Ubiquitous Computing

CS 6456 Lecture

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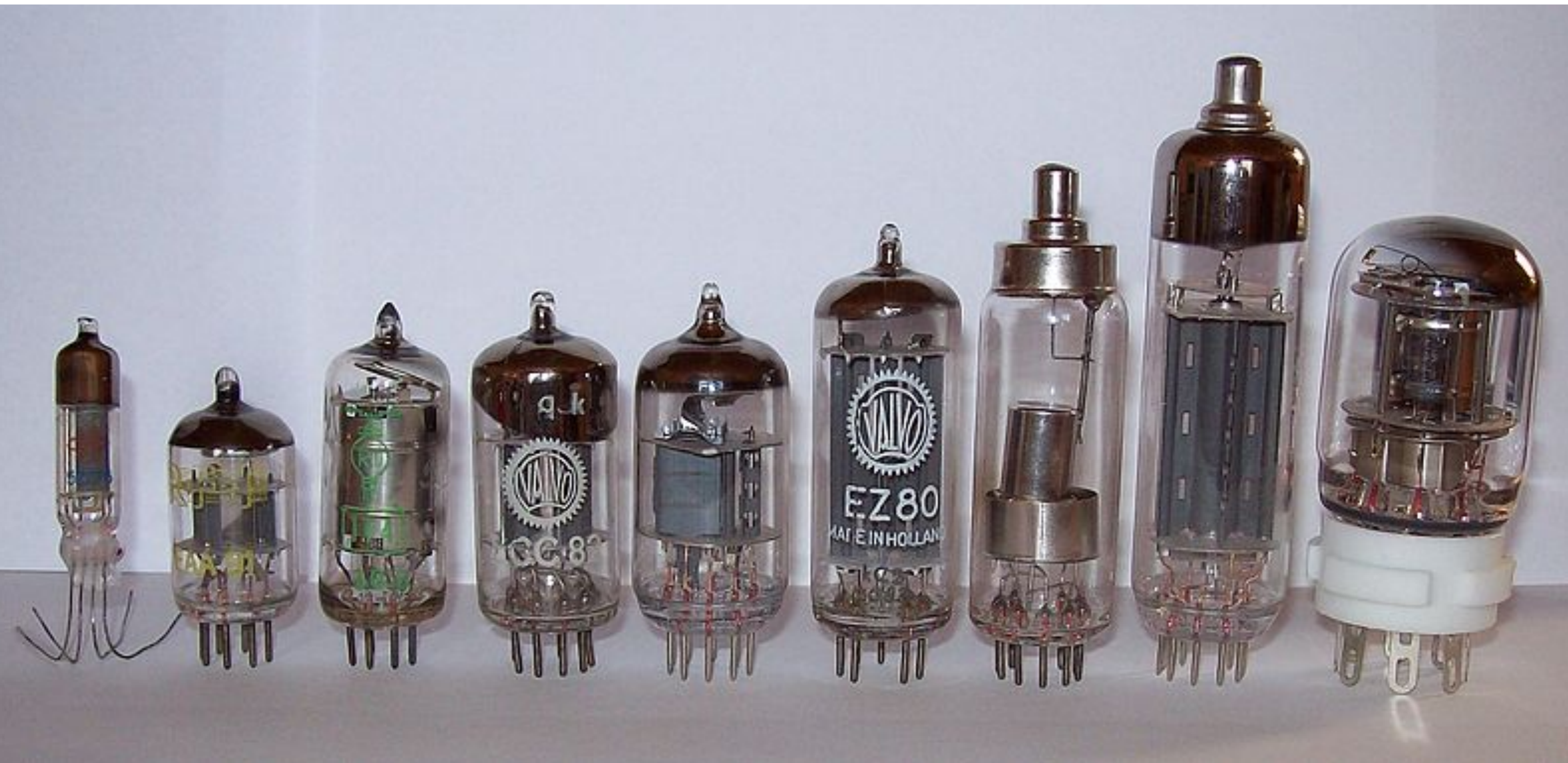
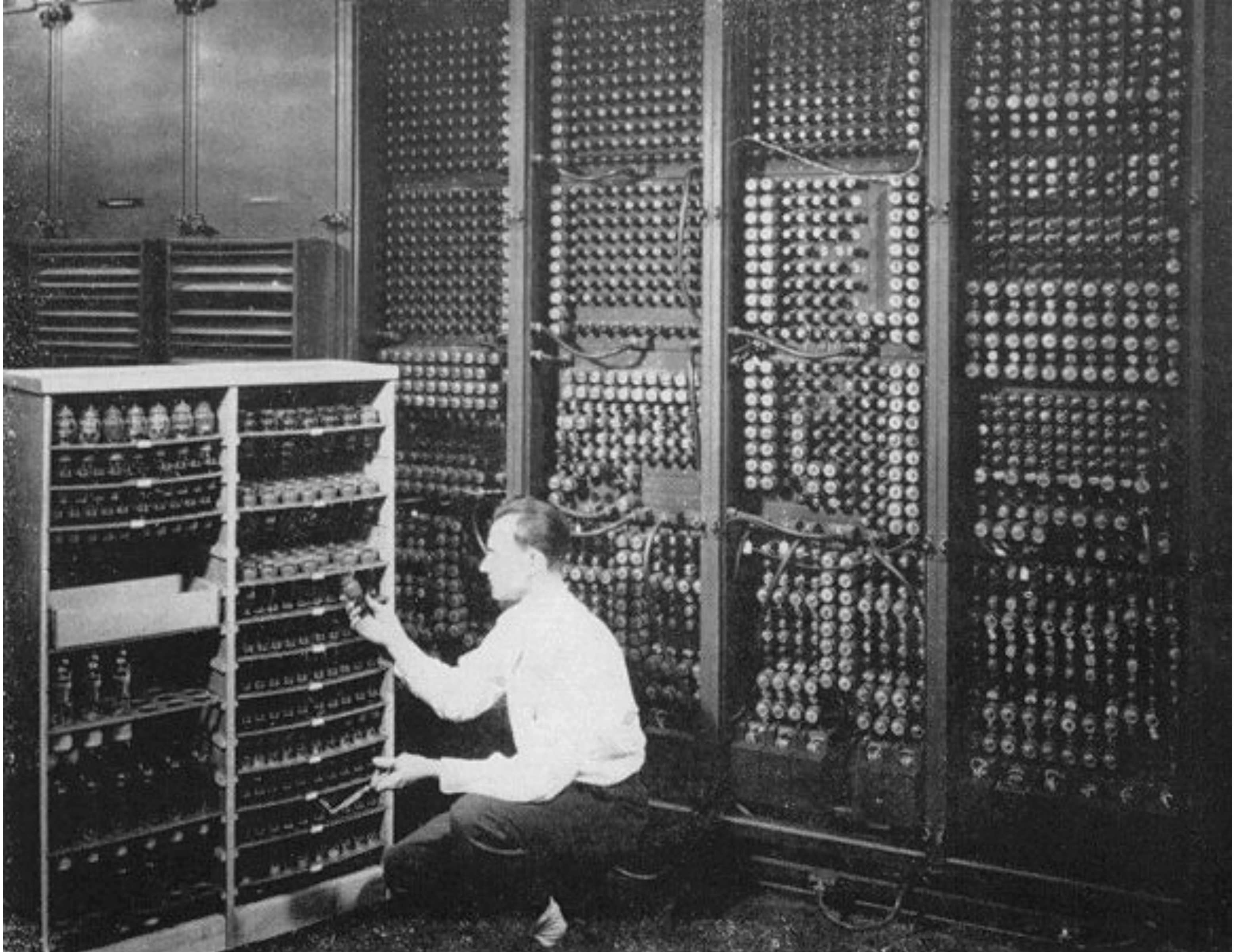
GVU
GEORGIA TECH

UNLOCKING
HUMAN POTENTIAL
THROUGH
TECHNICAL INNOVATION

Evolution of Computer Hardware

- First Generation (1940-1956)
  - Vacuum Tubes

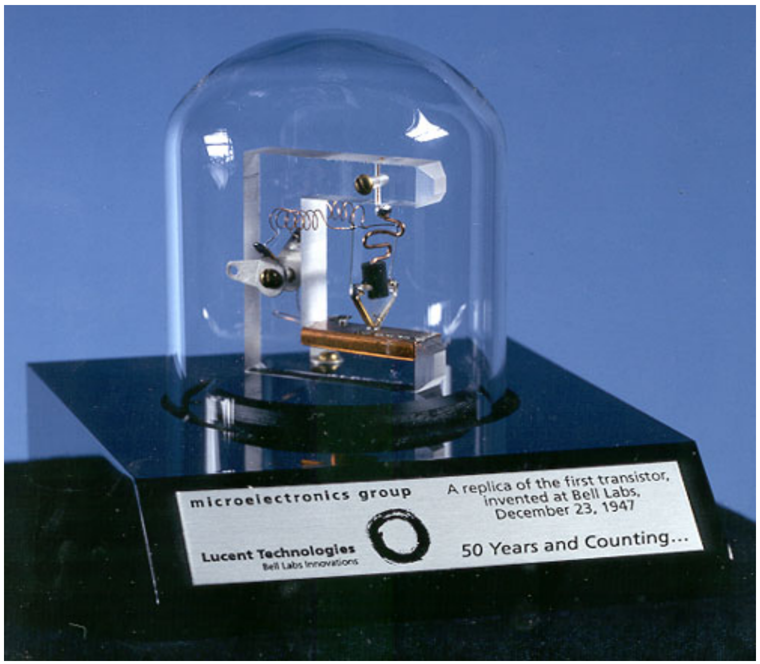




Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

Evolution of Computer Hardware

- Second Generation (1956-1963)
  - Transistors



A replica of the first working transistor.

John Bardeen, William Shockley and Walter Brattain, the inventors of the transistor, 1948

Evolution of Computer Hardware

- Third Generation (1964-1971)
  - Integrated Circuits

What does "Intel" stand for?

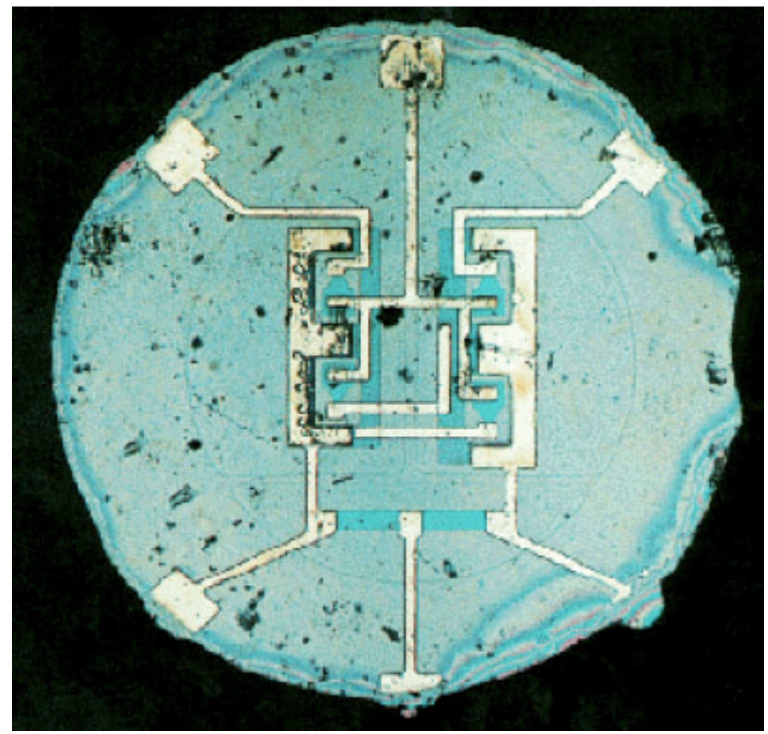
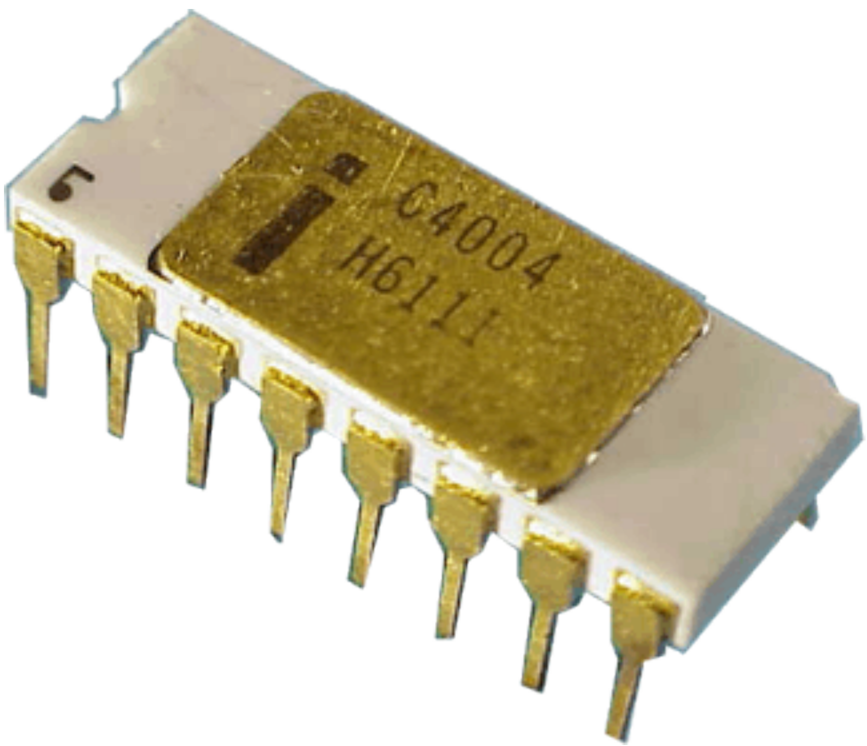


Figure --- Original integrated circuit, with aluminum interconnections on silicon. (G. Moore, ISSCC '03, Intel Corp.)

Evolution of Computer Hardware

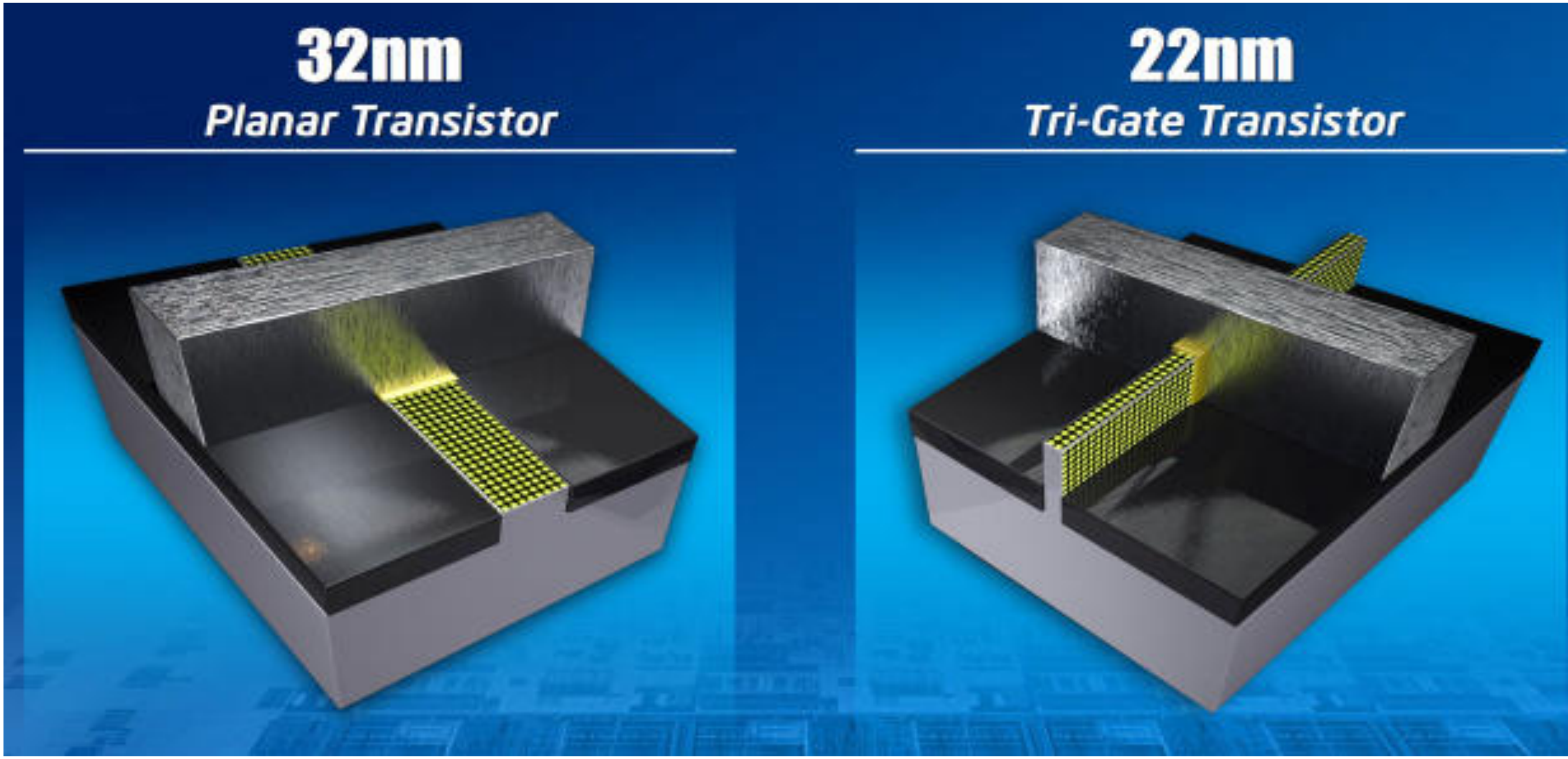
- Fourth Generation (1971-Present)
  - Microprocessors



Evolution of Computer Hardware

- Fifth Generation (Present-Beyond)
  - Quantum computing
  - Bio-inspired computing
  - Heterogeneous computing
  - 3D transistors
  - Beyond...........

Evolution of Computer Hardware



What is Ubiquitous Computing?

What comes to mind when someone says ubiquitous computing? What do ubiquitous computing researchers research?

Evolution of Computing Eras

1st Generation	2nd Generation	3rd Generation

1st Generation

An IBM 704 mainframe (1964)

Mainframe Computing
(1 computer, many people)

2nd Generation

Xerox Alto (1973)

Personal Computing
(1 computer, 1 person)

3rd Generation

Ubiquitous Computing
(many computers, 1 person)

Vision of Ubiquitous Computing

- Mark Weiser
  - Researcher at Xerox PARC
  - Hailed as "father of ubiquitous computing"
  - Landmark paper titled "The Computer for the 21st Century" in Scientific American, 1991
    - "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Visions of Computing

Ubiquitous Computing at Xerox PARC circa 1991

http://youtu.be/b1w9_cob_zw
[9:50 min]

"The Computer for the 21st Century" - Scientific American Special Issue on Communications, Computers, and Networks, September, 1991

Ubiquitous Computing

- 3rd generation of computing
- Computation embedded in the physical spaces around us – “ambient intelligence”
- Appropriate & take advantage of naturally-occurring actions/activities in environment

- Research topics: location-based services, context-awareness, privacy, user interfaces, sensing, actuation, connectivity, mobility

What's Next Ubicomp?

Gregory D. Abowd. 2012. What next, ubicomp?: celebrating an intellectual disappearing act. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing* (UbiComp '12). ACM, New York, NY, USA, 31-40.

- Current trends
  - Commoditization of computation and storage
  - Cloud computing
  - Crowdsourcing
  - Artificial intelligence
- Fourth generation of computing?
  - 1st, 2nd, and 3rd generations suggest divide between computing device and individual
  - Physical being and sense of identity become indistinguishable from elements of computing

Apple's 1987 Knowledge Navigator

http://youtu.be/HGYFEI6uLy0

[5:46 min]

Productivity Future Vision (2011)

http://youtu.be/a6cNdhOKwi0

[6:18 min]

Productivity Future Vision (2009)

http://youtu.be/t5X2PxtvMsU

[5:46 min]

"A Day Made of Glass" by Corning

http://youtu.be/6Cf7IL_eZ38

[5:33 min]

Vision in the Interface

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Computer Vision

- Goal to make computers understand images and video like humans
- Vision is an amazing feat of natural intelligence
- 50% of human brain is directly or indirectly devoted to vision

Computer Vision

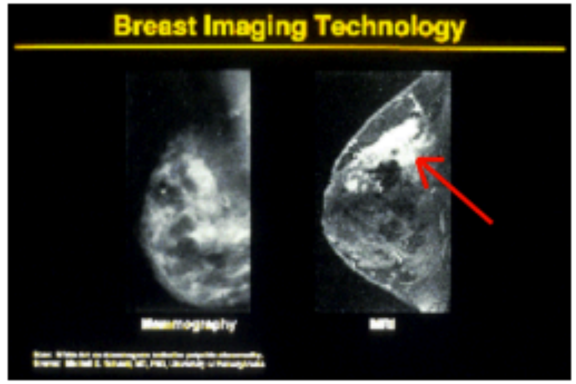
- Methods and algorithms for…
  - Acquiring
  - Processing
  - Analyzing
  - Understanding

  > Images

- Wide range of applications where computer vision is critical and matters

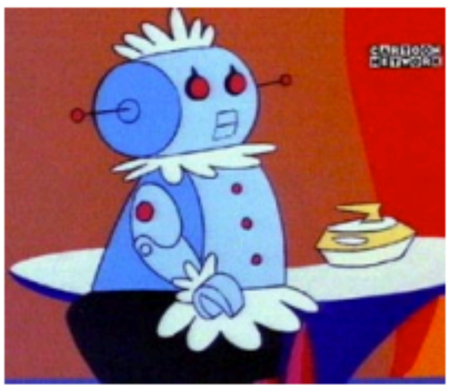
Can you provide any examples of computer vision applied in the real world?

Safety



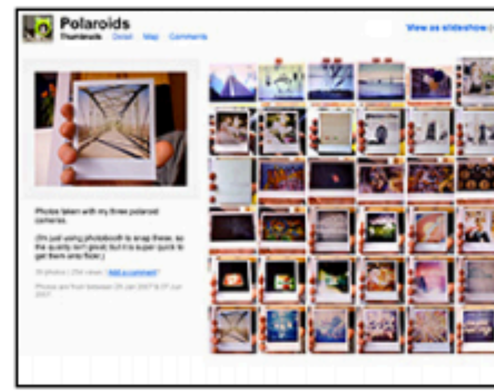
Health

Security



Comfort

Fun



Access

Credit: CS543/ECE549
University of Illinois

Industrial Robotics

Autonomous Vehicles

Visual surveillance

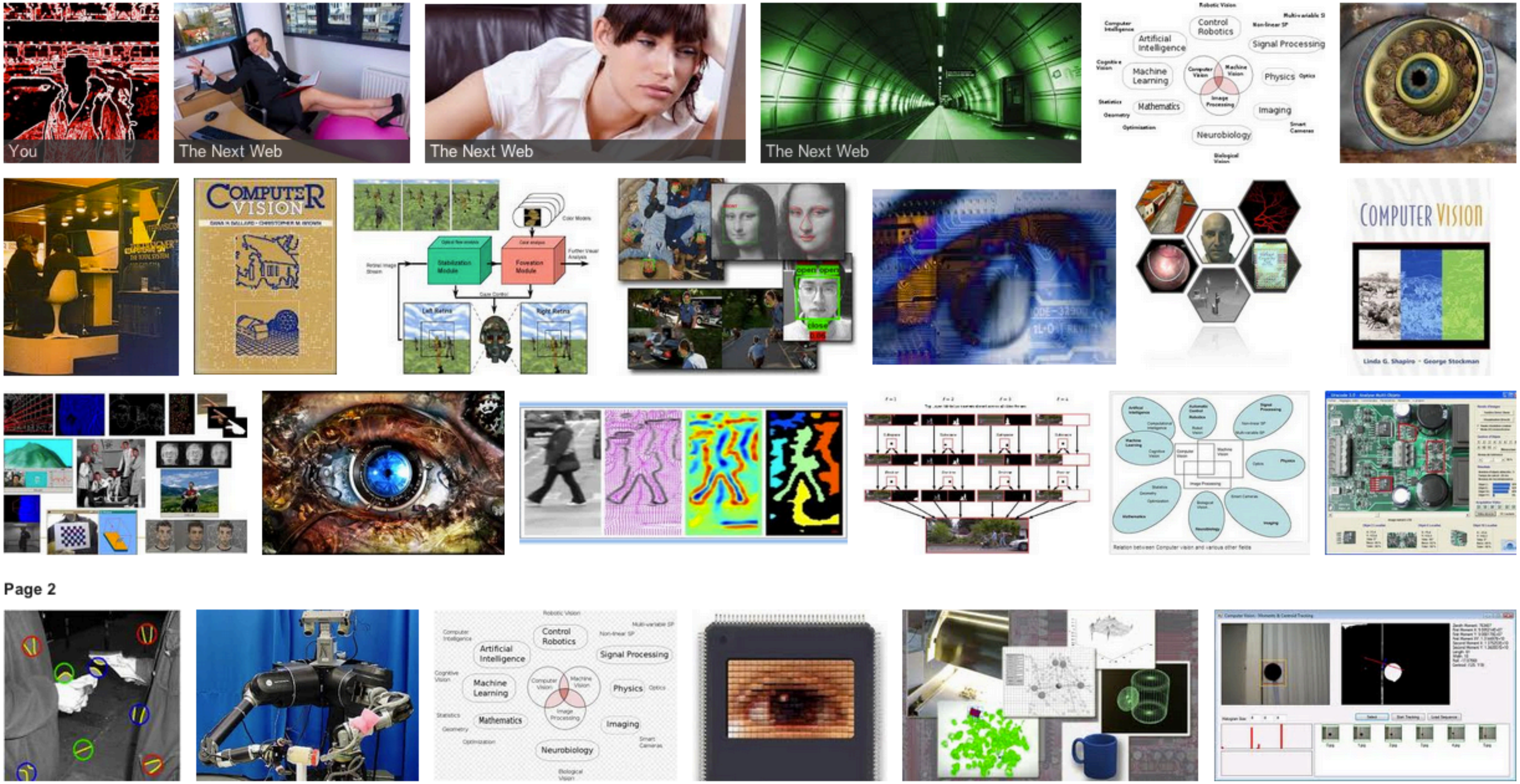
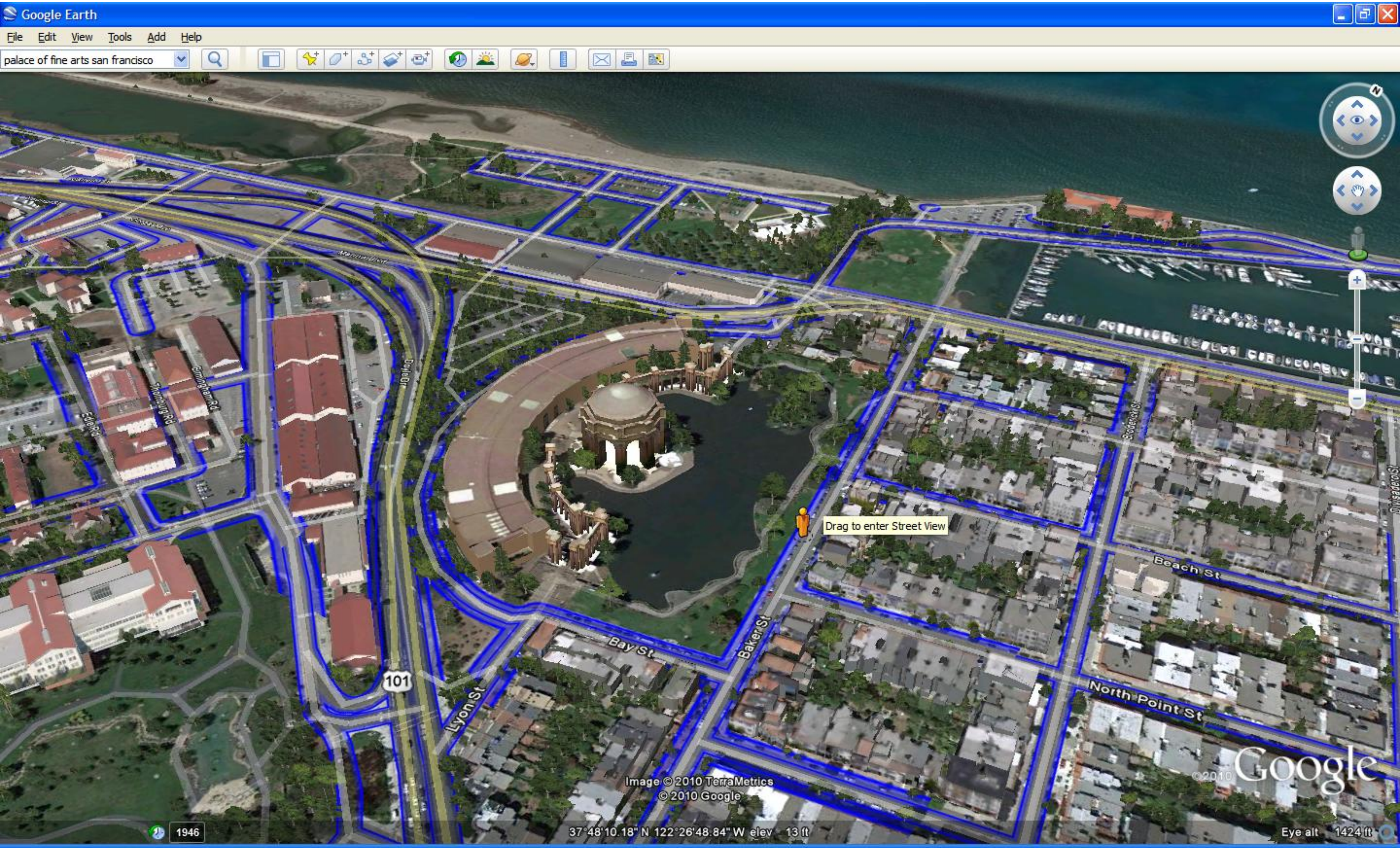
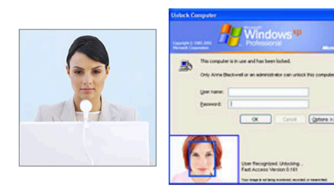


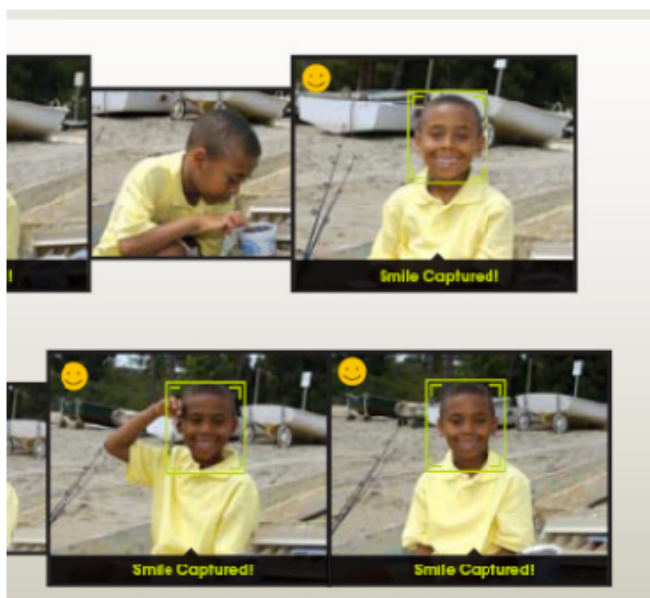
Image databases

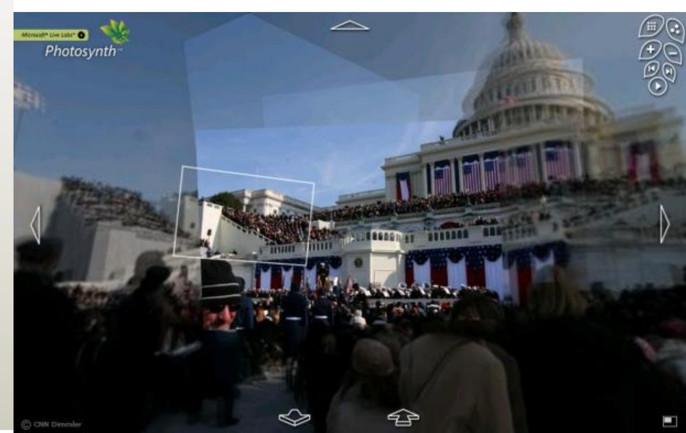


Modeling objects & environments

Interaction







Computer Vision Toolkits

- VIPER Vision Toolkit
  - Toolkit of scripts and Java programs that enable the markup of visual data ground truth
  - http://viper-toolkit.sourceforge.net/

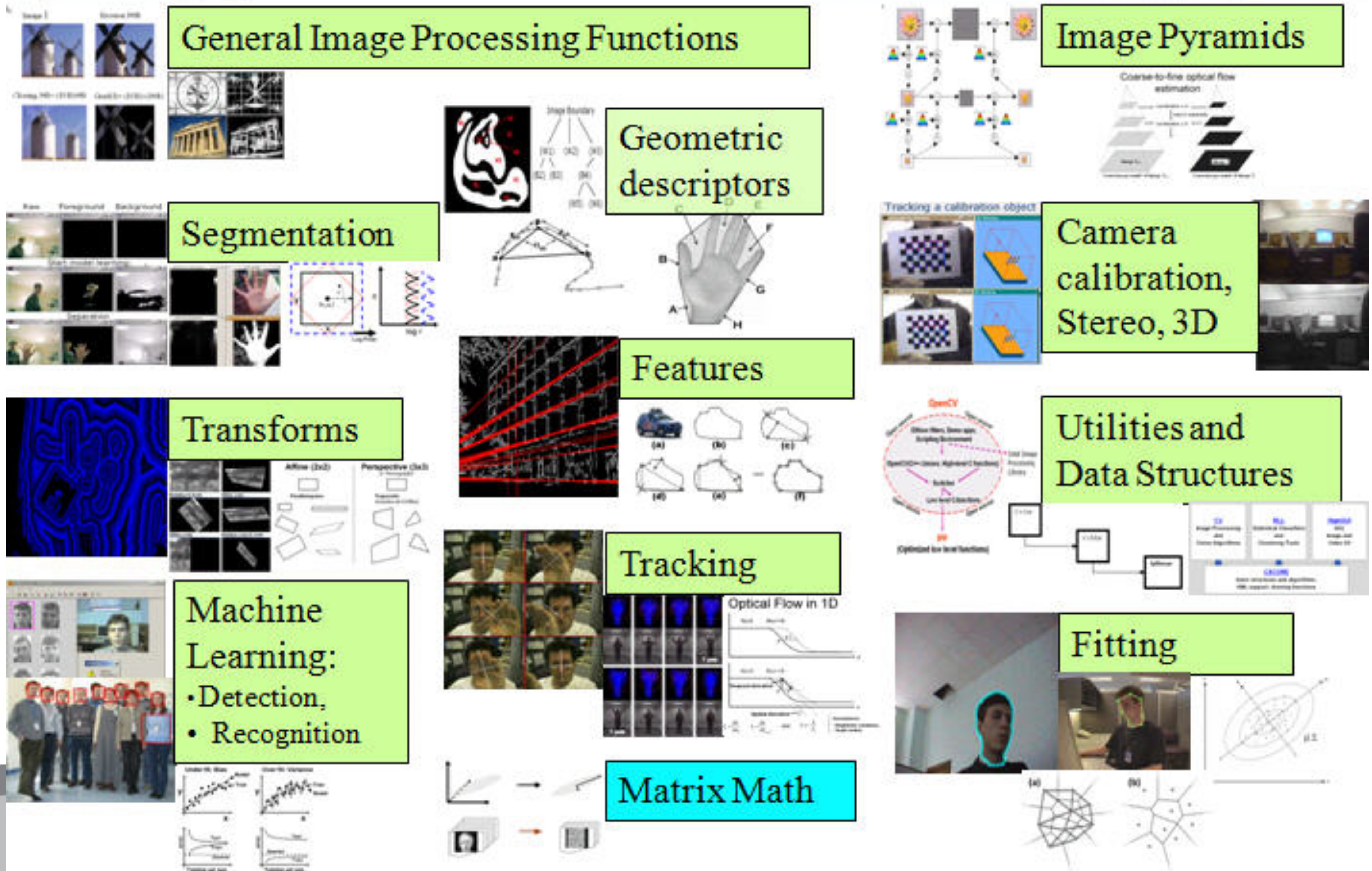
- Java Media Framework
  - Enables audio and video media to be added and processed in applications and applets built on Java technology
  - http://www.oracle.com/technetwork/java/index.html

Computer Vision Toolkits

- OpenCV Vision Toolkit
  - **Open** Source **C**omputer **V**ision is a library of programming functions for real time computer vision
  - Free for both academic and commercial use
  - C++, C, Python and Java interfaces
  - Supports Windows, Linux, Android and Mac
  - Library has >2500 optimized algorithms
  - http://opencv.willowgarage.com/wiki/

OpenCV Overview: > 500 functions

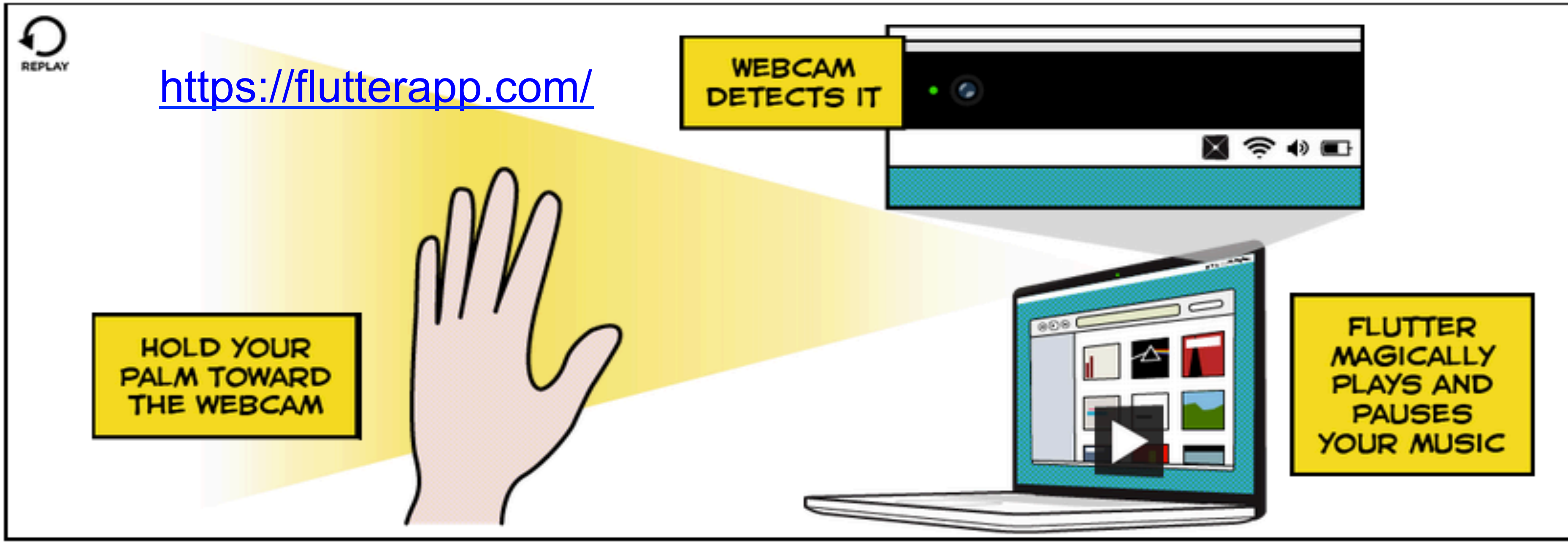
opencv.willowgarage.com



Vision-Based Interfaces

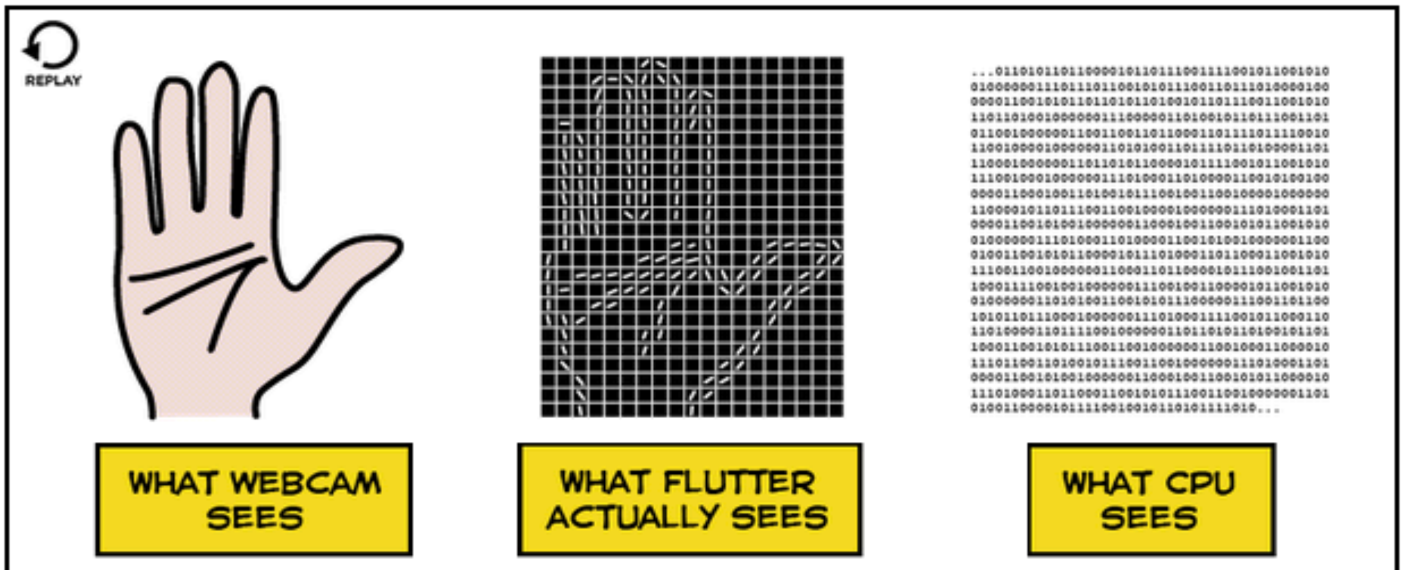
- Computer vision in the context of user interfaces and human-computer interaction
- Input and output devices and software used to interact with computers & environment

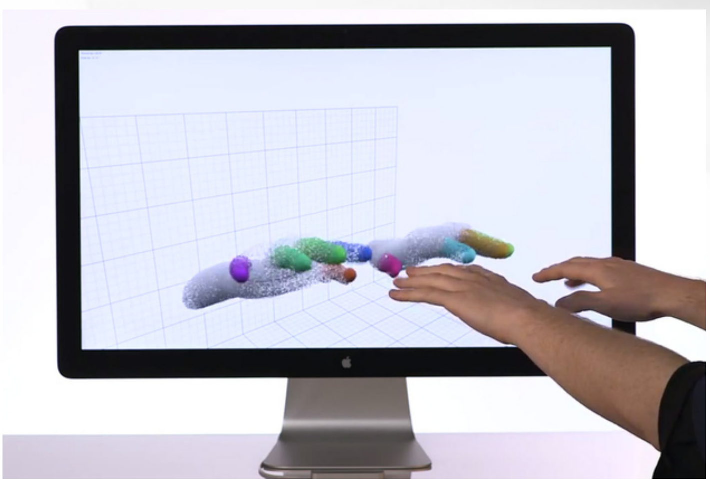
HAVE NO FEAR. FLUTTER IS HERE



https://flutterapp.com/

HOW DOES FLUTTER (ACTUALLY) DO IT?





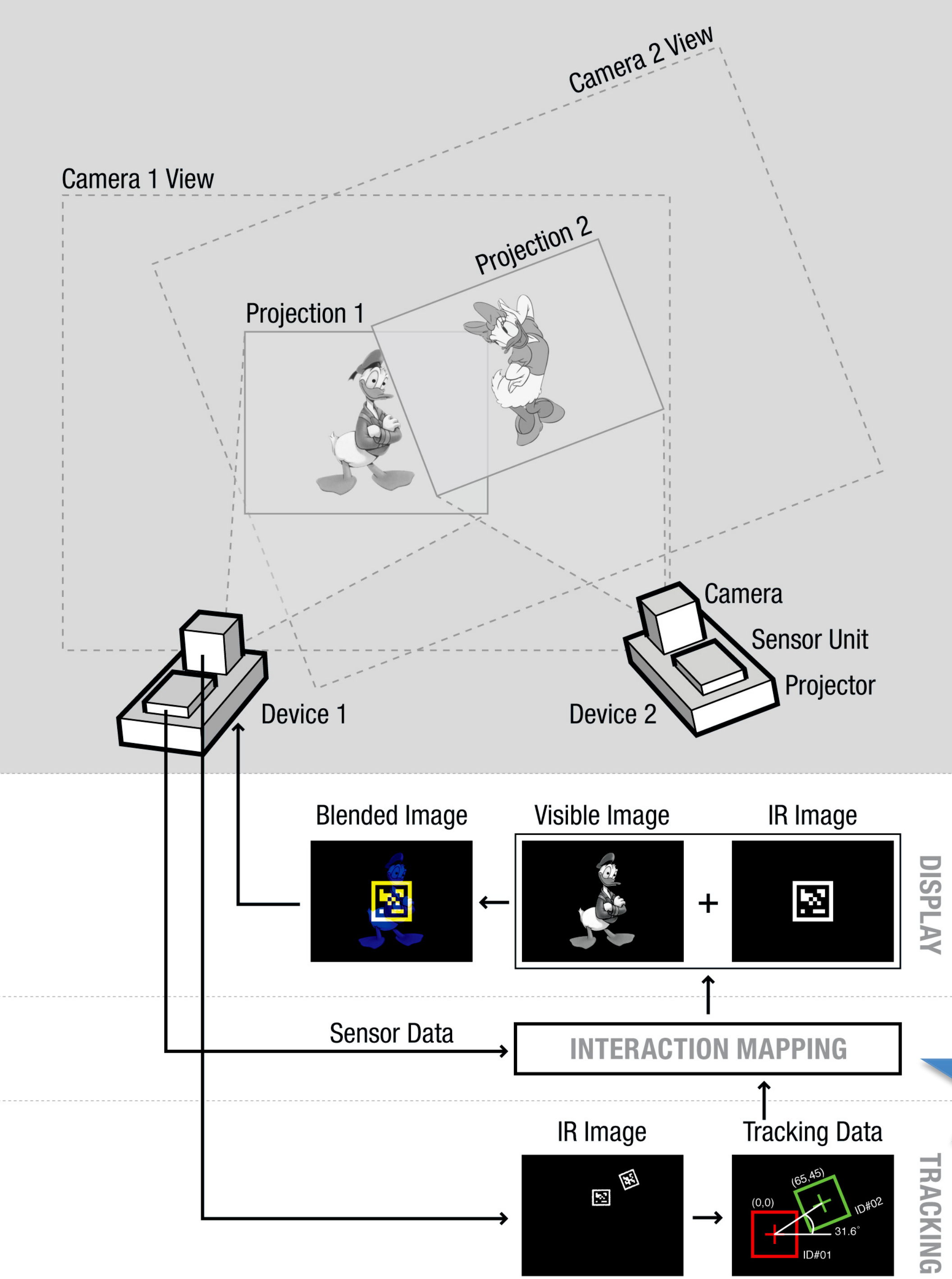
Leap Motion

http://youtu.be/_d6KuiuteIA

Projectors & Pico Projectors
(e.g. Ever Win's EWP1000)

Moveable interactive projected displays using projector based tracking

Johnny C. Lee, Scott E. Hudson, Jay W. Summet, and Paul H. Dietz. 2005. In *Proceedings of the 18th annual ACM symposium on User interface software and technology* (UIST '05). ACM, New York, NY, USA, 63-72.



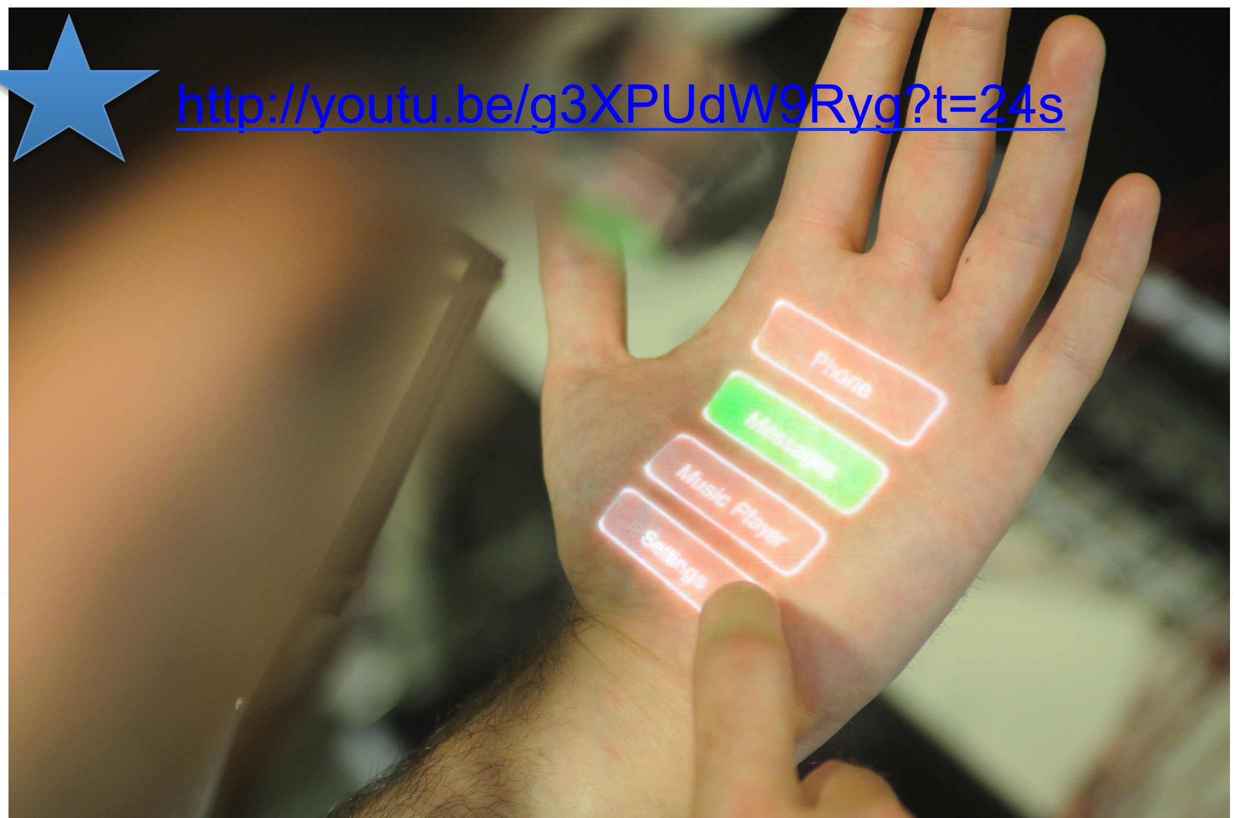
SideBySide: Ad-hoc Multi-user Interaction with Handheld Projectors

Willis, K. D.D., Poupyrev, I., Hudson, S. E., and Mahler, M. SideBySide: Ad-hoc Multi-user Interaction with Handheld Projectors. In Proc. ACM UIST (2011).

http://www.disneyresearch.com/project/sidebyside/

Skinput: Appropriating the Body as an Input Surface

Harrison, C., Tan, D. Morris, D. 2010. Skinput: Appropriating the Body as an Input Surface. In Proceedings of the 28th Annual SIGCHI Conference on Human Factors in Computing Systems (Atlanta, Georgia, April 10 - 15, 2010). CHI '10. ACM, New York, NY. 453-462.



http://youtu.be/g3XPUdW9Ryg?t=24s


POWER
A
HOME
1
2
Wii
Wii

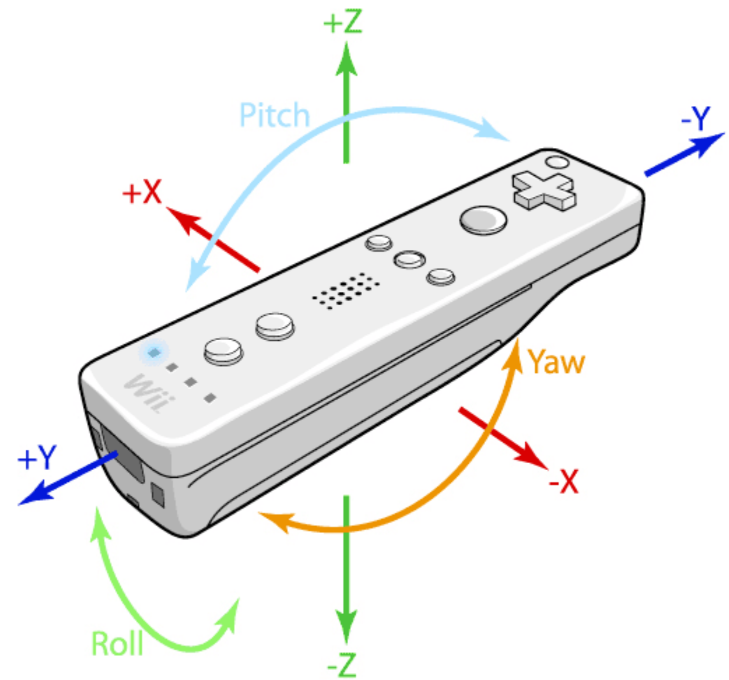

POWER
A
HOME
1
2
Wii
Nintendo

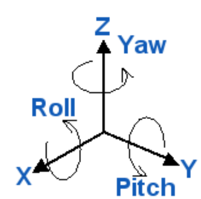
Nintendo Wii Remote

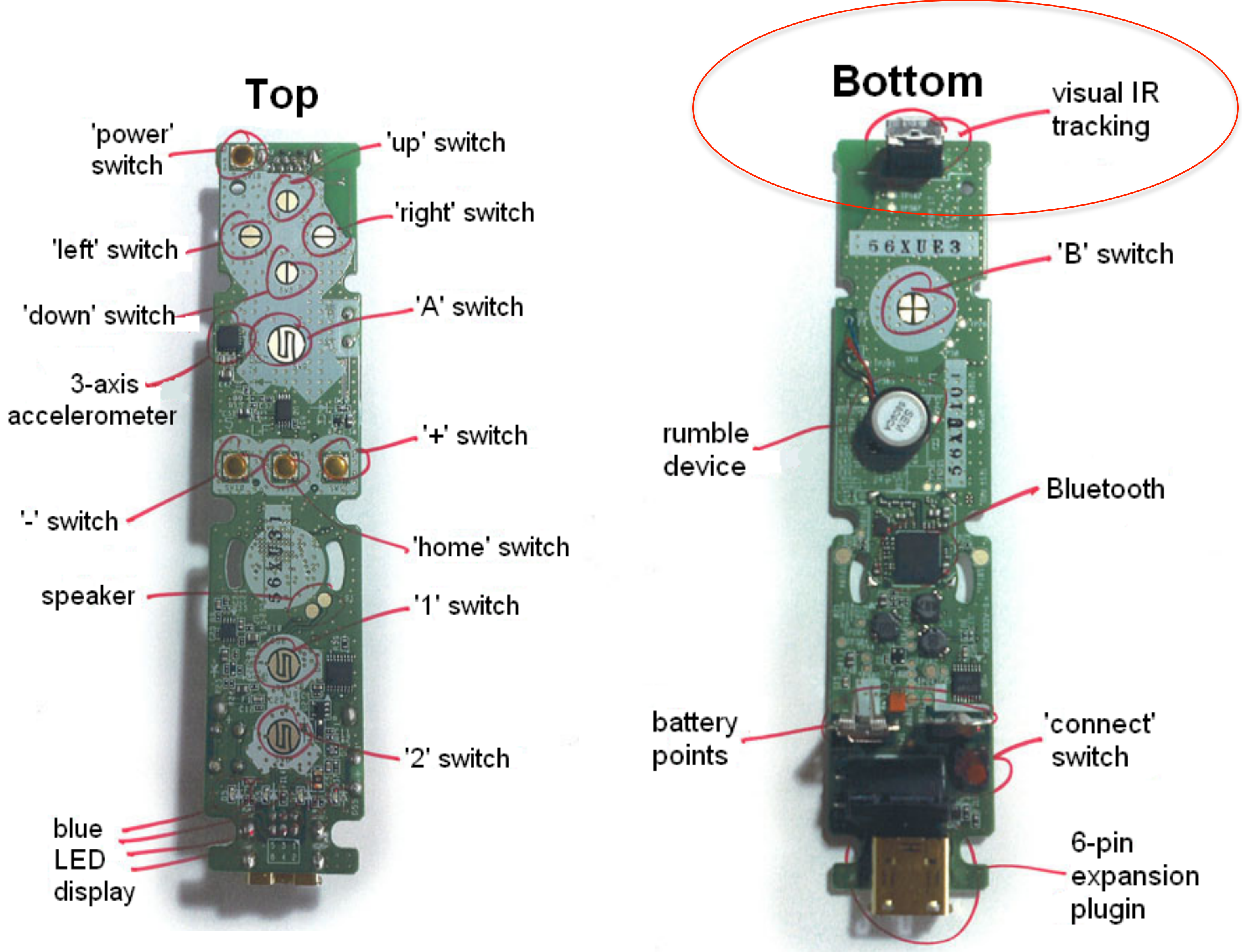
- Primary controller for Nintendo Wii
  - Basic audio
  - Rumble feedback
  - ADXL330 accelerometer
  - Optical sensor

- Motion sensing capability
  - Interact with and manipulate objects on screen
  - Gesture recognition
  - Pointing

Nintendo Wii Remote (Wiimote)






Top
'power' switch
'up' switch
'right' switch
'left' switch
'down' switch
'A' switch
3-axis accelerometer
'+' switch
'-' switch
'home' switch
speaker
'1' switch
'2' switch
blue LED display
Bottom
visual IR tracking
'B' switch
rumble device
Bluetooth
battery points
'connect' switch
6-pin expansion plugin

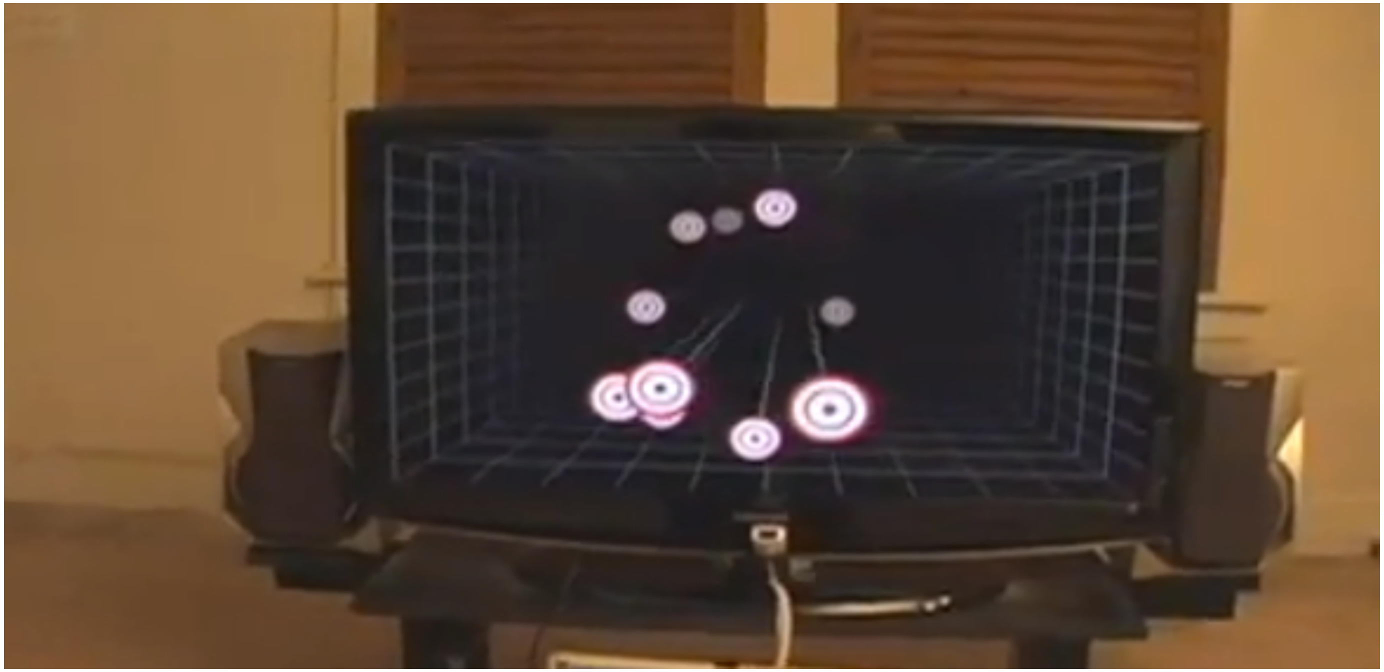
Wiimote Sensor Bar

- Optical bar to determine location of controller using the visual IR tracking camera
- Sensor Bar with 10 infrared LEDs placed on TV

Head Tracking for Desktop Virtual Reality Displays using the Wii Remote

Johnny Chung Lee, Human-Computer Interaction Institute, Carnegie Mellon University, 2007

http://youtu.be/Jd3-eiid-Uw?t=57s



Tracking Fingers with the Wii Remote

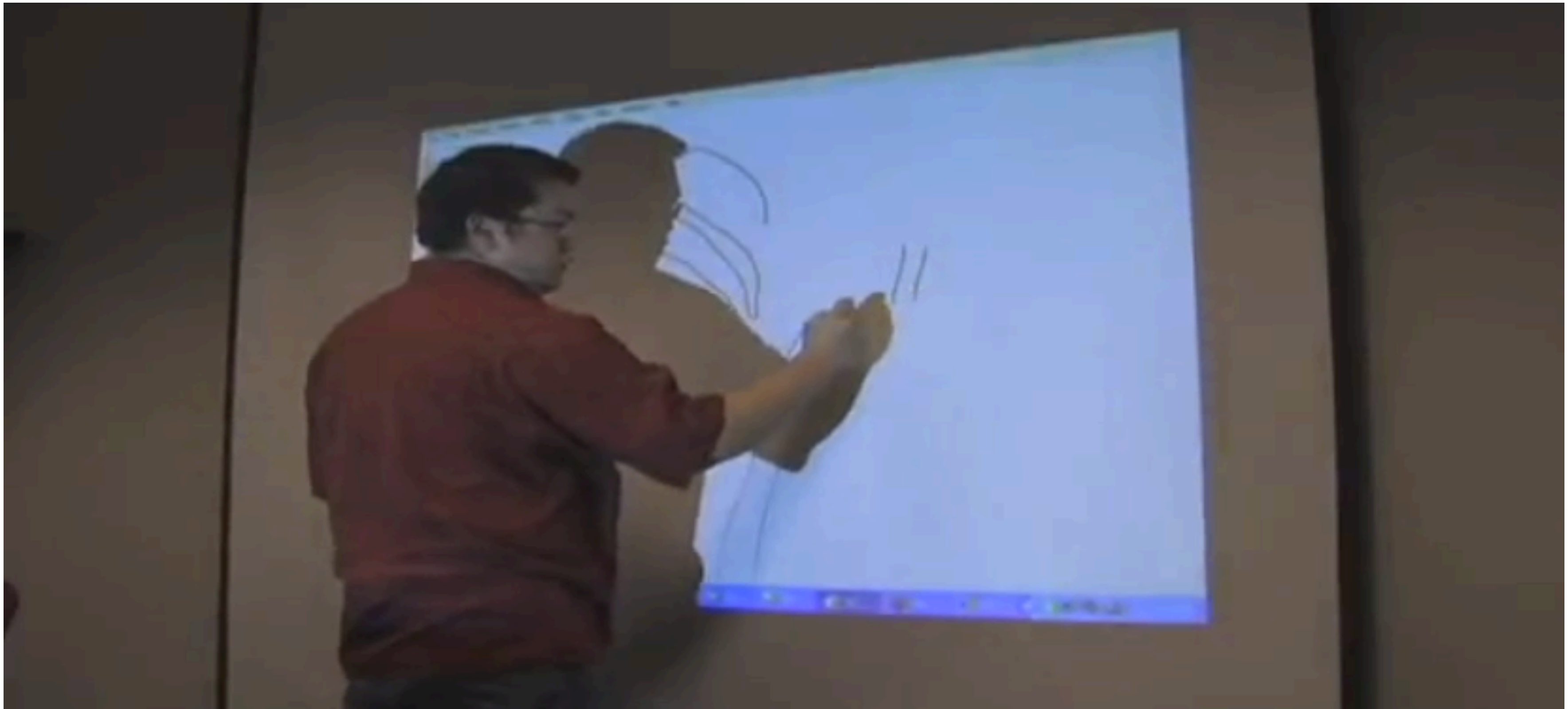
Johnny Chung Lee, Human-Computer Interaction Institute, Carnegie Mellon University, 2007

http://youtu.be/0awjPUkBXOU?t=1m35s

Low-Cost Multi-touch Whiteboard using the Wiimote

Johnny Chung Lee, Human-Computer Interaction Institute, Carnegie Mellon University, 2007

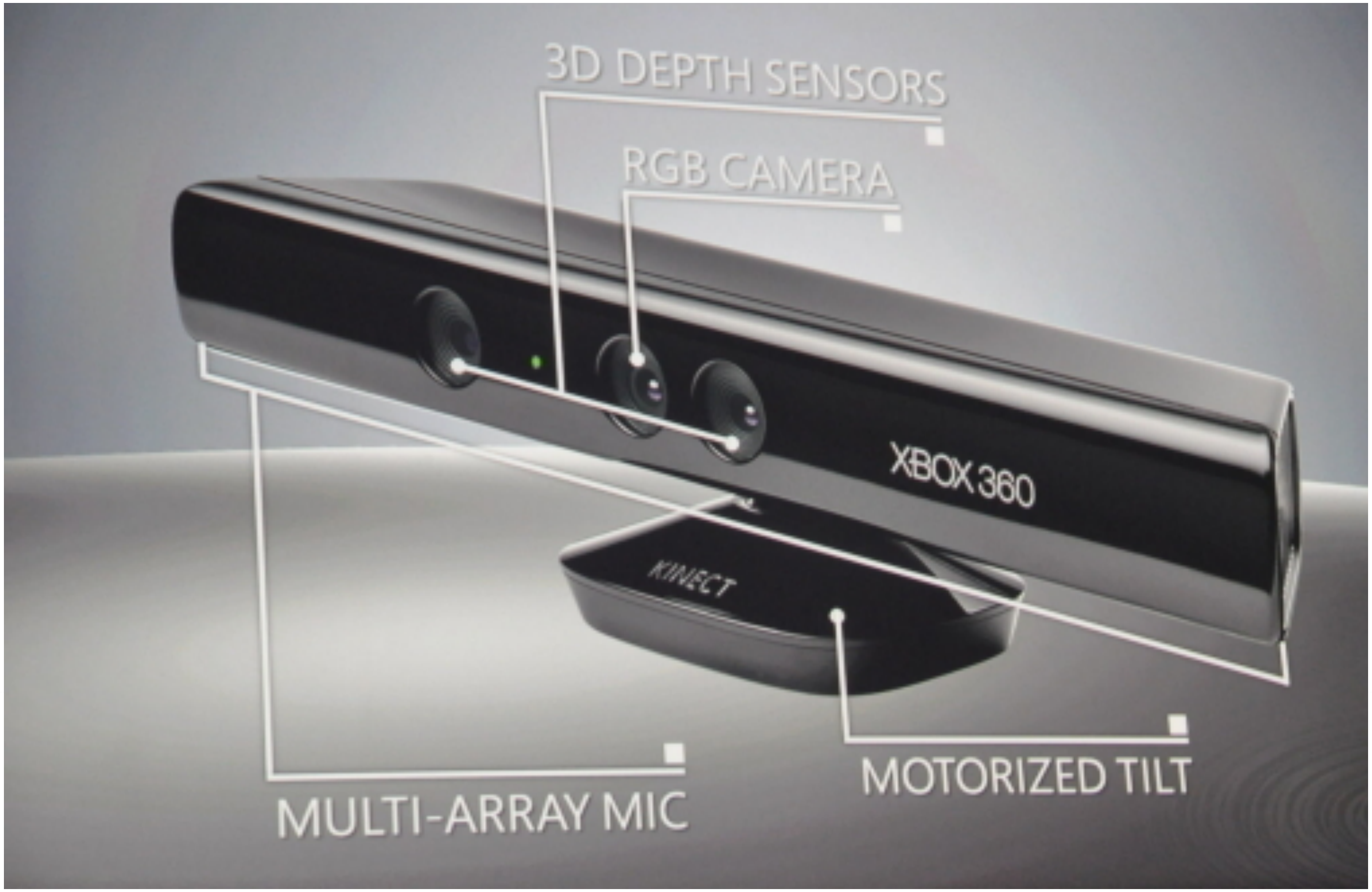
http://youtu.be/5s5EvhHy7eQ?t=2m1s




XBOX 360
KINECT

Microsoft Kinect

- Full body motion sensing input device
- Released by Microsoft in November 2010



How does Kinect work?

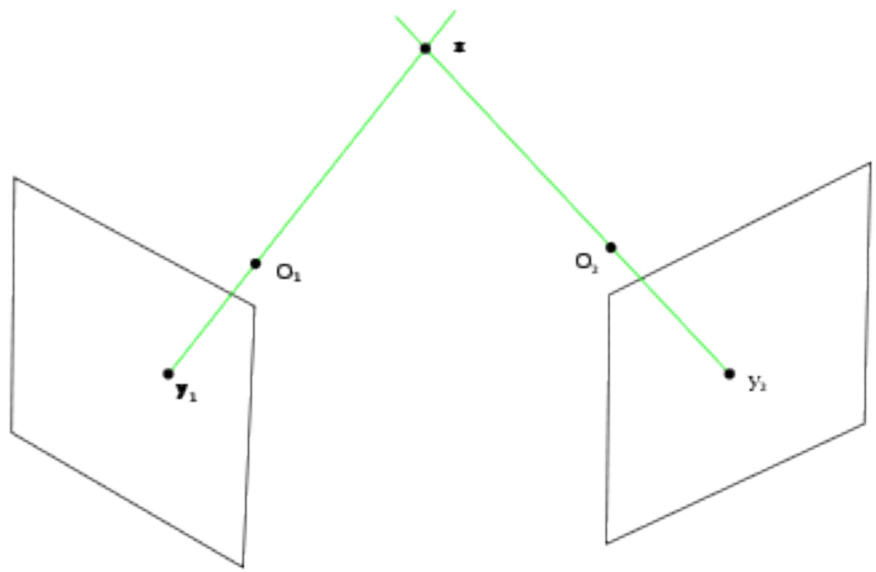
- Color VGA RGB camera
  - VGA resolution (640x480) with 8-bit resolution and a Bayer color filter
  - Operates at 30 FPS (frames per second)
- Depth sensor
  - Infrared laser projector with monochrome CMOS sensor, used to capture video data in 3D in ambient light conditions
  - Video stream in VGA resolution (640×480) with 11-bit depth, which provides 2,048 levels of sensitivity

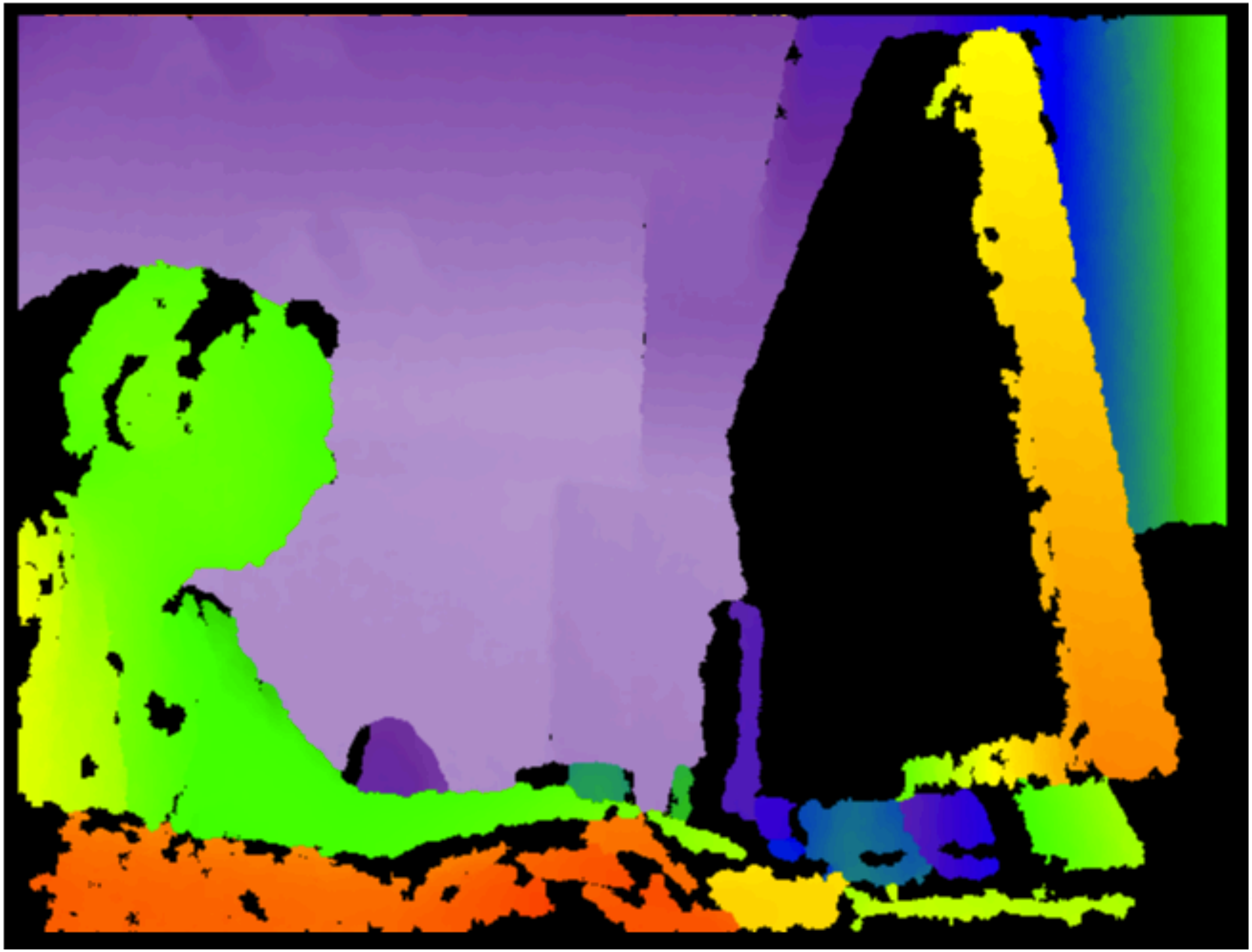
How does Kinect work?

- IR VGA camera emits laser speckle across field of view, creating a 'depth field'

How does Kinect work?

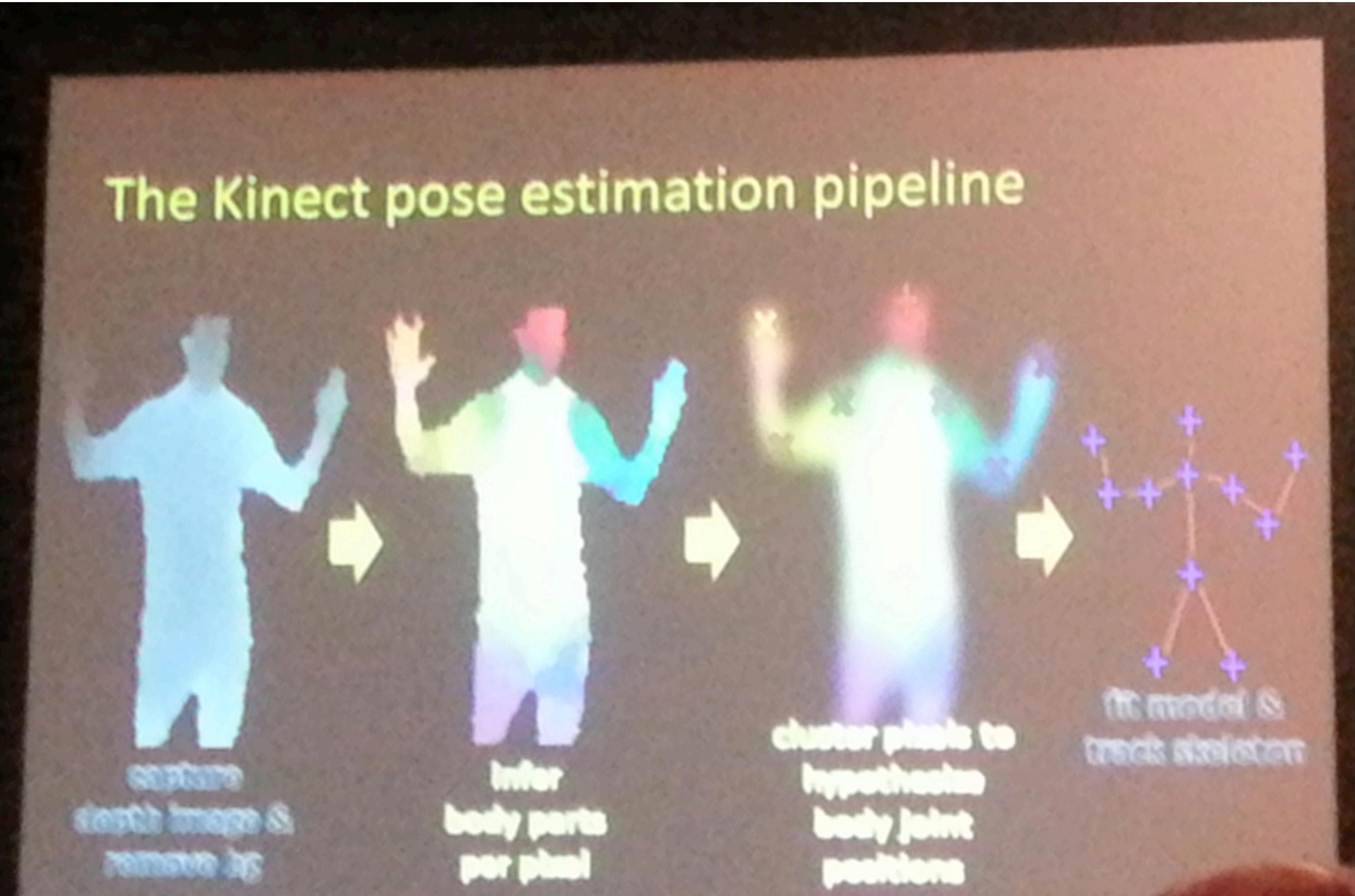
- The depth is computed from the difference between the speckle pattern that is observed and a reference pattern at a known depth.
- Process is known as stereo triangulation.

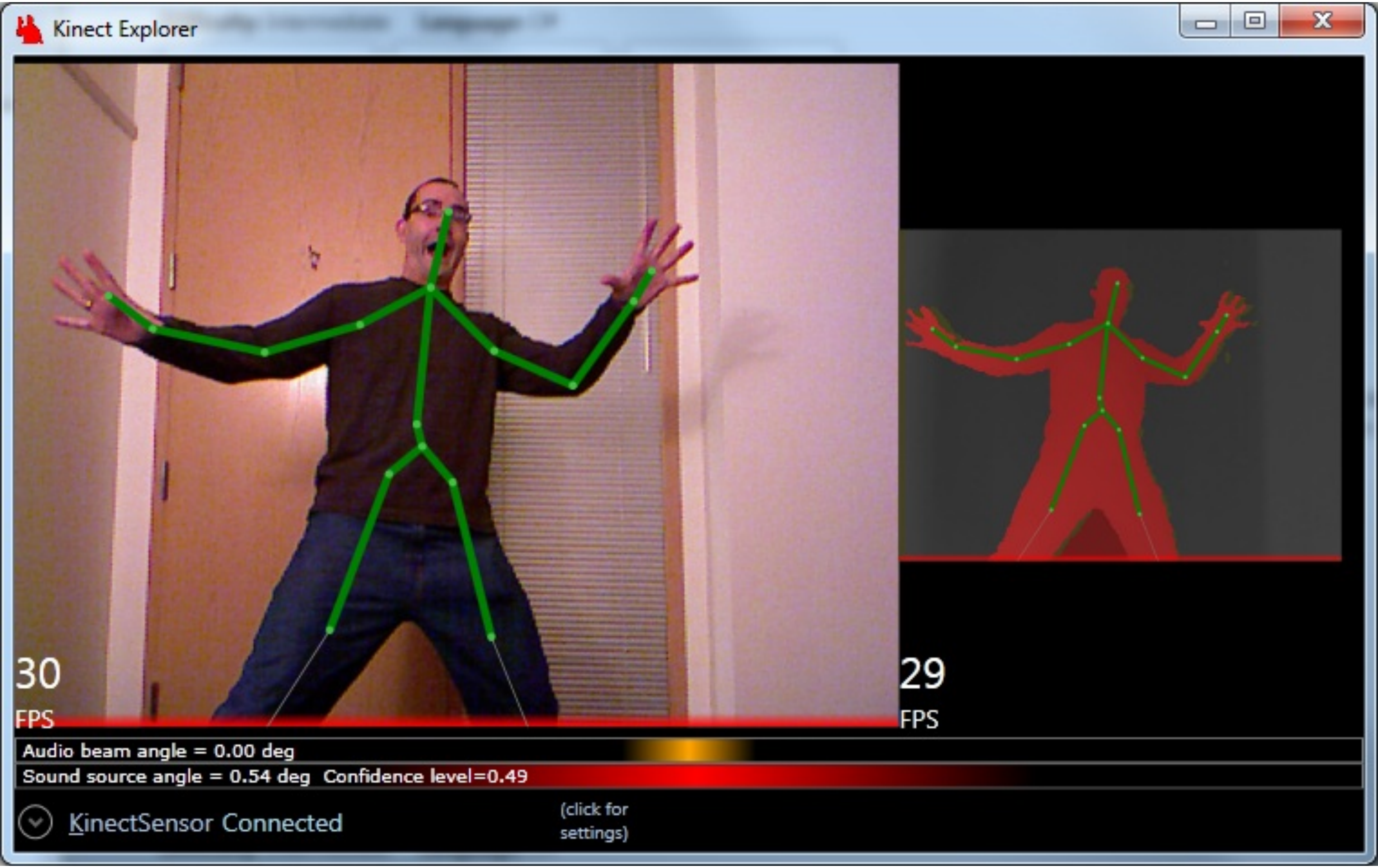




How does Kinect work?

- Skeleton is obtained using a pose estimation pipeline as follows here:
    - Capture depth image
    - Remove background
    - Infer body part per pixel
    - Cluster pixels to hypothesize joint location
    - Fit model and track skeleton


The Kinect pose estimation pipeline
capture depth image & remove bg
infer body parts per pixel
cluster pixels to hypothesize body joint positions
fit model & track skeleton


Kinect Explorer
30
FPS
29
FPS
Audio beam angle = 0.00 deg
Sound source angle = 0.54 deg Confidence level=0.49
KinectSensor Connected
(click for settings)

Depth cameras became accessible at much lower price point ~$150

World record holder for…?

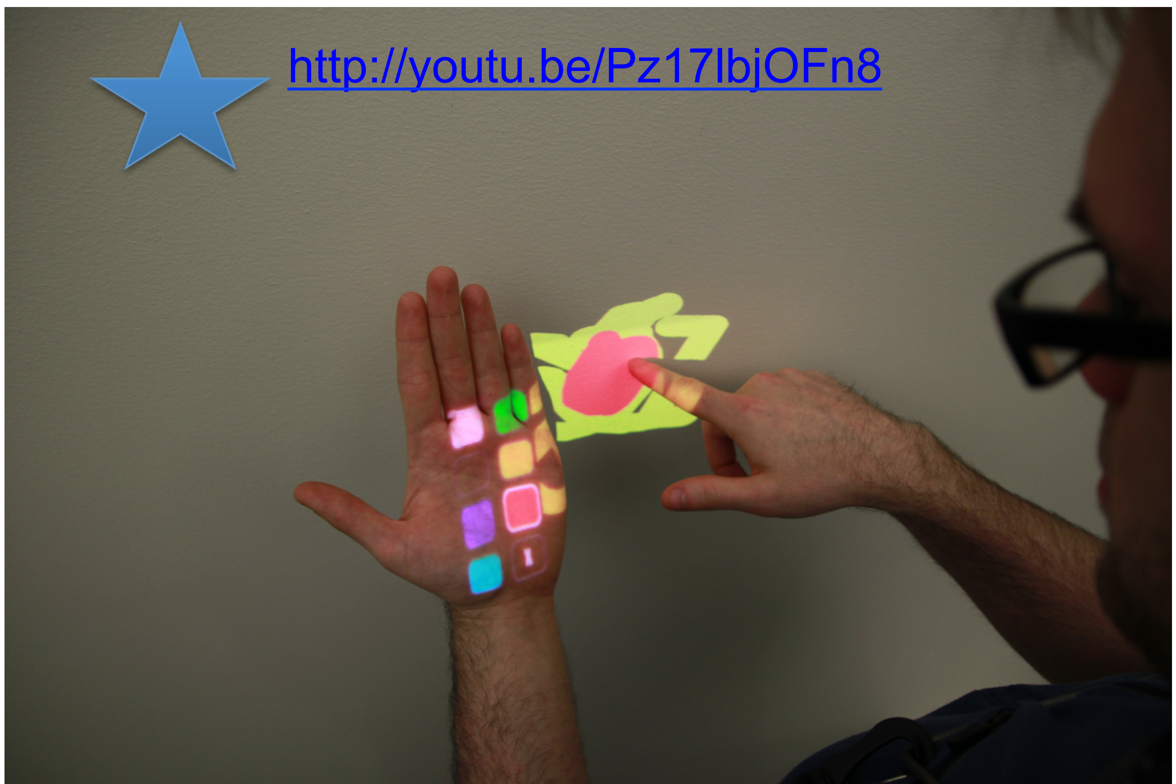
Opened up a large hacker community

5 months after launch…

http://youtu.be/8nlk6HhDpDw

OmniTouch: Wearable Multitouch Interaction Everywhere

Harrison, C., Benko, H., and Wilson, A. D. 2011. OmniTouch: Wearable Multitouch Interaction Everywhere. In Proceedings of the 24th Annual ACM Symposium on User interface Software and Technology (Santa Barbara, California, October 16 - 19, 2011). UIST '11. ACM, New York, NY. 441-450.



Next Generation Interfaces

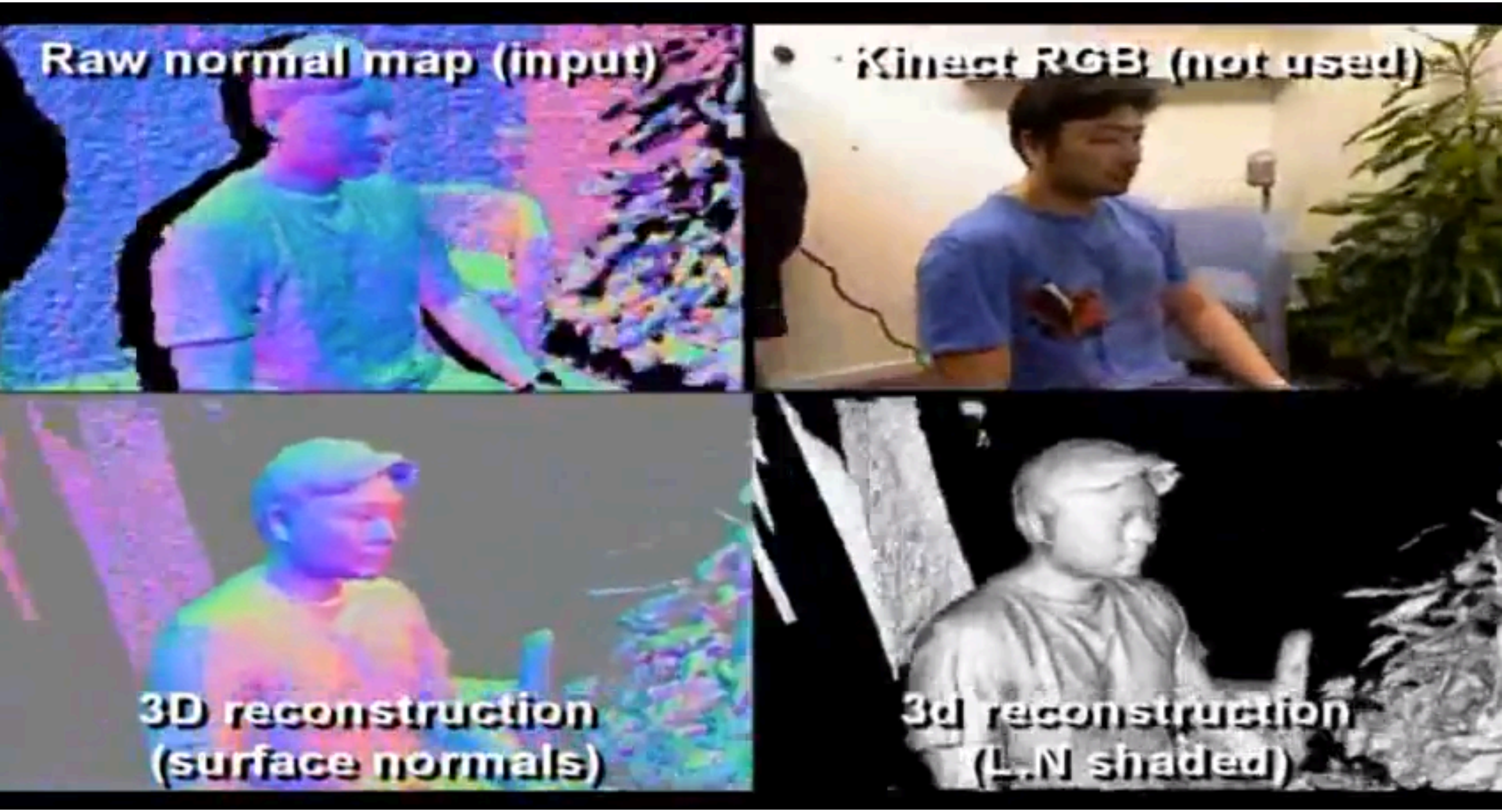
- Shahram Izadi, Microsoft Research Cambridge
- Recent talk on next generation UIs and the future of HCI presented at ISMAR 2012
- Transition from from traditional mouse/keyboard to natural user interfaces (NUI) requires:
  - Sensing spaces
  - Freeing pixels
  - Adding physicality

Sensing Spaces

Shahram Izadi, David Kim, Otmar Hilliges, David Molyneaux, Richard Newcombe, Pushmeet Kohli, Jamie Shotton, Steve Hodges, Dustin Freeman, Andrew Davison, and Andrew Fitzgibbon. 2011. KinectFusion: real-time 3D reconstruction and interaction using a moving depth camera. In *Proceedings of the 24th annual ACM symposium on User interface software and technology*(UIST '11). ACM, New York, NY, USA, 559-568.

- KinectFusion
  - Magic ---> 3D reconstruction of spaces
  - Allows for tracking and segmenting objects
  - Provides understanding foreground/background
  - Made available to public in next Kinect SDK

- KinectFusion++
  - Using new cameras with combined RGB+infrared
  - Passive matching illumination allows outdoor use

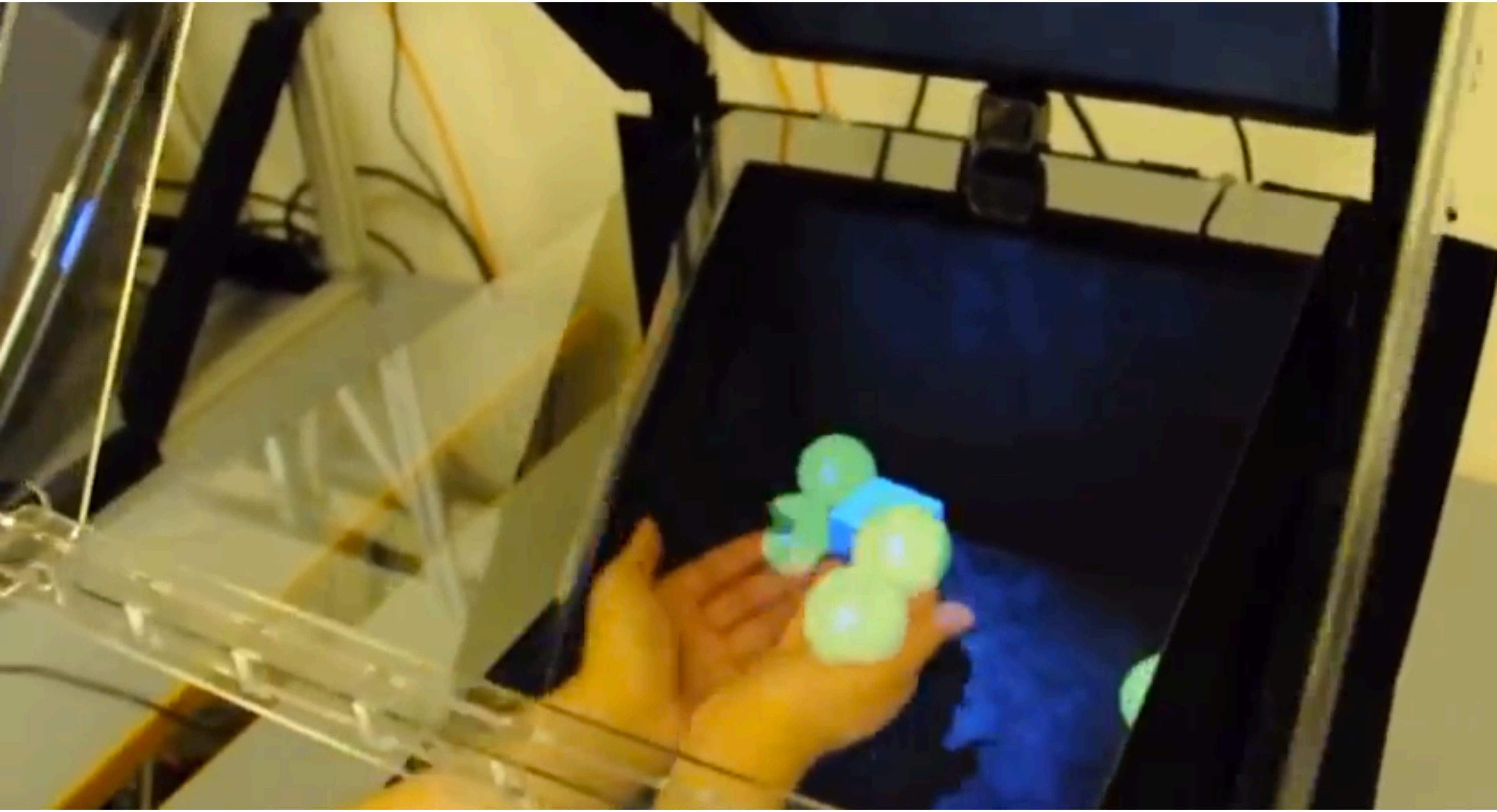


http://youtu.be/quGhaggn3cQ
[7:47 min]

Freeing Pixels

Otmar Hilliges, David Kim, Shahram Izadi, Malte Weiss, and Andrew Wilson. 2012. HoloDesk: direct 3d interactions with a situated see-through display. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12). ACM, New York, NY, USA, 2421-2430.

- Holodesk
  - Novel interactive system that combines the physical with the virtual world
  - Combines an optical see-through display and Kinect camera to create the illusion that users are directly interacting with 3D graphics
  - A virtual image of a 3D scene is rendered through a half silvered mirror and spatially aligned with the real-world for the viewer
  - Users easily reach into an interaction volume displaying the virtual image. This allows the user to literally get their hands into the virtual display.

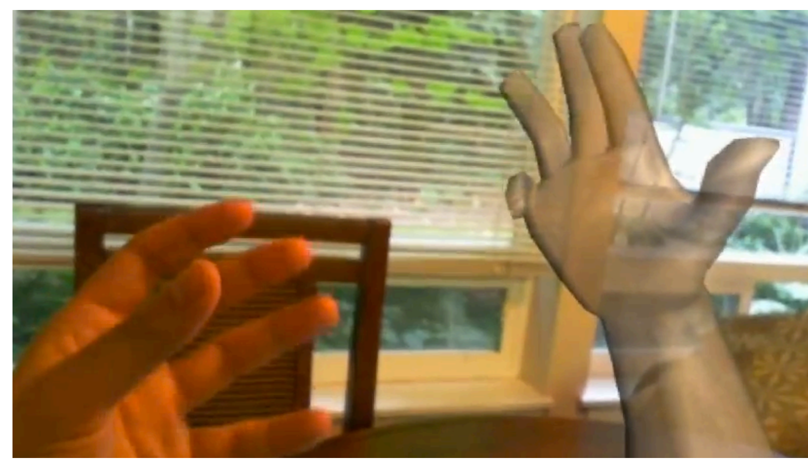


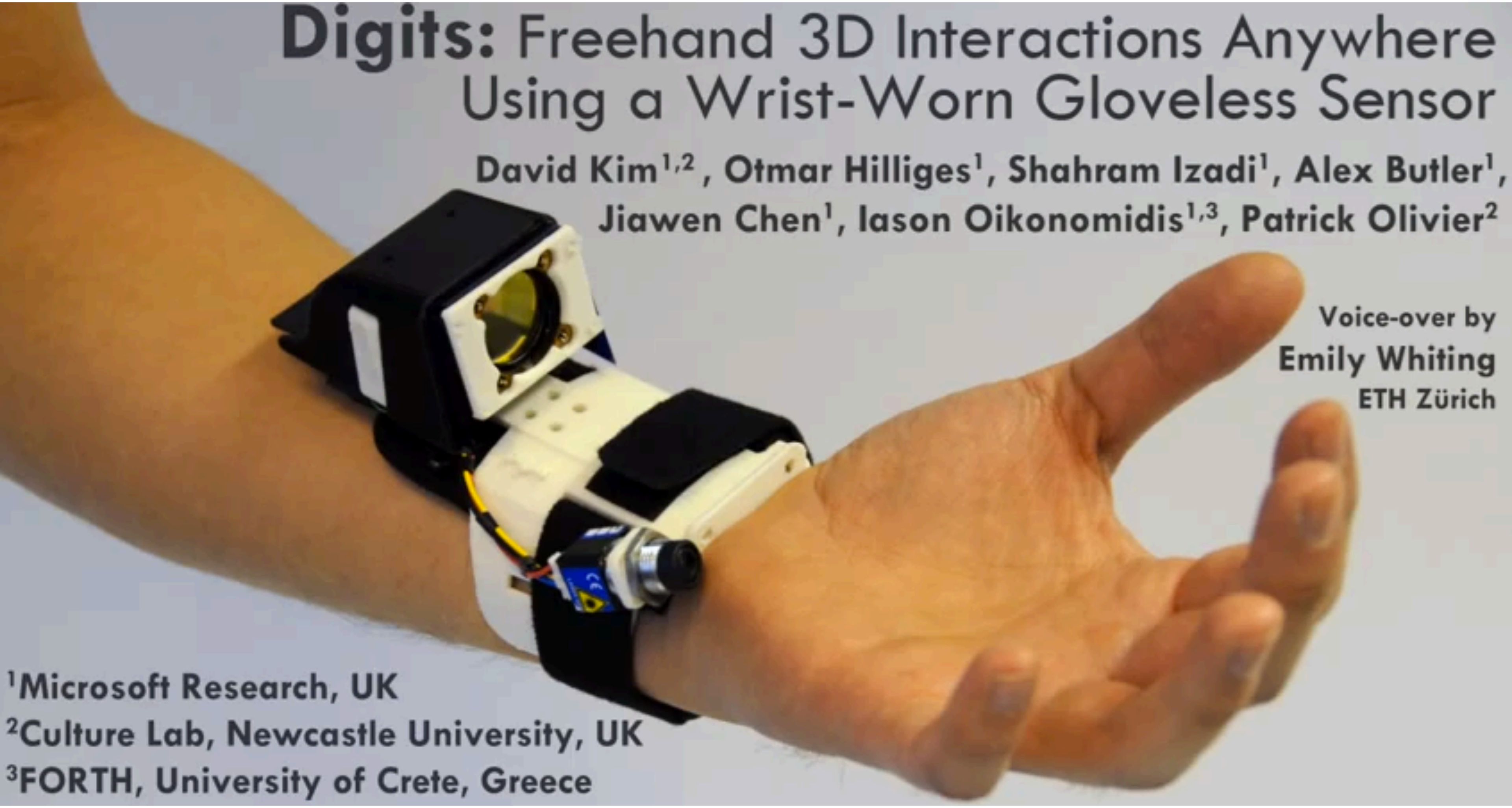
http://youtu.be/JHL5tJ9ja_w
[4:15 min]

Adding Physicality

David Kim, Otmar Hilliges, Shahram Izadi, Alex D. Butler, Jiawen Chen, Iason Oikonomidis, and Patrick Olivier. 2012. Digits: freehand 3D interactions anywhere using a wrist-worn gloveless sensor. In Proceedings of the 25th annual ACM symposium on User interface software and technology (UIST '12). ACM, New York, NY, USA, 167-176.

- Digits
  - Freehand 3D computer interaction without gloves
  - "Let your hands do the talking"
  - Hands are difficult to sense
    - Deforming surfaces
    - Occlusion
    - No wearables
    - Gripping
  - 3D manipulation of world
  - Non-visual UI





http://youtu.be/Tm2IuVfNEGk

[2:35 min]

Questions?

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@greyesgt