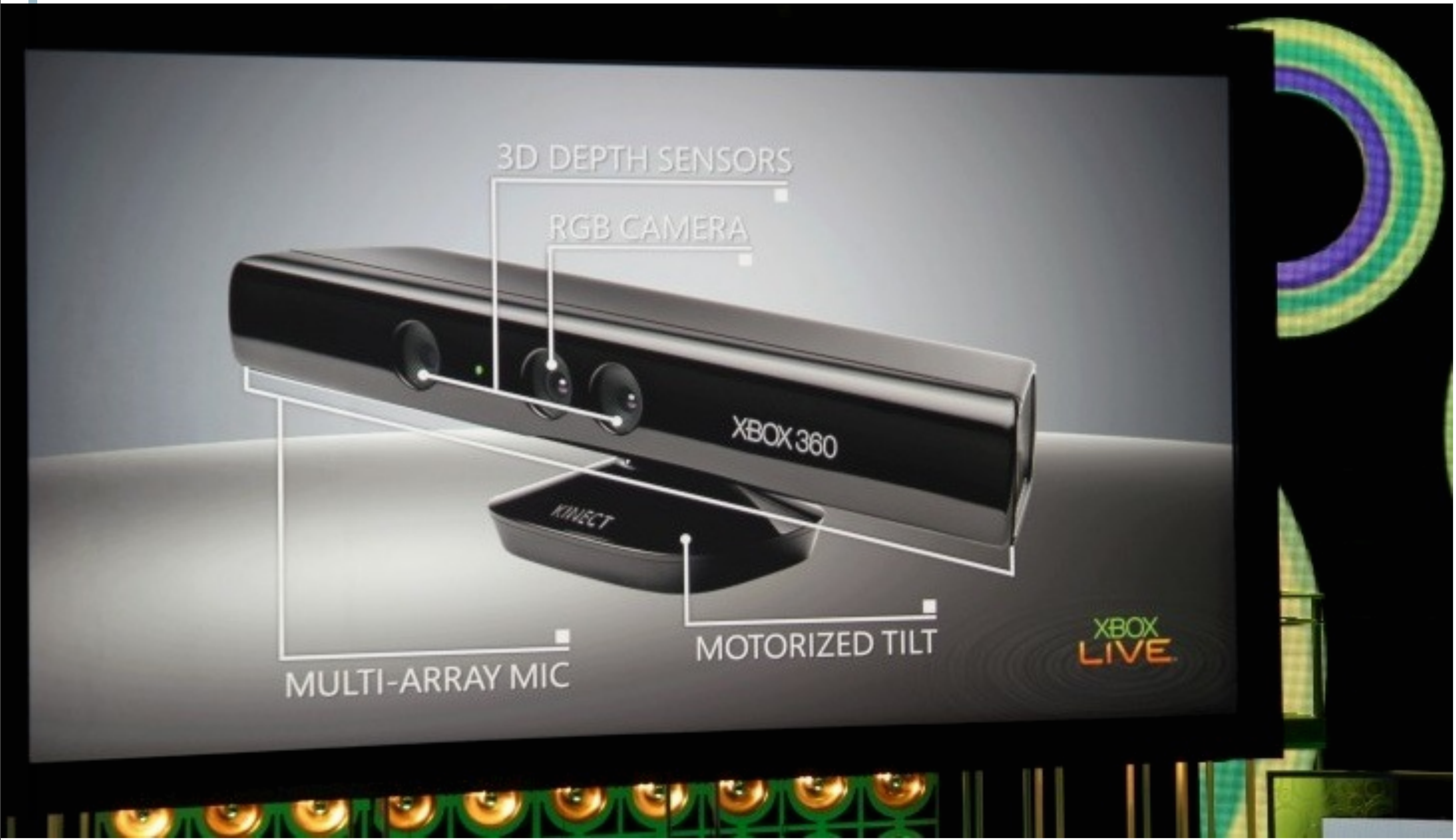
http://en.wikipedia.org/wiki/Kinect

Intro to Kinect

- A Horizontal bar
  - motorized base
  - RGB camera
  - depth sensor
  - multi-array microphone
- Supports
  - full-body 3D motion capture
    - skeletal tracking
  - facial recognition
  - voice recognition
  - acoustic source localization
  - ambient noise suppression

http://en.wikipedia.org/wiki/Kinect

Intro to Kinect



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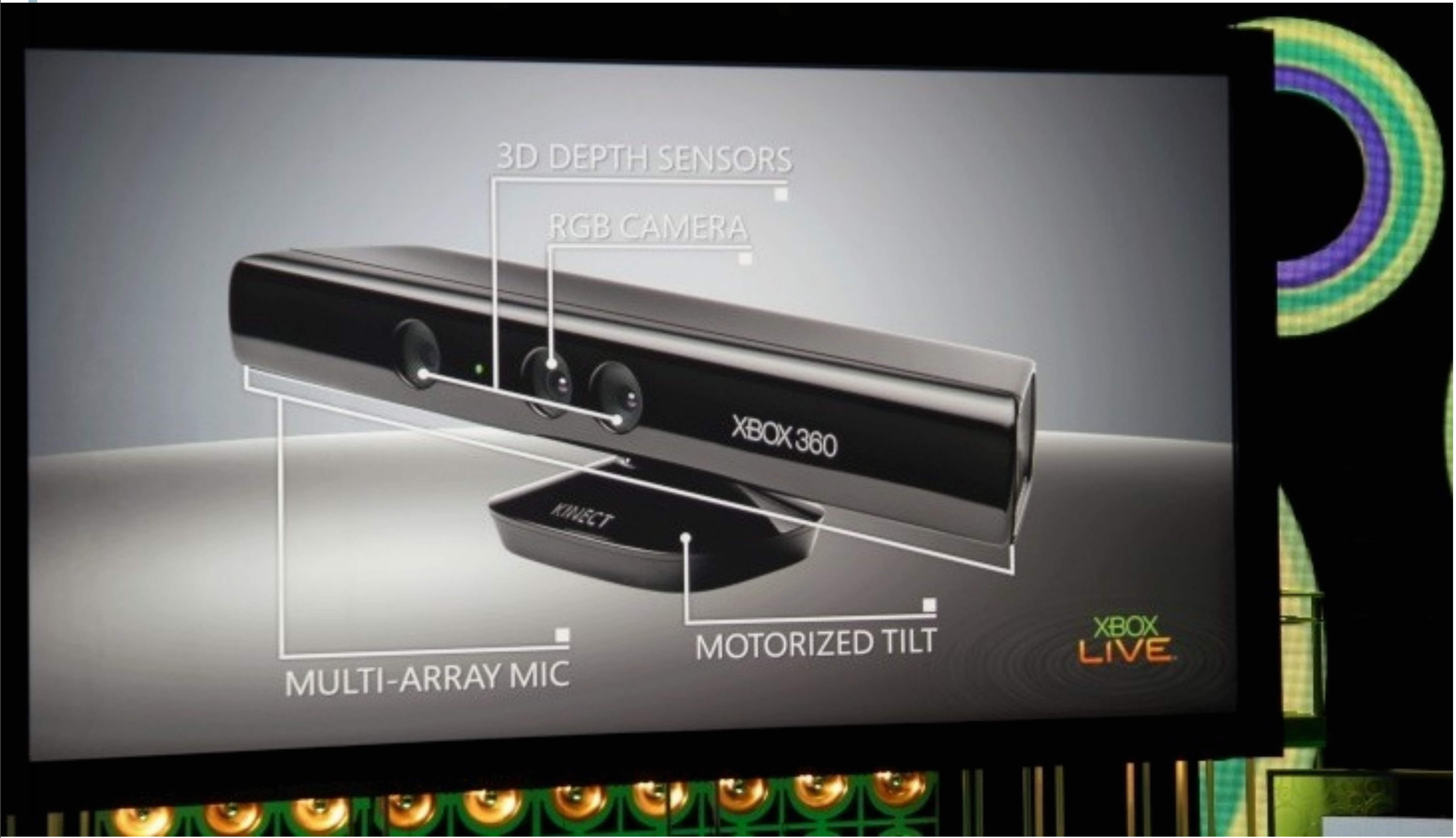
Intro to Kinect



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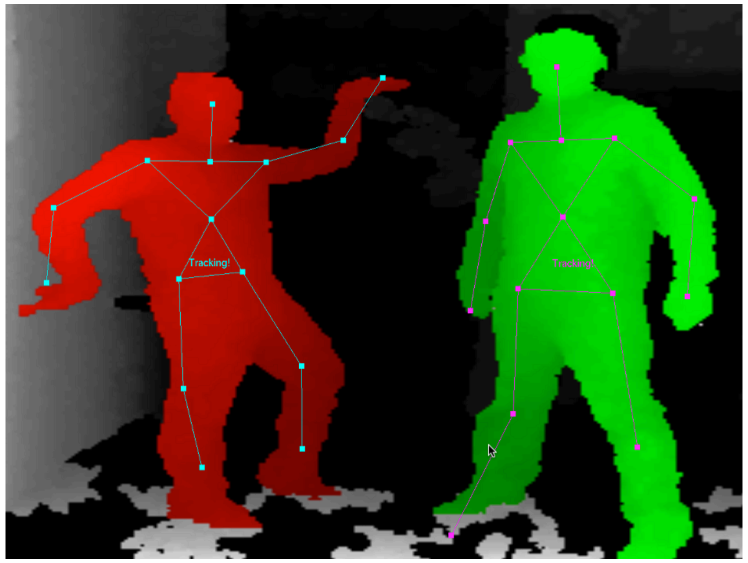
Intro to Kinect

- Code name was "Project Natal"
- Released in late 2010
- Based on software developed by Microsoft Game Studios
- Based on company "PrimeSense"
    - developed hardware to decode gestures
    - using infrared projector
    - infrared camera
    - algorithms implemented on chip for speed

http://en.wikipedia.org/wiki/Kinect

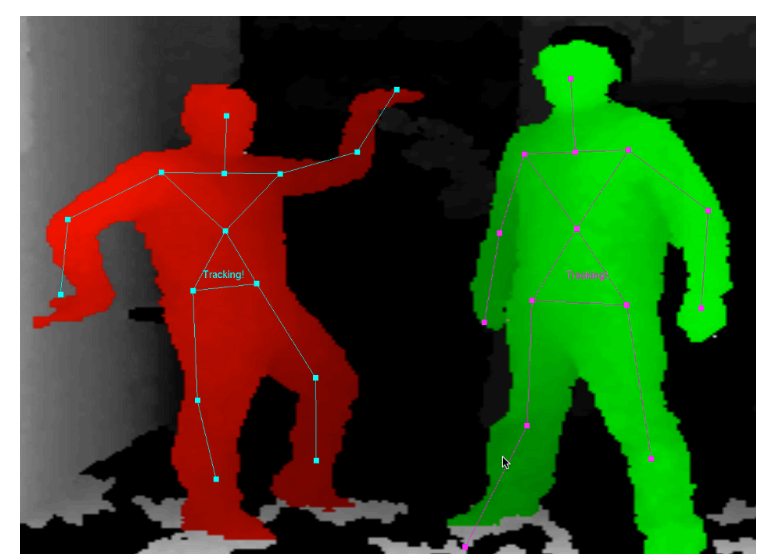
Intro to Kinect



http://en.wikipedia.org/wiki/Kinect

Intro to Kinect

- Specs of gesture recognition
  - Can track 6 people total
    - 2 active players
  - Tracks in the range of 3 - 11 ft using XBox software
  - Uses ~10-15% of the CPU of Kinect
  - requires 190 MB of storage space for software
- API available
  - official: Kinect for Windows 1.5 (released in May 2012)
  - open: NITE by OpenNI



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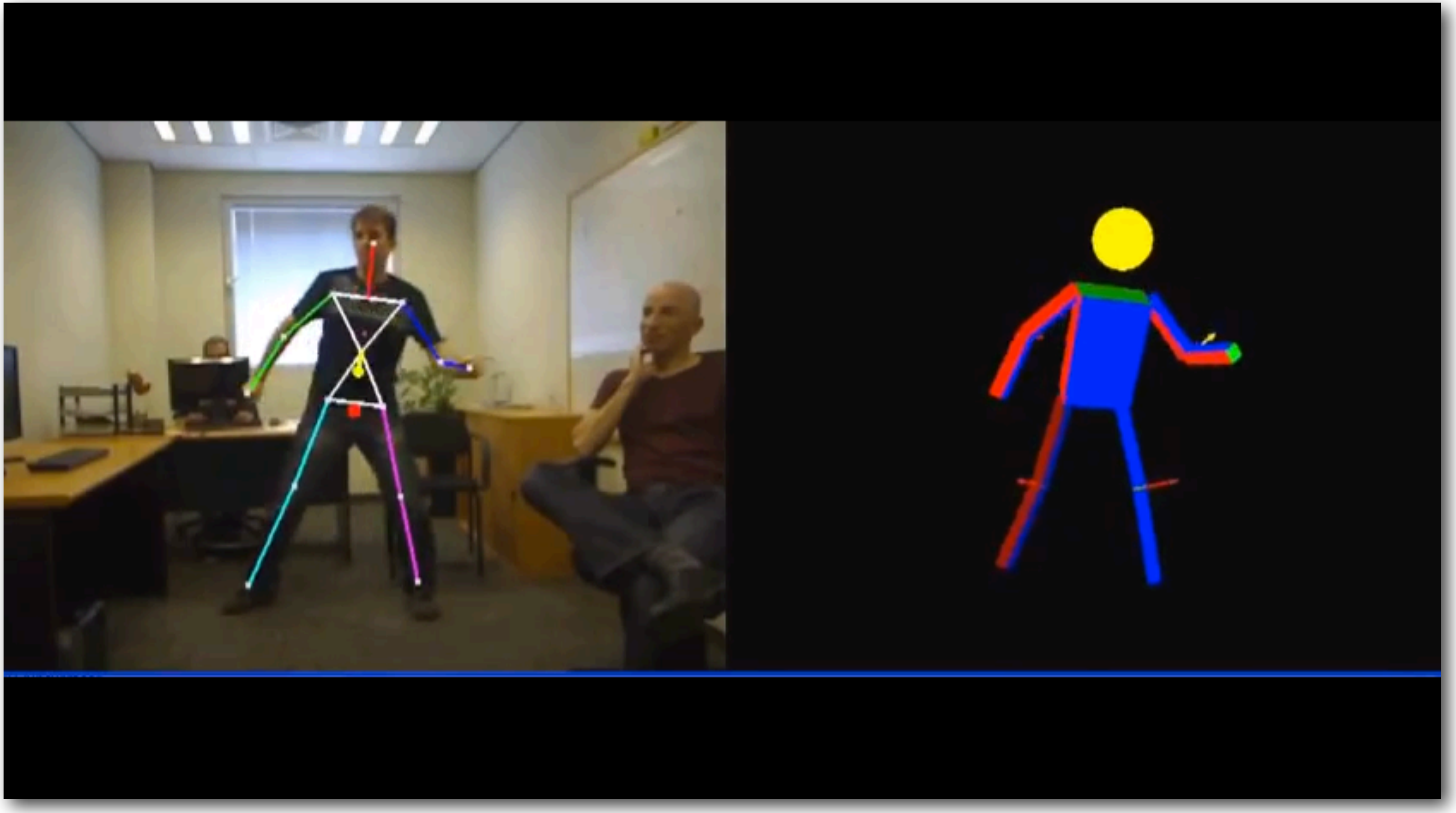
Intro to Kinect



http://youtu.be/nuVPiXetfdM

http://www.openni.org/files/nite/

Intro to Kinect

http://www.youtube.com/watch?v=diy7rkWkDtU

Intro to Playstation Move

Intro to Playstation Move

- Playstation Move
  - Game market
  - Wands
    - lit colored balls
      - tracked by camera
    - internal accelerometers

Intro to Playstation Move

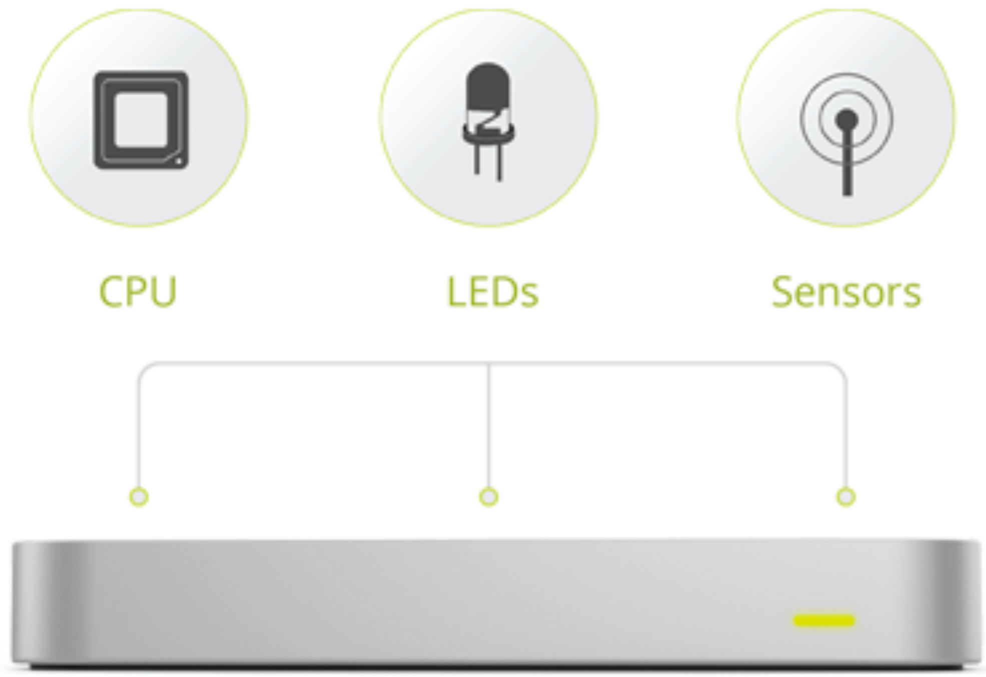
http://www.youtube.com/watch?v=s9ybHddDMgM

Intro to Wii

Intro to Wii

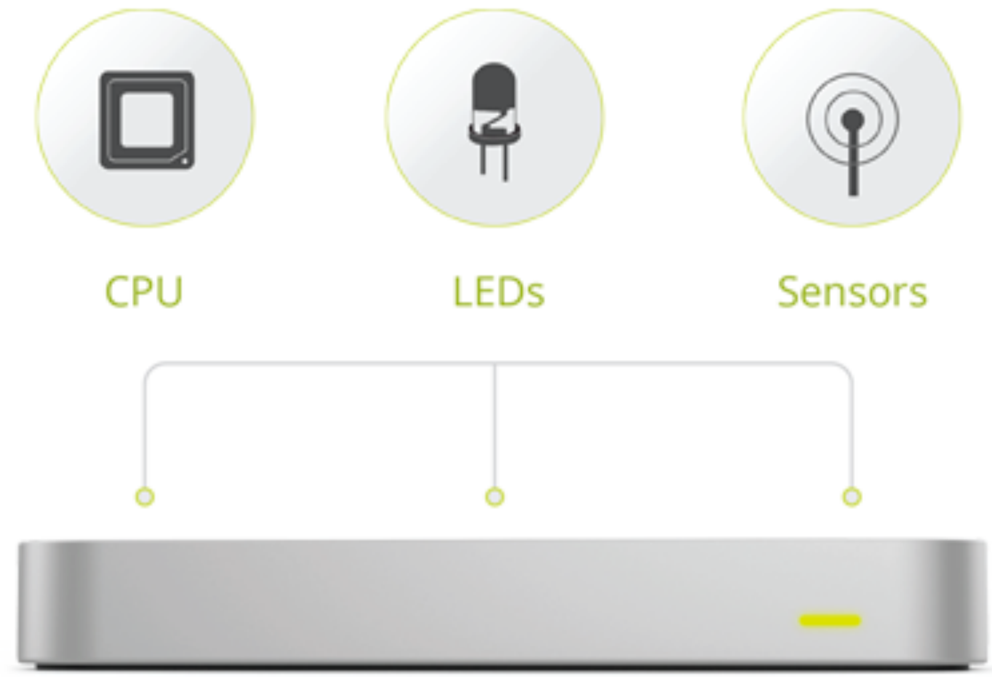
- Wii
  - Game market
  - Wands
    - infrared LEDS
      - tracked by sensor bar on console
    - internal accelerometers

Intro to LEAP

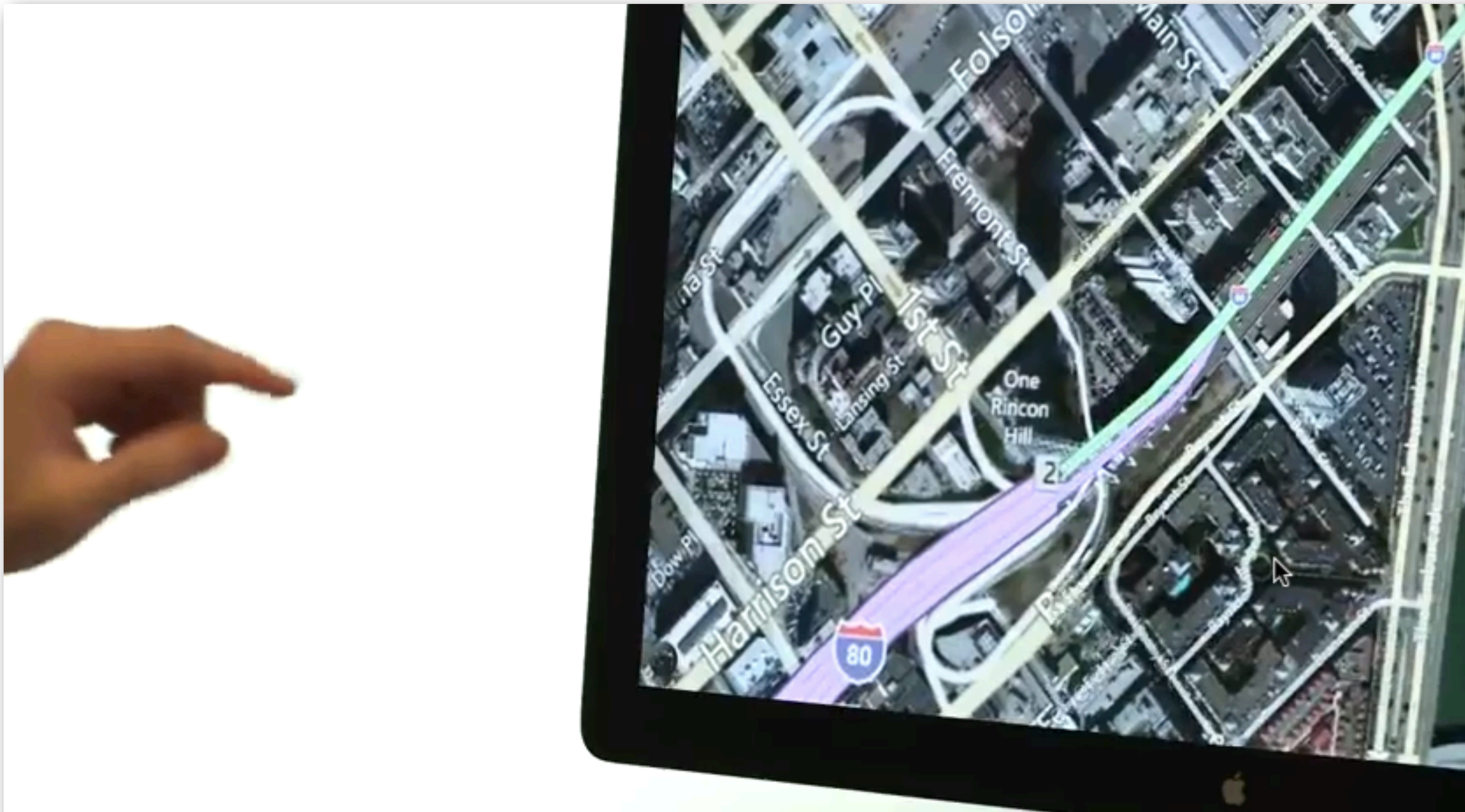


Intro to LEAP

- LEAP
  - High resolution
  - Small observation area
  - cheap $69.99

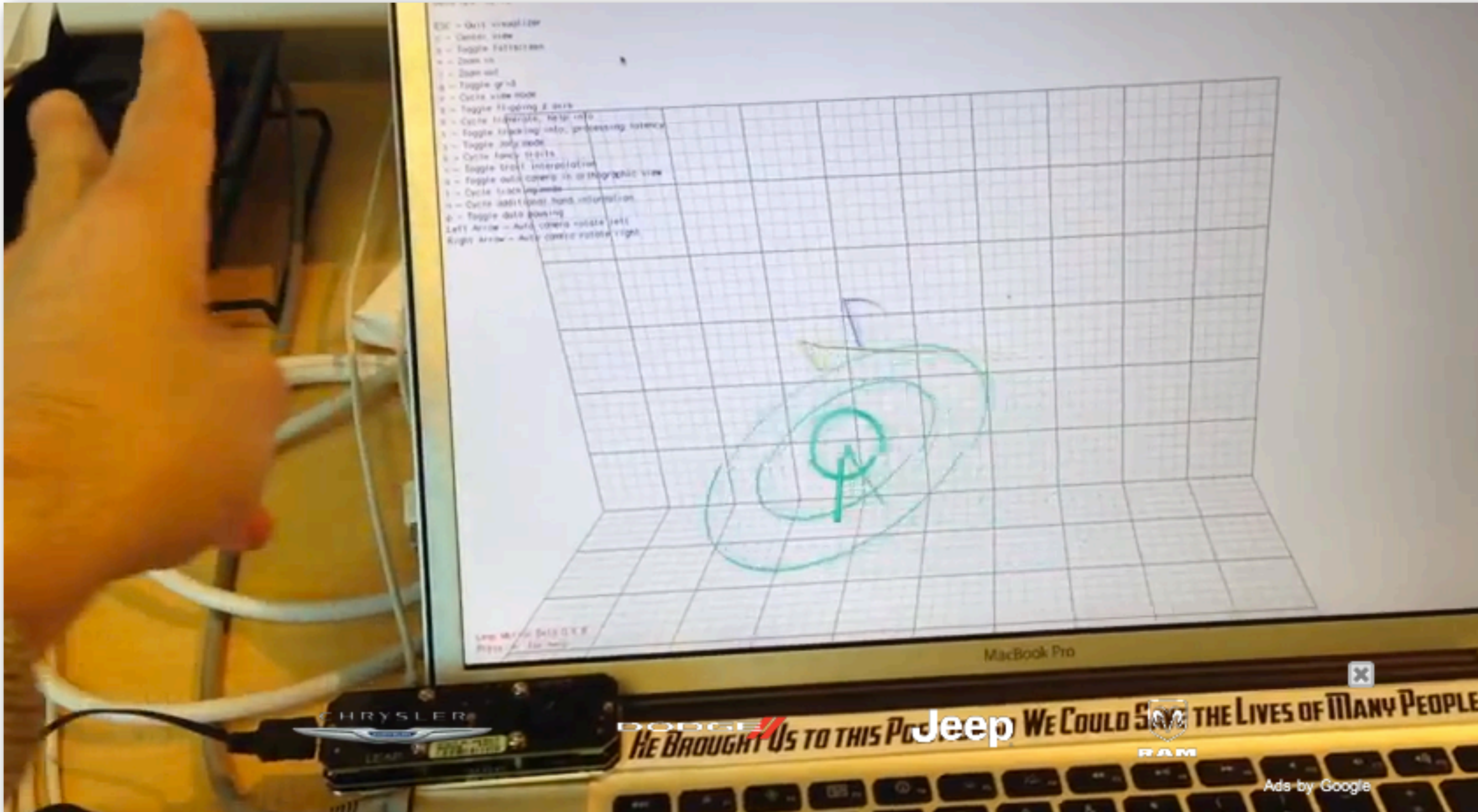


Intro to Kinect



http://youtu.be/_d6KuiuteIA

Intro to Kinect



http://youtu.be/bZW03AMyGUw

User Interface Software Projects:

Intro to Kinect

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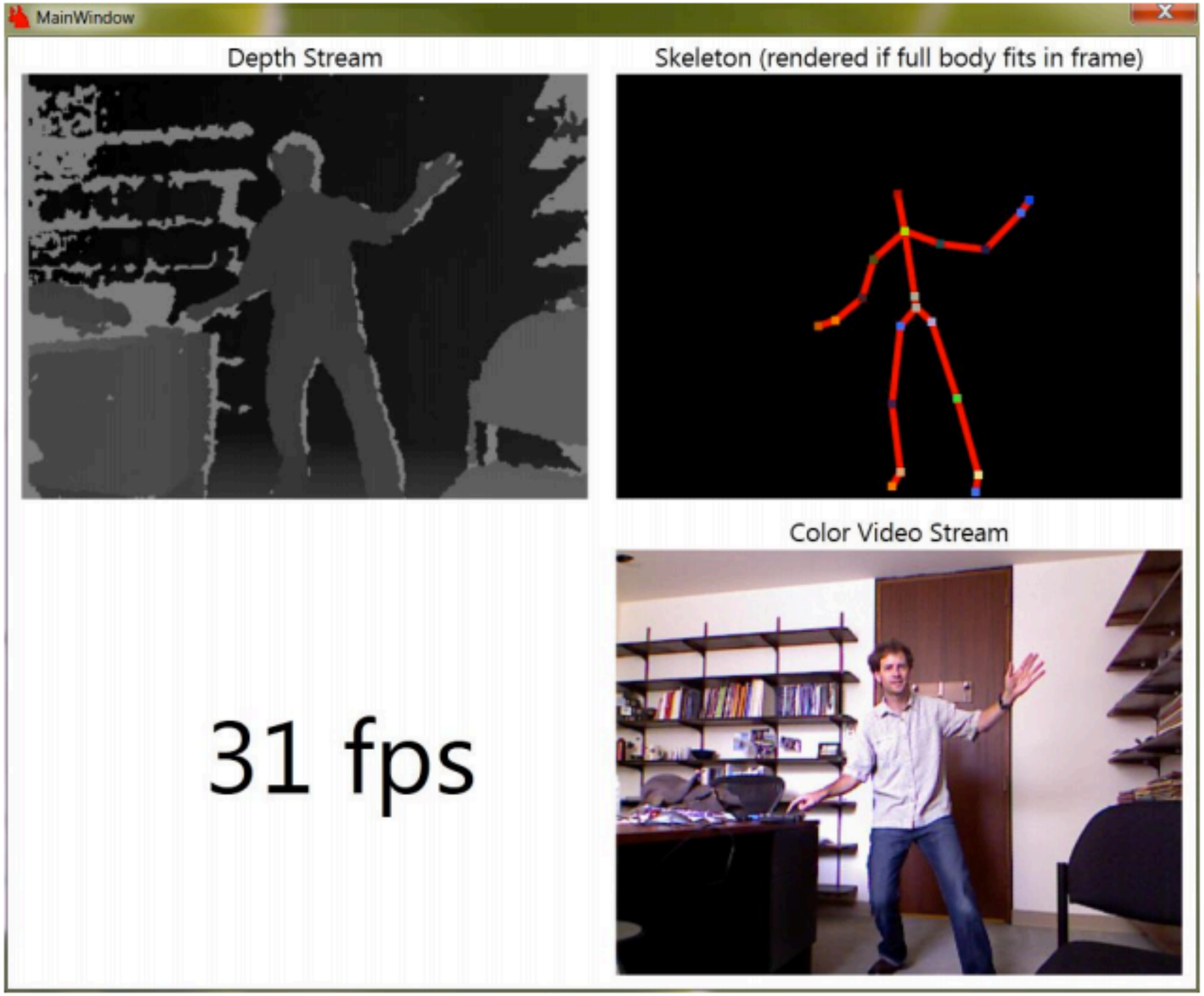
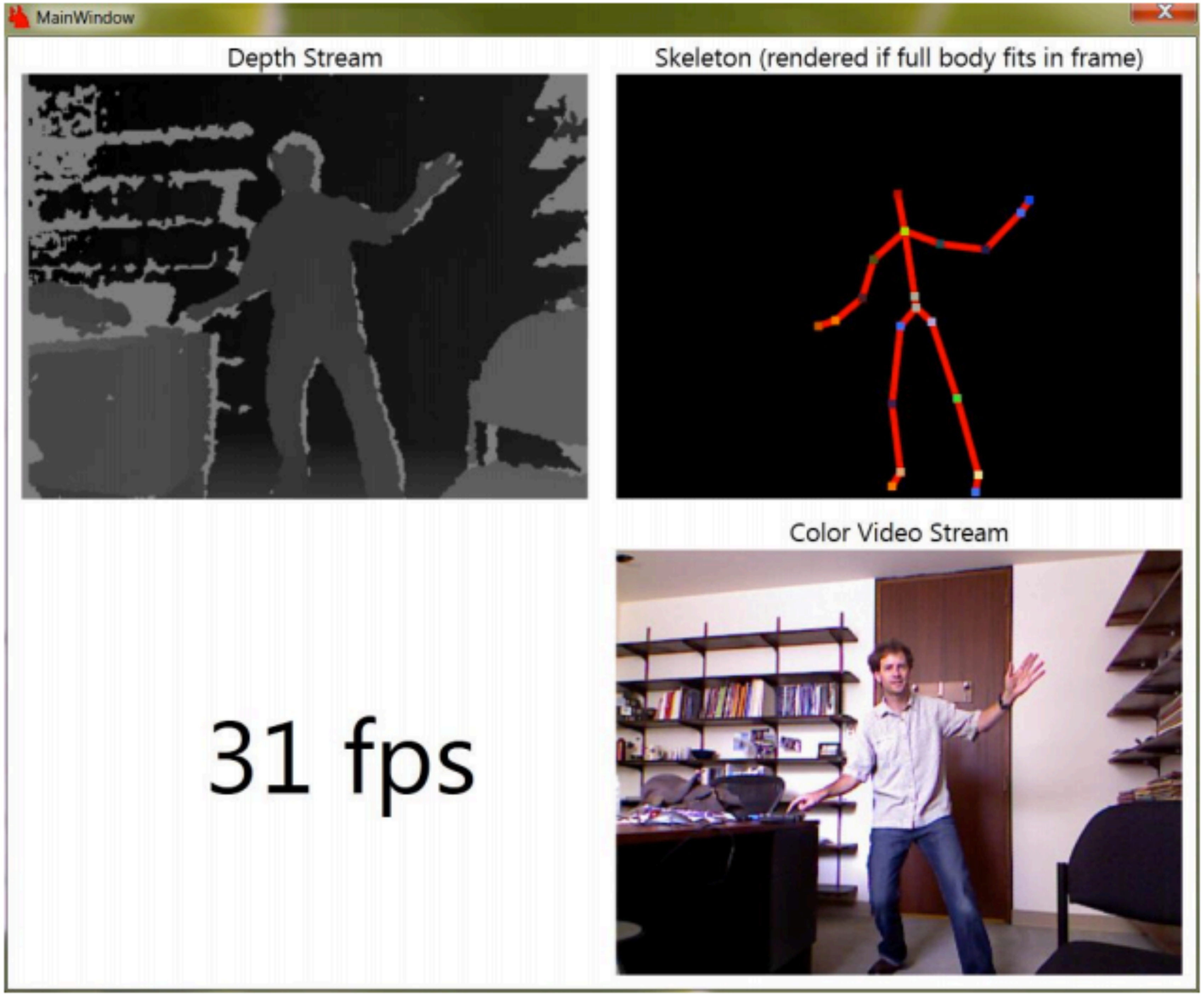
Slides adapted from John MacCormick, Guido Gerig:
http://users.dickinson.edu/~jmac/selected-talks/kinect.pdf
http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf

How does the Kinect Gesture Tracking Work



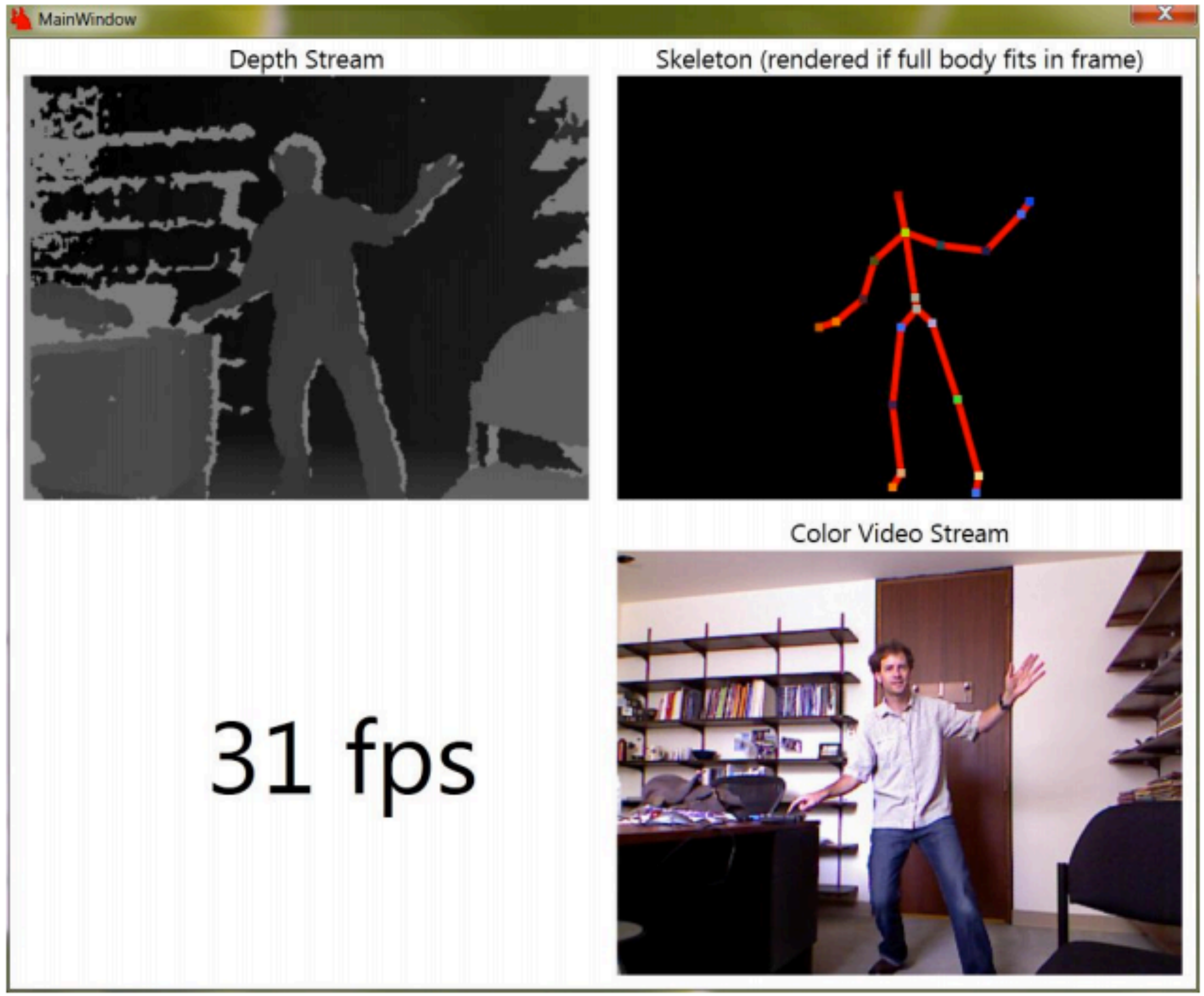
How does the Kinect Gesture Tracking Work

- Depth Video Stream



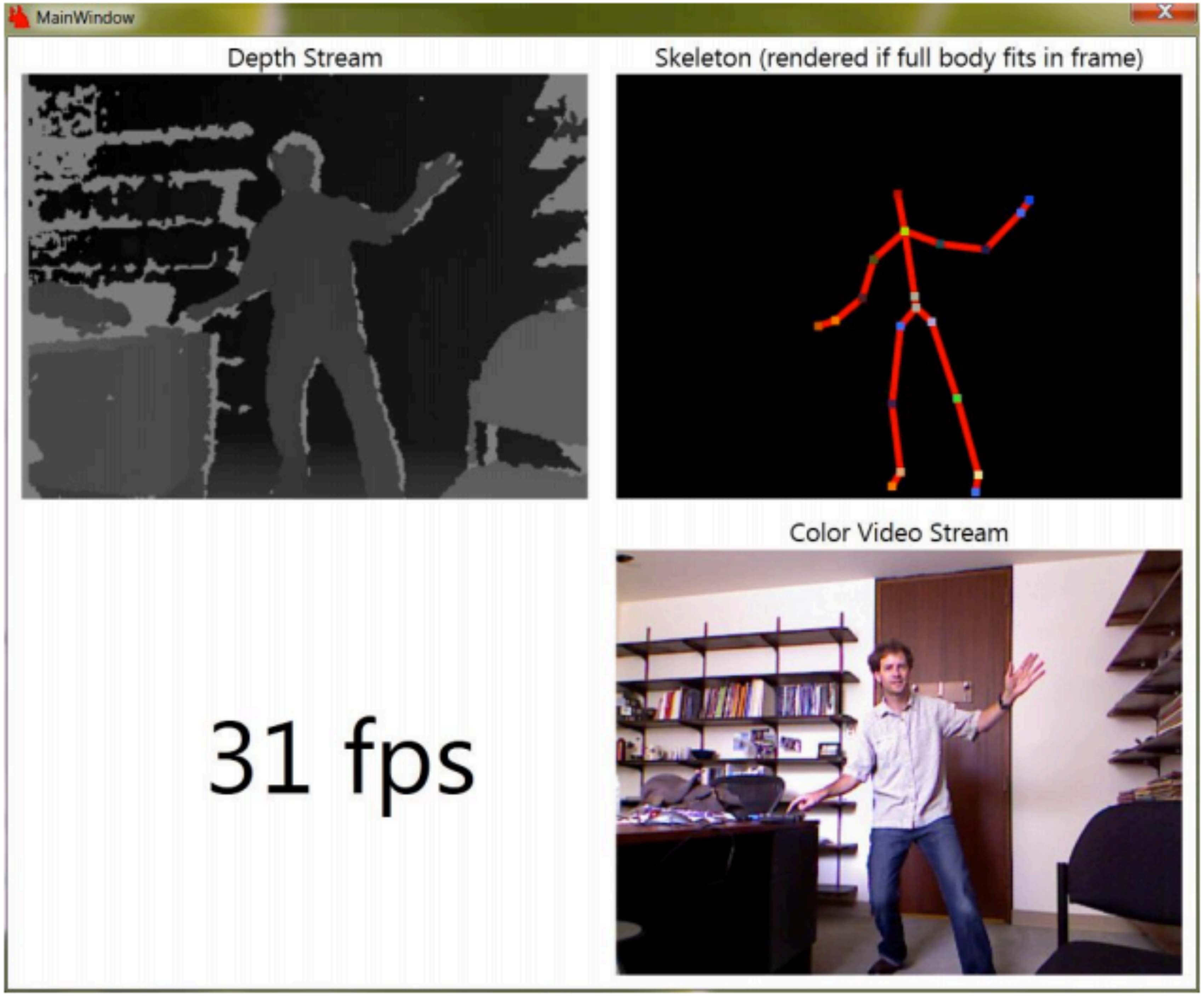
How does the Kinect Gesture Tracking Work

- Depth Video Stream
- Skeleton detection



How does the Kinect Gesture Tracking Work

- Depth Video Stream
- Skeleton detection
- Color Video Stream



How does the Kinect Gesture Tracking Work

How does the Kinect Gesture Tracking Work

- Several key technologies
  - to compute a depth image
    - Structured light
    - Depth from focus
    - Depth from stereo
  - Machine learning to infer skeleton position

How does the Kinect Gesture Tracking Work

How does the Kinect Gesture Tracking Work

- Structured light
  - The depth map is constructed by analyzing a projected speckle pattern of infrared laser light
    - Microsoft licensed this technology from PrimeSense
  - The depth computation is done by the PrimeSense hardware in the Kinect
  - Details are not public, the following is speculation based on patent applications

How does the Kinect Gesture Tracking Work

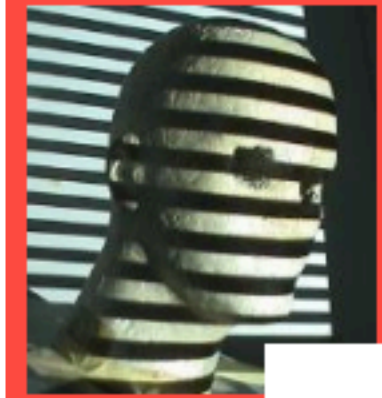
How does the Kinect Gesture Tracking Work

- Structured light
  - A Computer Vision concept
  - Based on projecting a known light pattern onto a scene
  - Analyzing how the observed light differs from the known projection
  - Assuming that the differences are due to the topology of the world

How does the Kinect Gesture Tracking Work

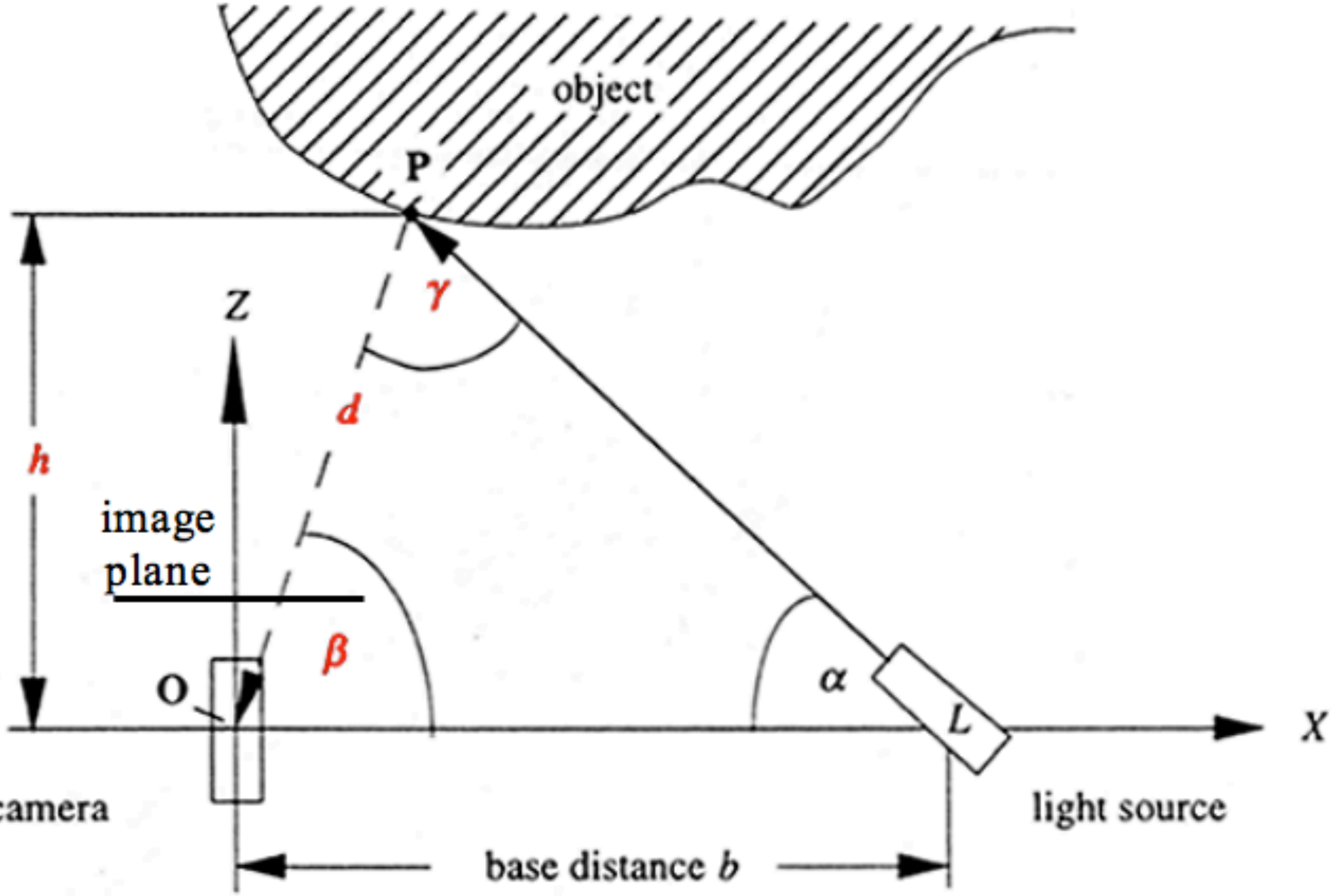
How does the Kinect Gesture Tracking Work

- Structured light
  - Technique #1

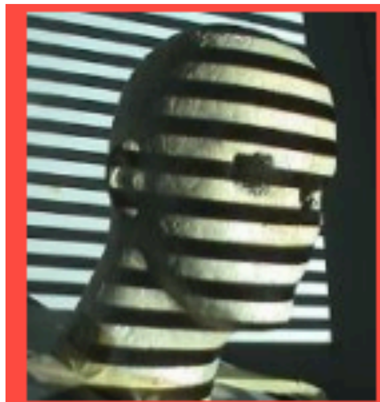


Light Spot Projection 2D

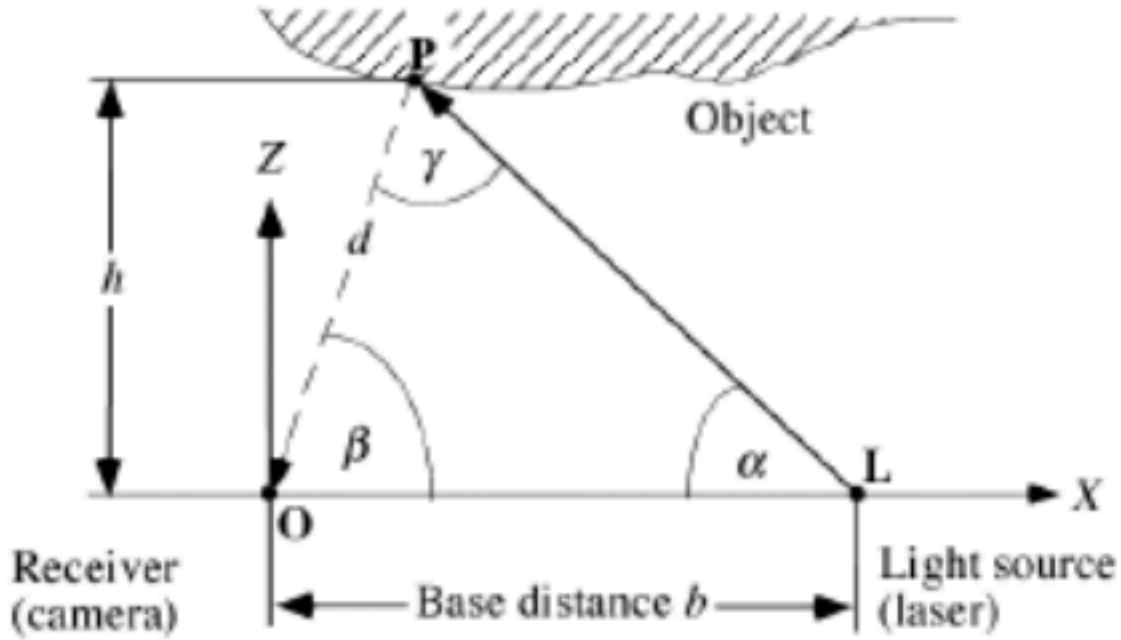
Assume point-wise illumination by laser beam, only 2D



http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf



Light Spot Projection 2D



O, **L**, and **P** define a triangle, and we determine the position of P by *triangulation*, using basic formulas about triangles such as the law of sines:

$$\frac{d}{\sin\alpha} = \frac{b}{\sin\gamma}$$

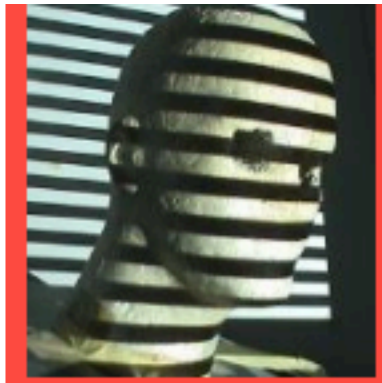
It follows that

$$d = \frac{b\cdot\sin\alpha}{\sin\gamma} = \frac{b\cdot\alpha}{\sin(\pi-\alpha-\beta)} = \frac{b\cdot\alpha}{\sin(\alpha+\beta)}$$

and, finally, $\mathbf{P} = (d\cdot\cos\beta, d\cdot\sin\beta)^T$. Note that β is determined by the position of the projected (illuminated) point **P** in the 1D image.

http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf

Structured Light Technique #1



Light Spot Projection 2D

- Coordinates found by triangulation
  - β can be found by projection geometry
  - $d = b*\sin(\alpha)/\sin(\alpha + \beta)$

  - $X_0 = d*\cos(\beta)$
  - $Z_0 = h = d*\sin(\beta)$

- Concept:
  - known b and α
  - β defined by projection geometry
  - Given image coordinate u and focal length f -> calculate β
  - Given b, α, β -> calculate d

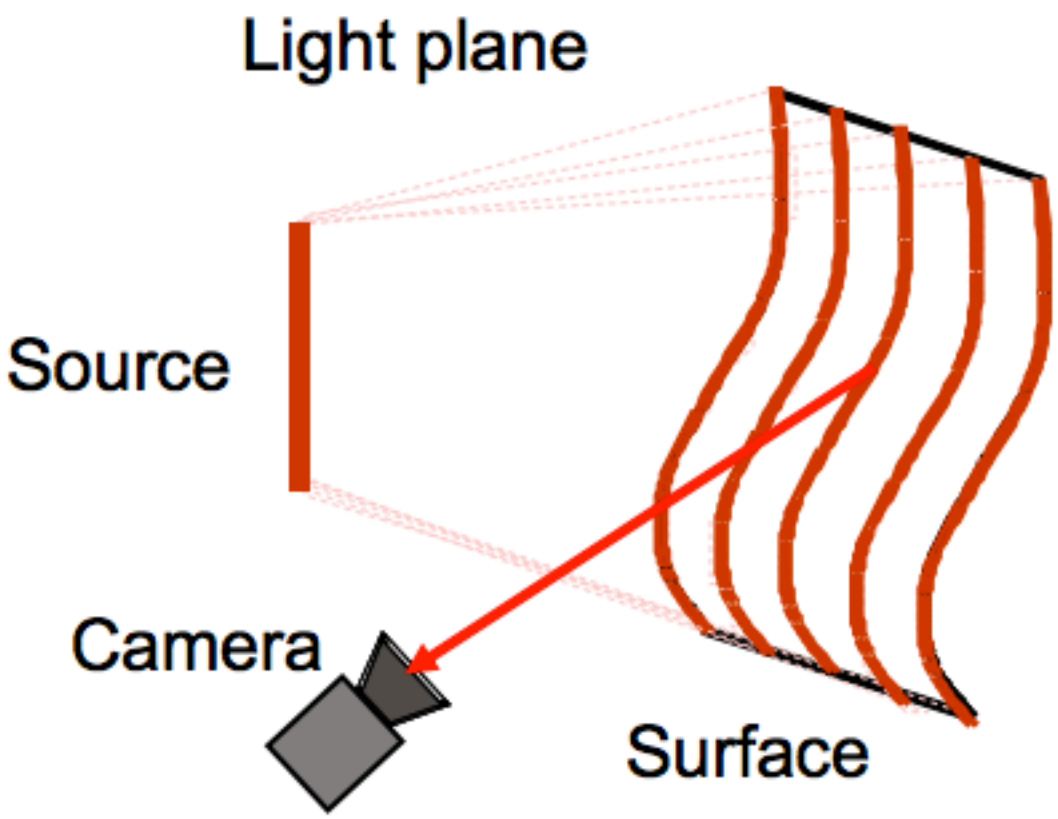
http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf

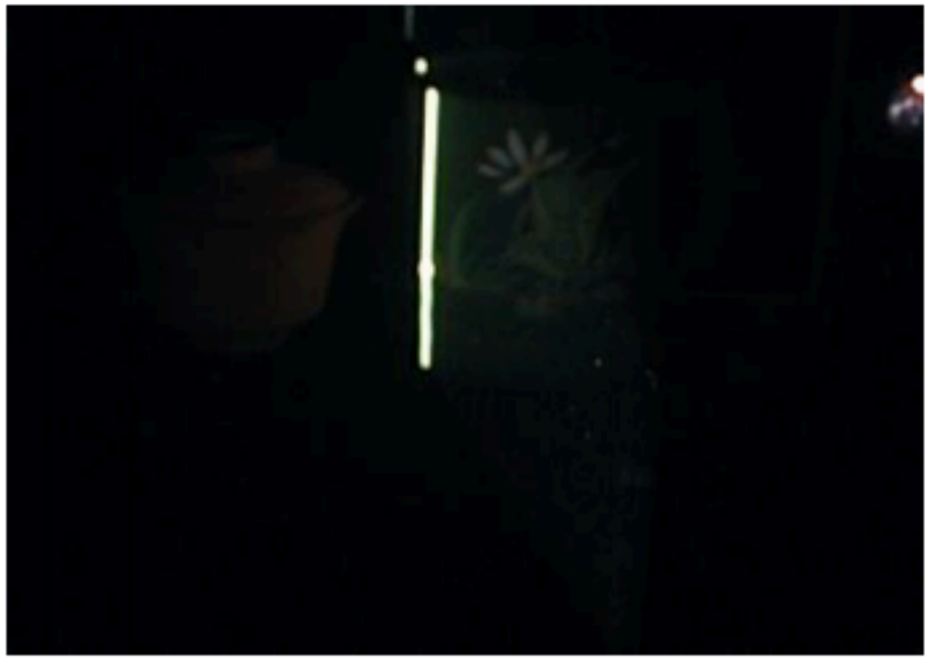
How does the Kinect Gesture Tracking Work

How does the Kinect Gesture Tracking Work

- Structured light
    - Technique #2

Light Stripe Scanning – Single Stripe



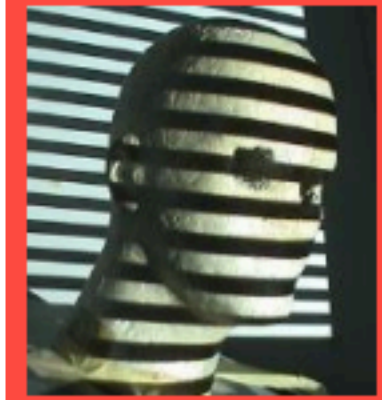


- Optical triangulation
  - Project a single stripe of laser light
  - Scan it across the surface of the object
  - This is a very precise version of structured light scanning
  - Good for high resolution 3D, but needs many images and takes time

Courtesy S. Narasimhan, CMU

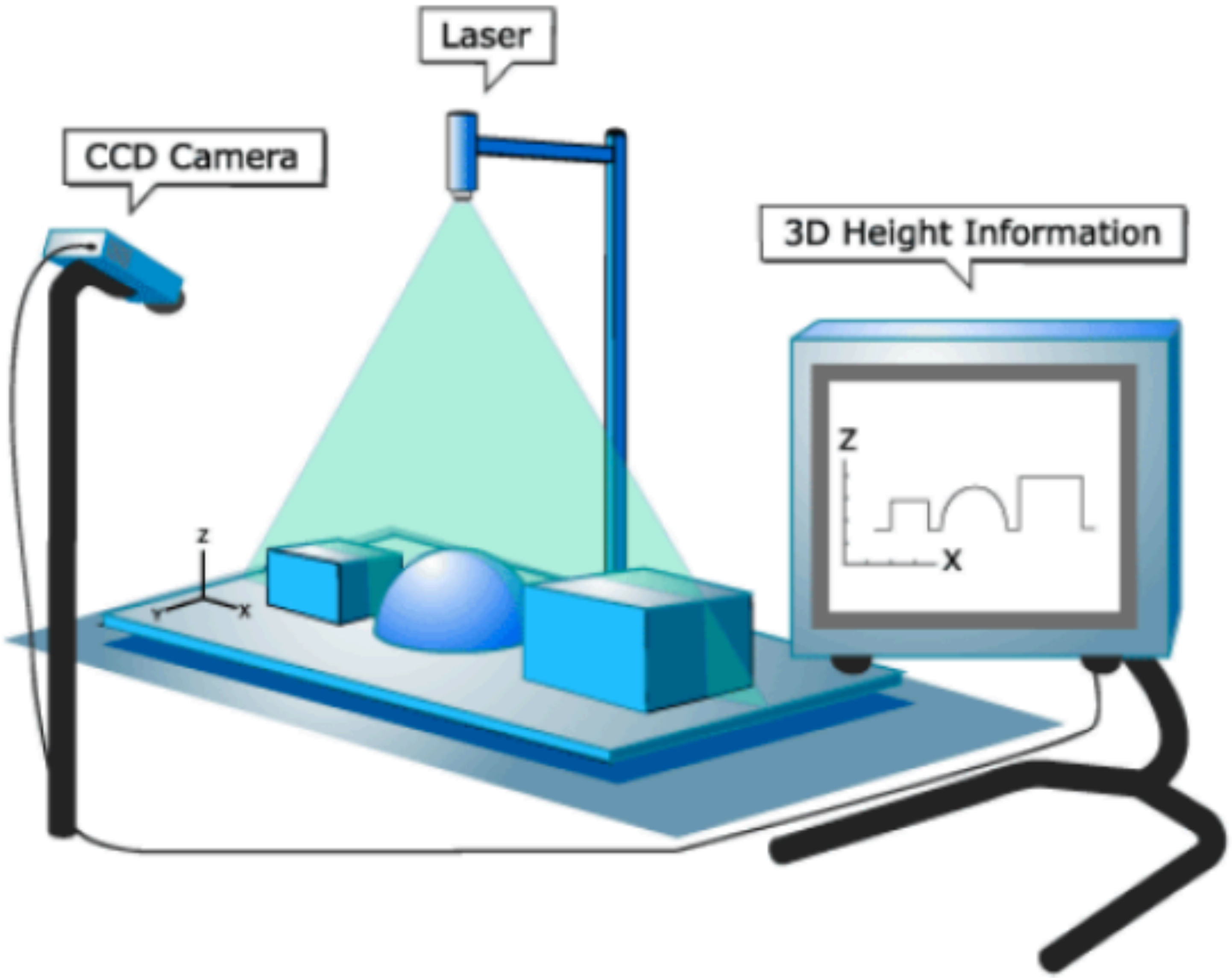
http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf

Structured Light Technique #2



Light Stripe Projection

Structured light is the projection of a light pattern (ray, plane, grid, encoded light, and so forth) under calibrated geometric conditions onto an object whose shape needs to be recovered.



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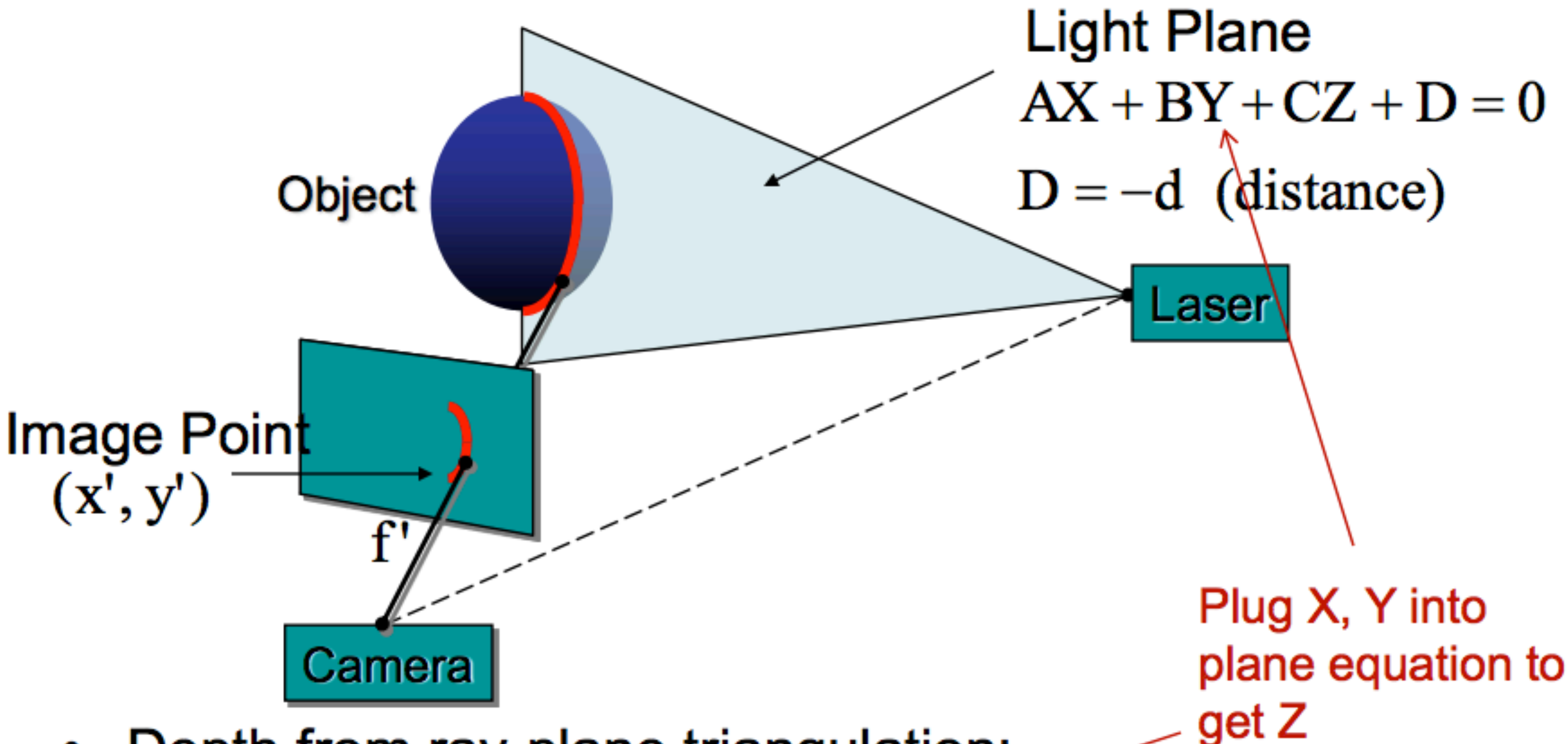
Structured Light Technique #2

Triangulation



- Depth from ray-plane triangulation:
  - Intersect camera ray with light plane

$$X = x'Z / f' \qquad Y = y'Z / f' \qquad Z = \frac{-Df'}{Ax' + By' + Cf'}$$

Courtesy S. Narasimhan, CMU

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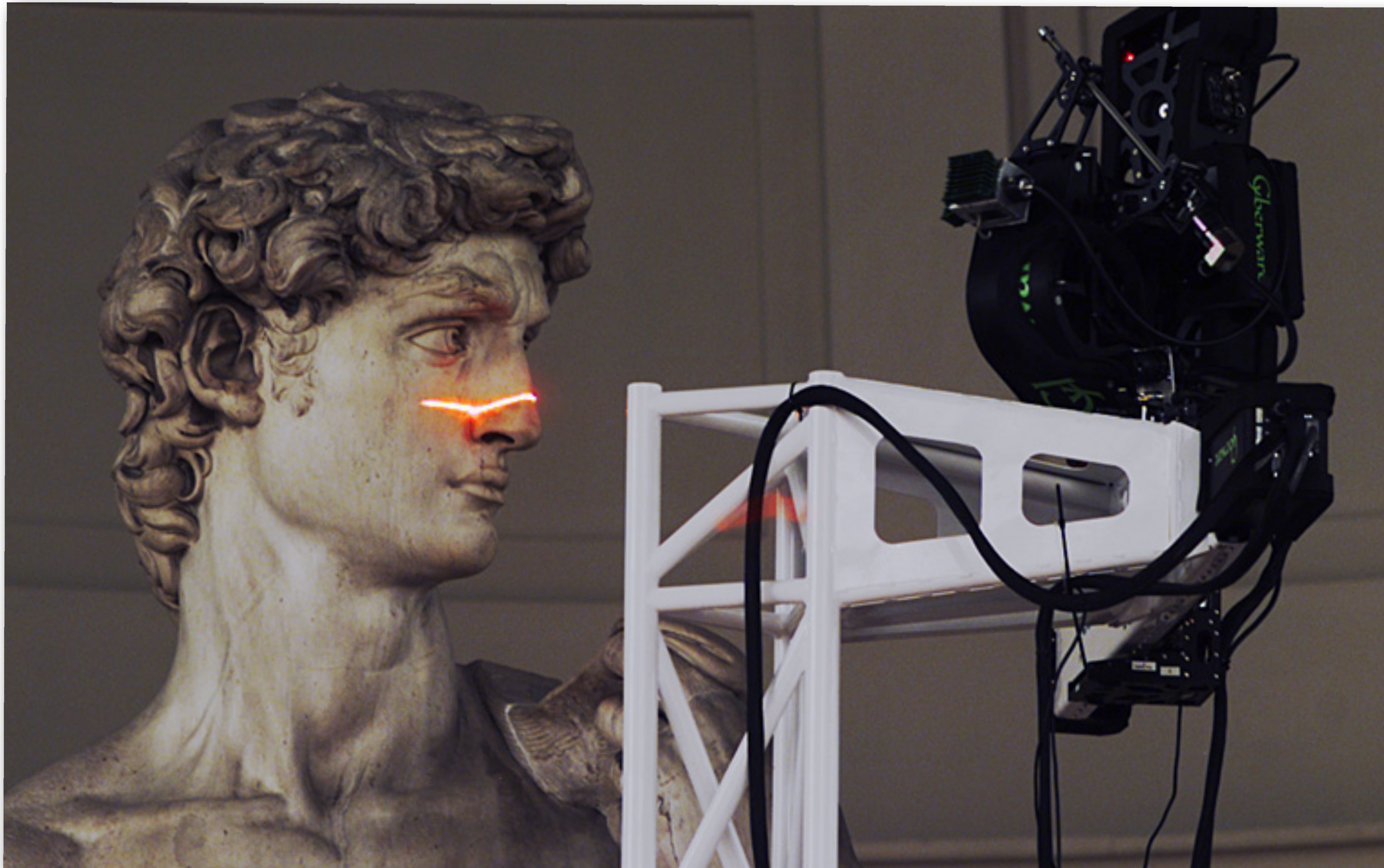
Structured Light Technique #2



http://graphics.stanford.edu/projects/mich/more-david/scanner-head-and-david-head-s.jpg

Application of Structured Light Scanning

Application of Structured Light Scanning

http://www.flickr.com/photos/nathaninsandiego/6165296066/sizes/z/in/photostream/

Application of Structured Light Scanning

http://graphics.stanford.edu/projects/mich/head-of-david/head-of-david.html

Application of Structured Light Scanning

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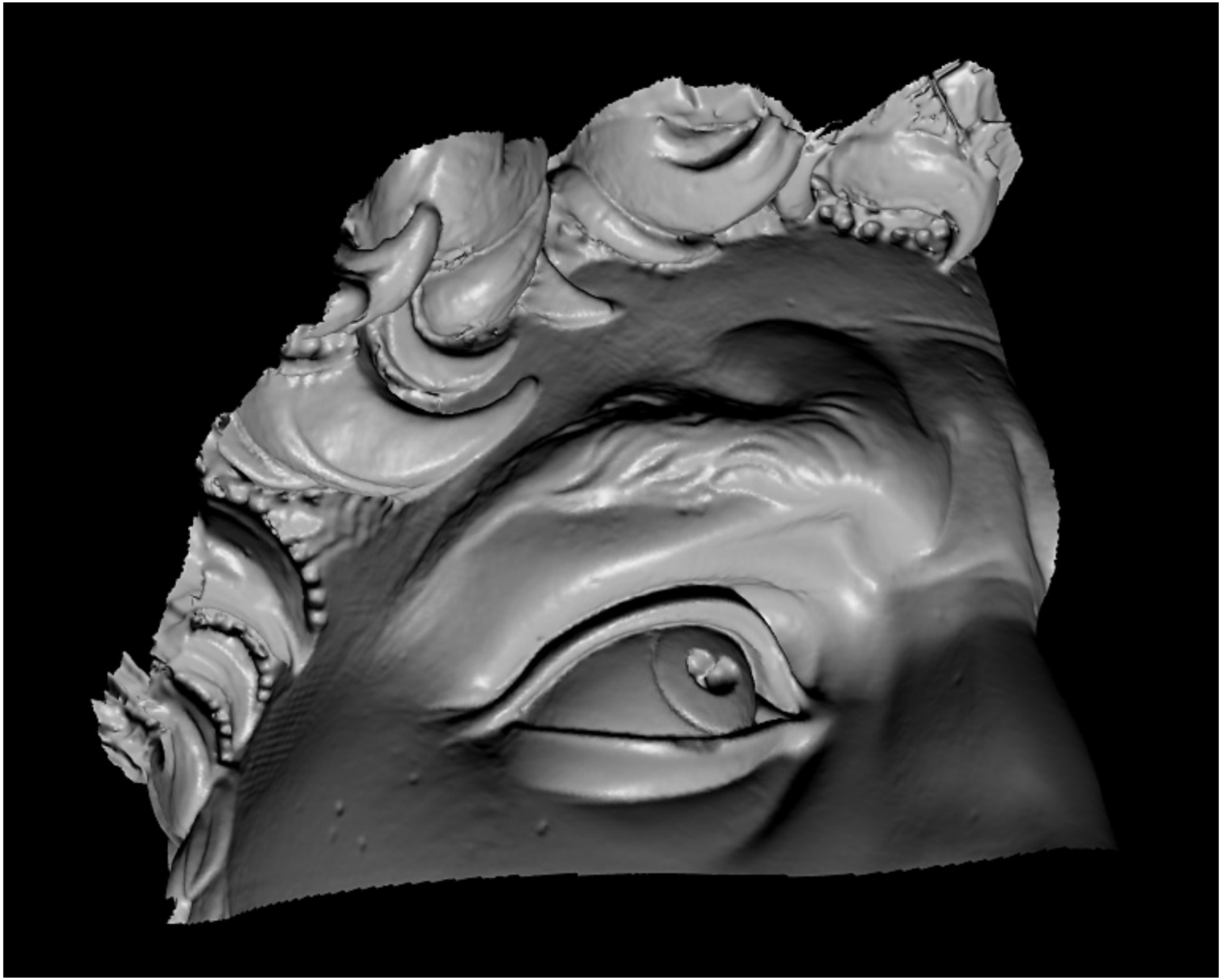
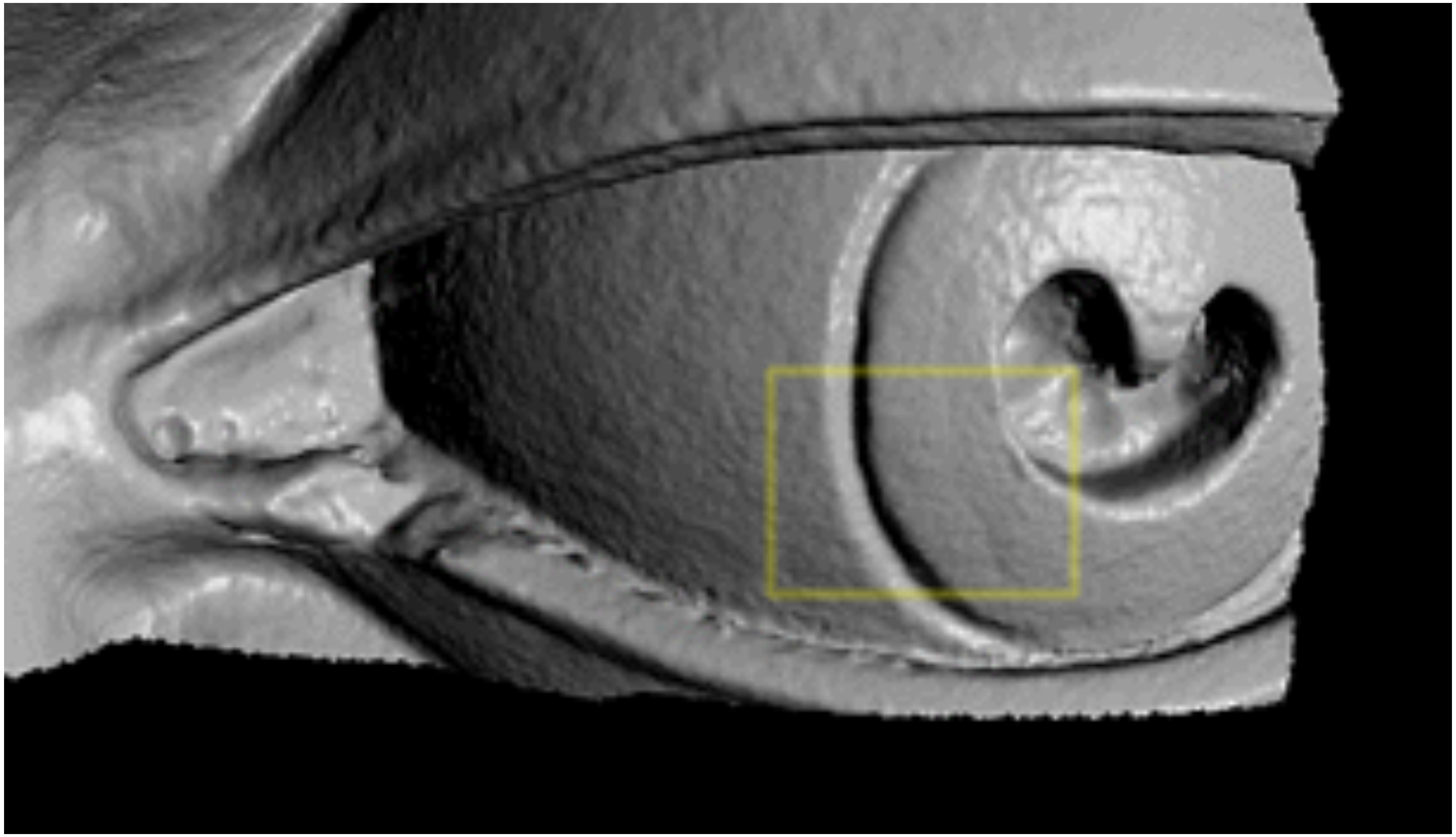
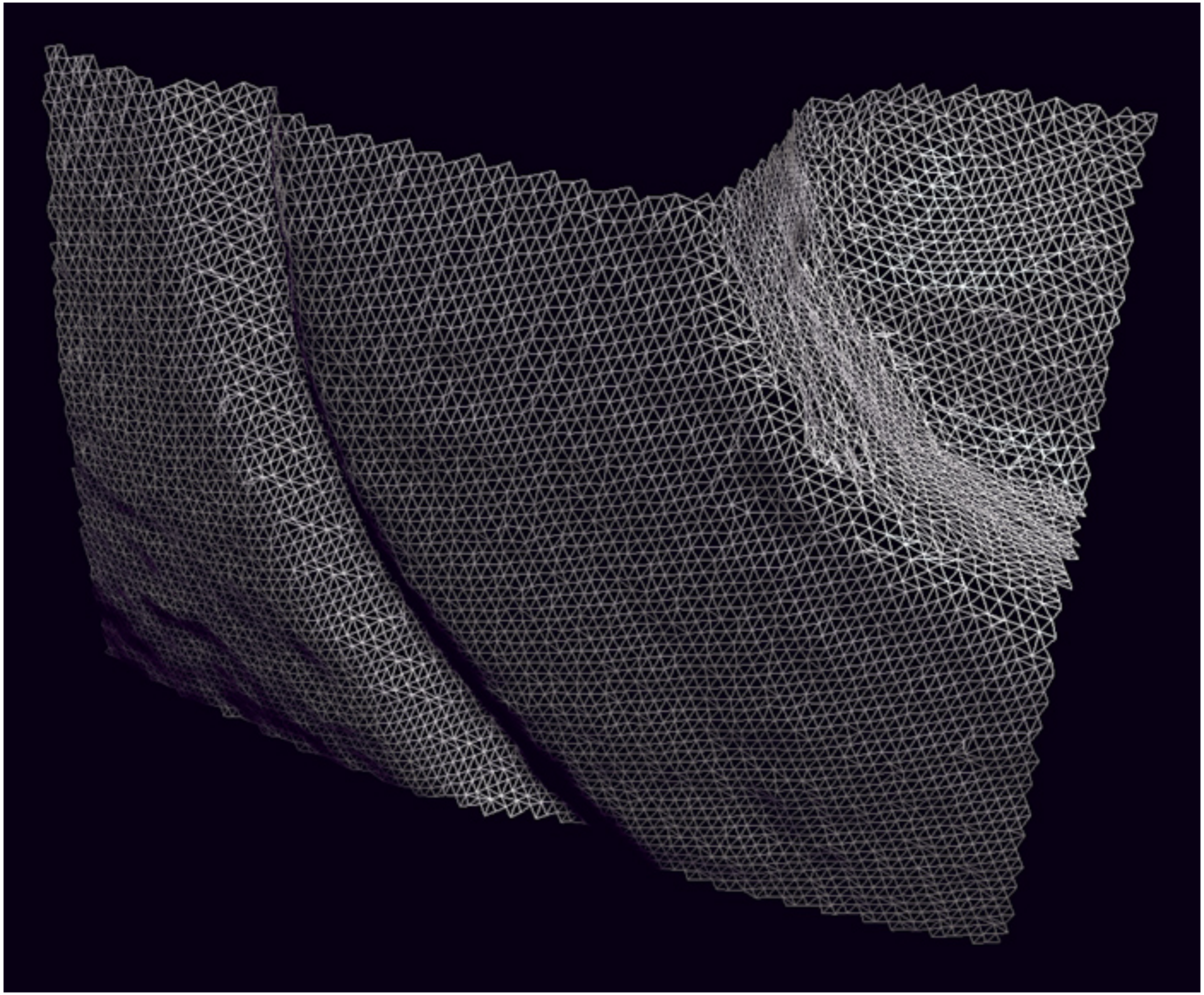


Application of Structured Light Scanning



Application of Structured Light Scanning



Digital Michelangelo Project:
http://graphics.stanford.edu/projects/mich/

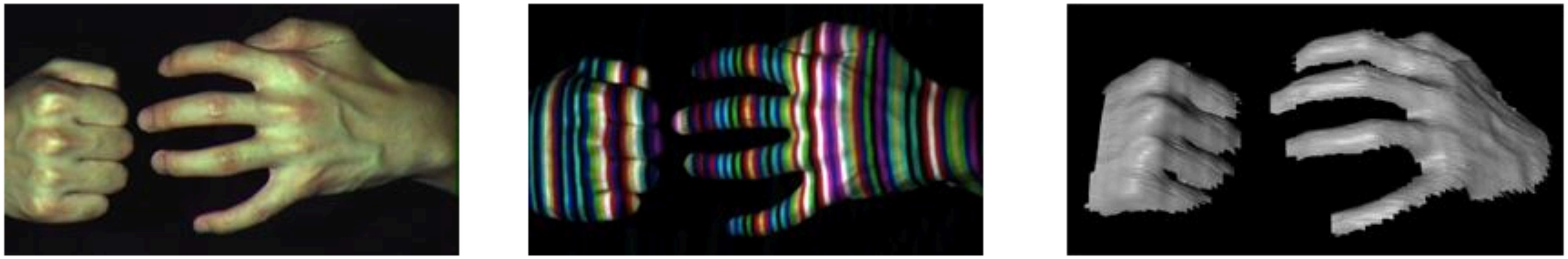
How does the Kinect Gesture Tracking Work

How does the Kinect Gesture Tracking Work

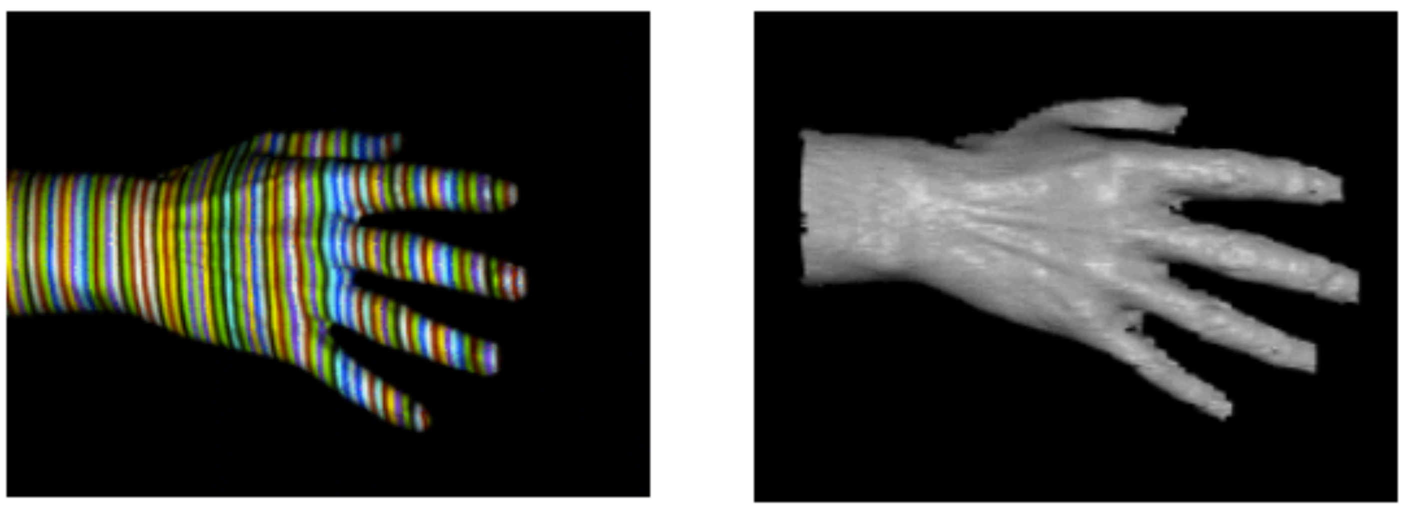
- Structured light
  - Technique #3

Structured Light Technique #2

Real Time by Color Coding



Works despite complex appearances



Works in real-time and on dynamic scenes

- Need very few images (one or two).
- But needs a more complex correspondence algorithm

Zhang et al, 3DPVT 2002

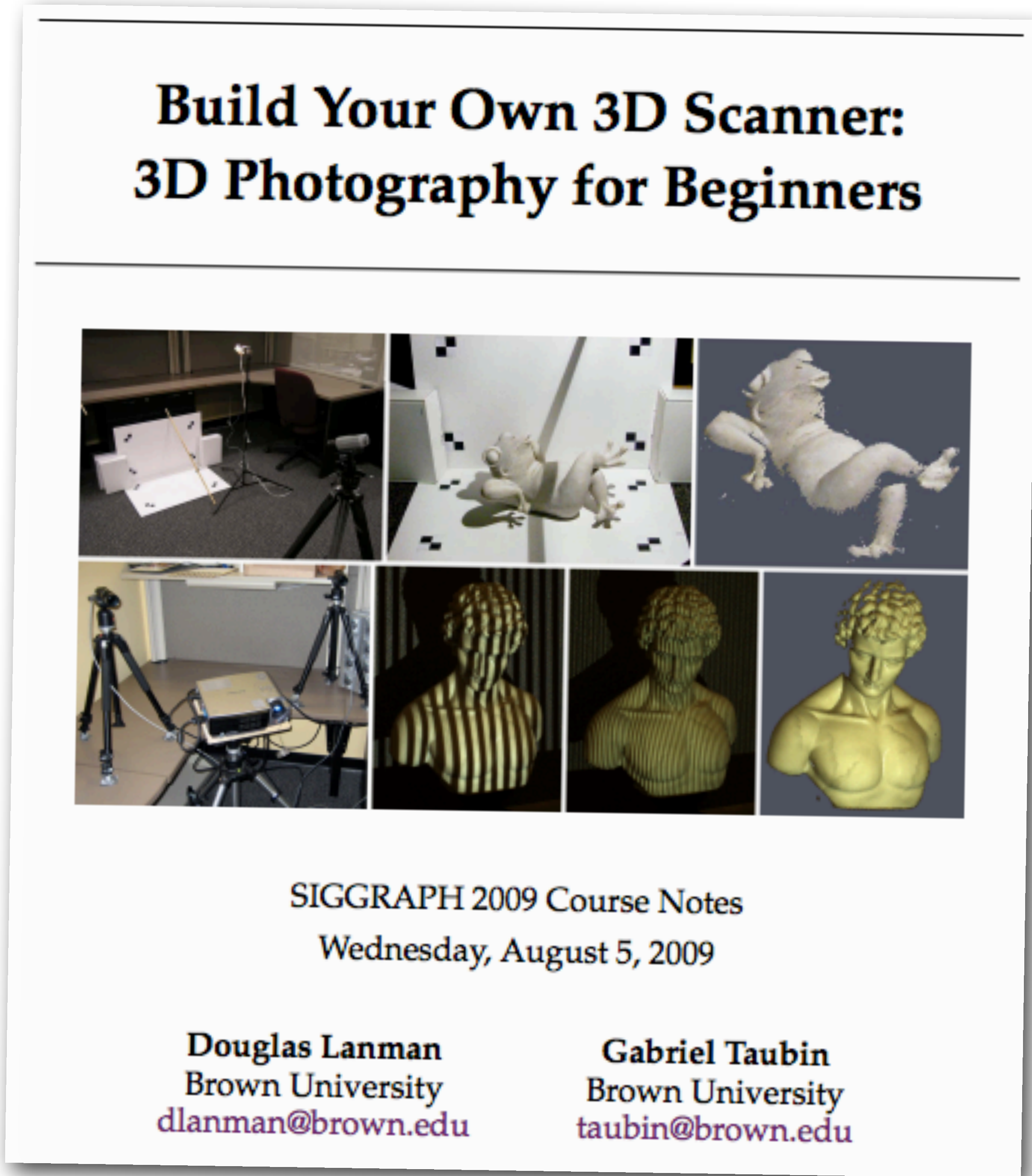
http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-S2012-StructuredLight.pdf

How does the Kinect Gesture Tracking Work

How does the Kinect Gesture Tracking Work

- Structured light
  - Do it yourself

How does the Kinect Gesture Tracking Work



- Course notes: http://mesh.brown.edu/byo3d/notes/byo3D.pdf
- Slides: http://mesh.brown.edu/byo3d/slides.html
- Source code: http://mesh.brown.edu/byo3d/source.html

How does the Kinect Gesture Tracking Work

Dual Photography

Pradeep Sen* Billy Chen* Gaurav Garg* Stephen R. Marschner†
Mark Horowitz* Marc Levoy* Hendrik P.A. Lensch*

*Stanford University †Cornell University

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