Introduction to Computer Vision

Dr. Gerhard Roth

COMP 4102A
Winter 2016
Version 1

General Information

Instructor: Adjunct Prof. Dr. Gerhard Roth

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Office Hours: 1:00 to 2:30, Tuesday HP5331

10:00 to 11:30, Thursday HP5331

TA: Anthony D'Angelo marks the assignments under my supervision, while I mark the two midterms.

Course website:

http://people.scs.carleton.ca/~roth/comp4102a-15/

Linked from http://www.scs.carleton.ca/courses/

Lectures in pdf have a version number, so you can check for updates – which are periodic

Course Organization

Textbook: Introductory Techniques for 3-D Computer Vision, by Trucco and Verri

No longer in print, CD has scanned chapters

Also contains SzeliskiBook_20100903_draft which will be used for some of the course (to be decided)

Two parts:

Part I (Before Feb. break) – Introduction, Review of linear algebra, Image formation, Image processing, Edge detection, Corner detection.

Part II (After Feb. break) – Camera calibration, Homography, Correspondence, Stereo, Epipolar geometry, Active sensors

Evaluation

Four or five assignments (40%)

-two before break and two after

-three or four of them will involve programming

-submit via CuLearn or put in the dropbox at 3115 HP (or e-mail me)

Two mid-terms (60% - 30% each)

-one just before reading week break, one at end of term (just before the exam period)

-will cover material up to that point, so once tested material in first part is not tested again

What is Computer Vision?

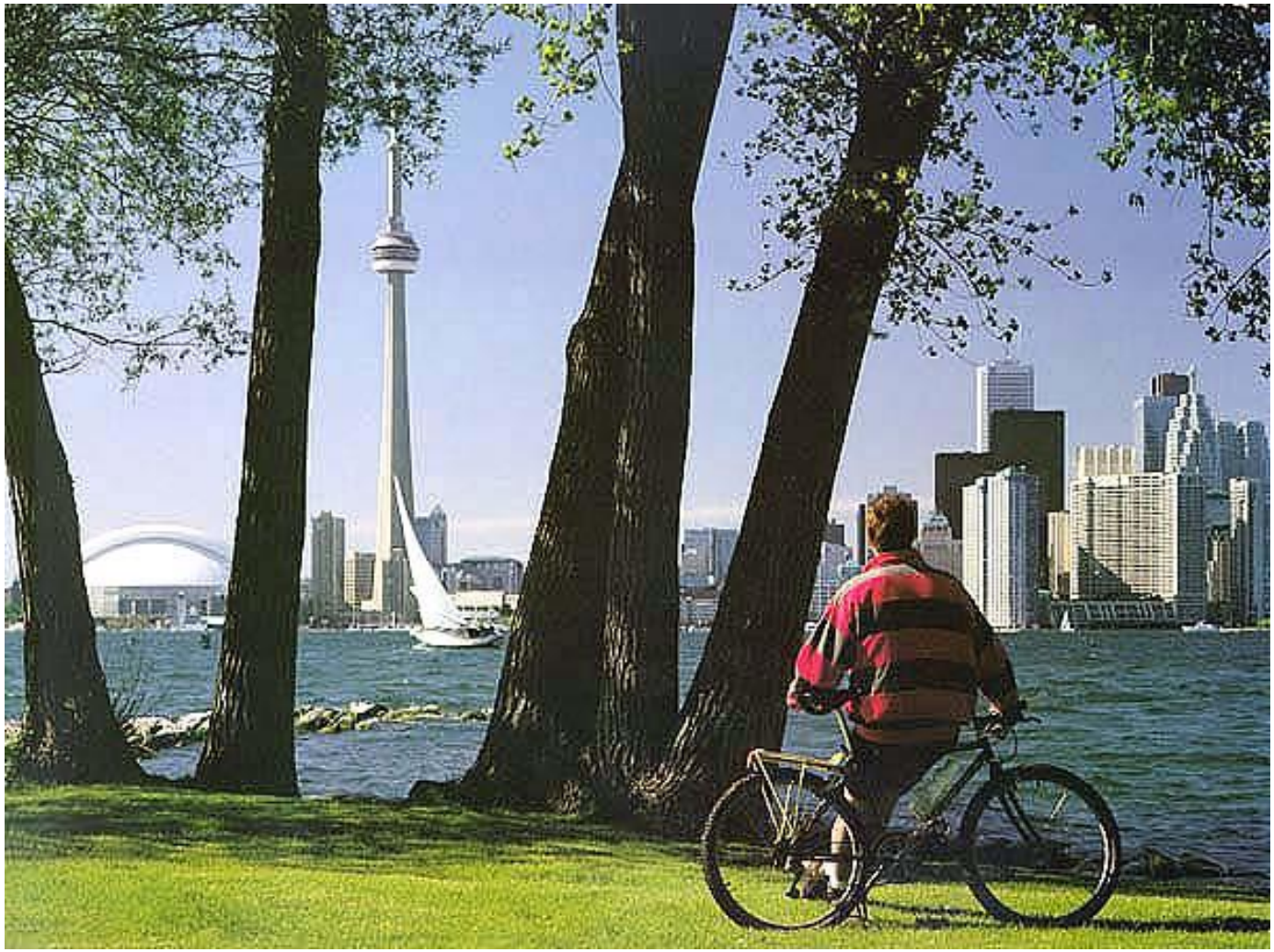
The goal of computer vision is to develop algorithms that allow computer to “see”.

Computer vision is sometimes called the inverse problem of computer graphics

Also called

- Image Understanding
- Image Analysis
- Machine Vision

General visual perception is hard



Digital Image

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A brief history of computer vision

- 1960s - started as a student summer project at MIT.
- 1970s and 80s – part of AI – understanding human vision and emulating human perception.
- 1990s – depart from AI , geometric approach.
- Today – various mathematical methods (statistics, differential equations, optimization), applications (security, robotics, graphics).
- Many applications of computer vision are now in common usage

What is Computer Vision?

Trucco & Verri:

Computing properties of the 3-D world from one or more digital images.

Properties: mainly physical (geometric, dynamic, etc.)

One common definition:

Computer vision is inverse optics or inverse graphics.

Related fields

- Image Processing
  - Generates one image from another – i.e. sharpen
- Pattern Recognition
  - Learn patterns for classifying or analyzing data – i.e. character recognition
- Photogrammetry
  - Measures 3d quantities from multiple 2d images – i.e. model building
- Computer graphics
  - Take a virtual scene and render it – i.e. gaming
- Human/Computer Interfaces
  - Ways of interacting between a computer and a human – i.e. kinect for xbox

Our Time

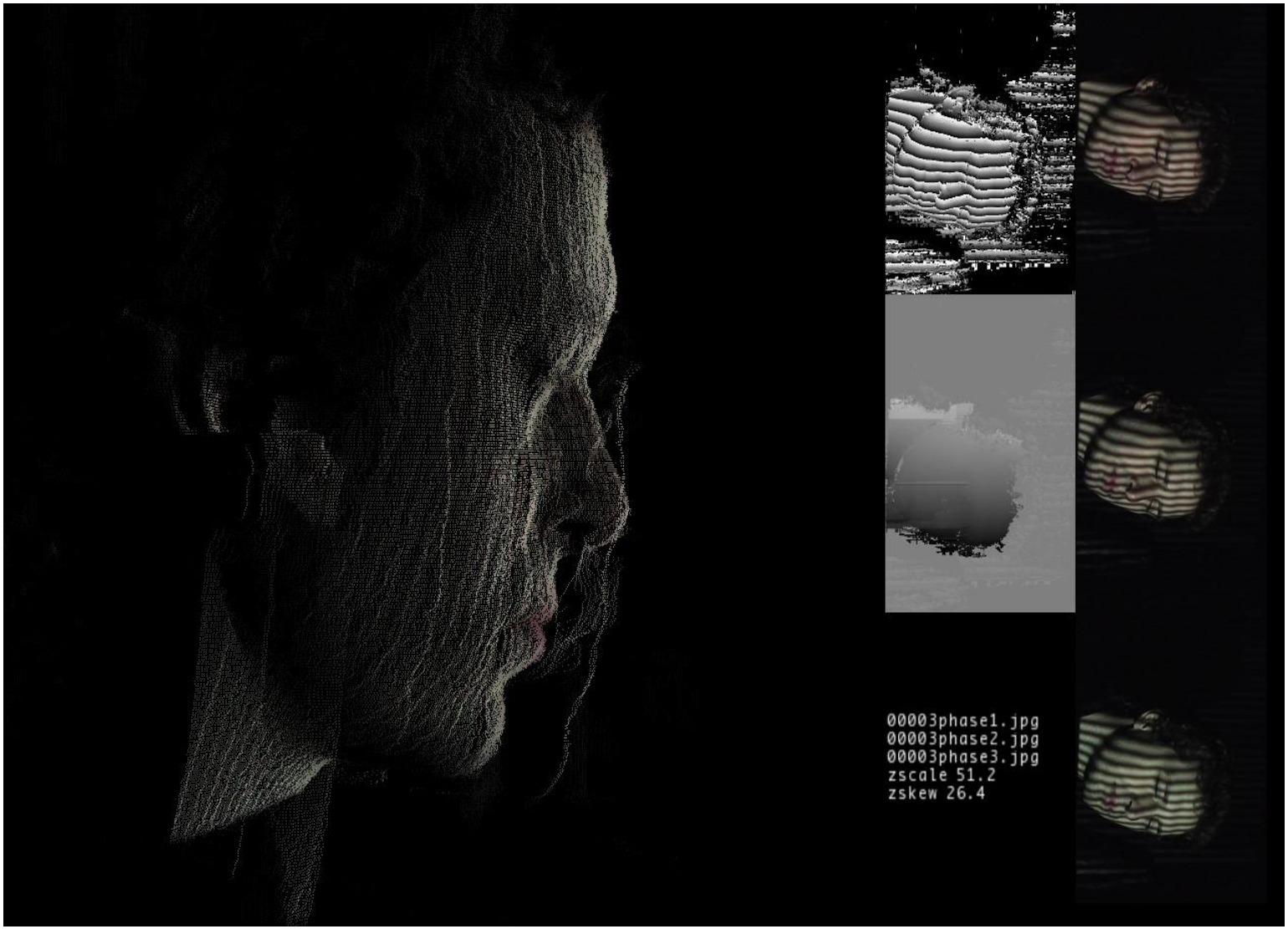
It is a good time to do computer vision now, because:

- Powerful computers (Nvidia X1 – 1 teralflop)
- Inexpensive cameras
- Algorithm improvements
- Understanding of vision systems
- Modern computer networks
- Cameras everywhere
  - Including mobile devices
- However one problem!
  - Doing anything reliably is very difficult!

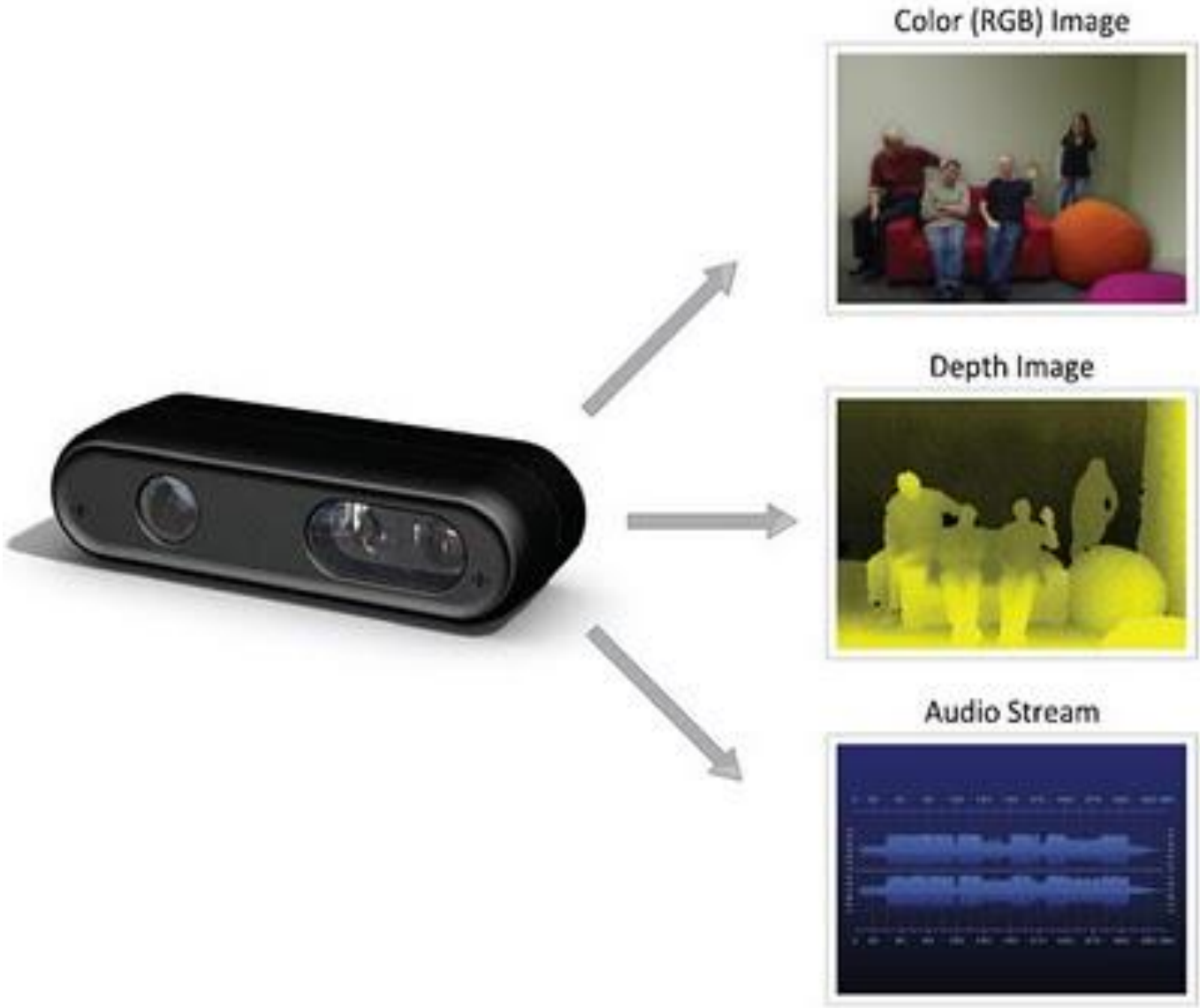
Human Computer Interfaces

- Microsoft Kinect camera
  - Uses infrared projected patterns
  - Single camera sees these and computes 3d data
  - Basically depth values on top of image pixel values
- 3d depth data is easier to use than 2d
  - At least for applications such as motion detection
  - Can detect motion of a person (including arms/legs)
- Use this motion information to control game
  - A more complex input device than the Wii
  - Wii also uses computer vision technology

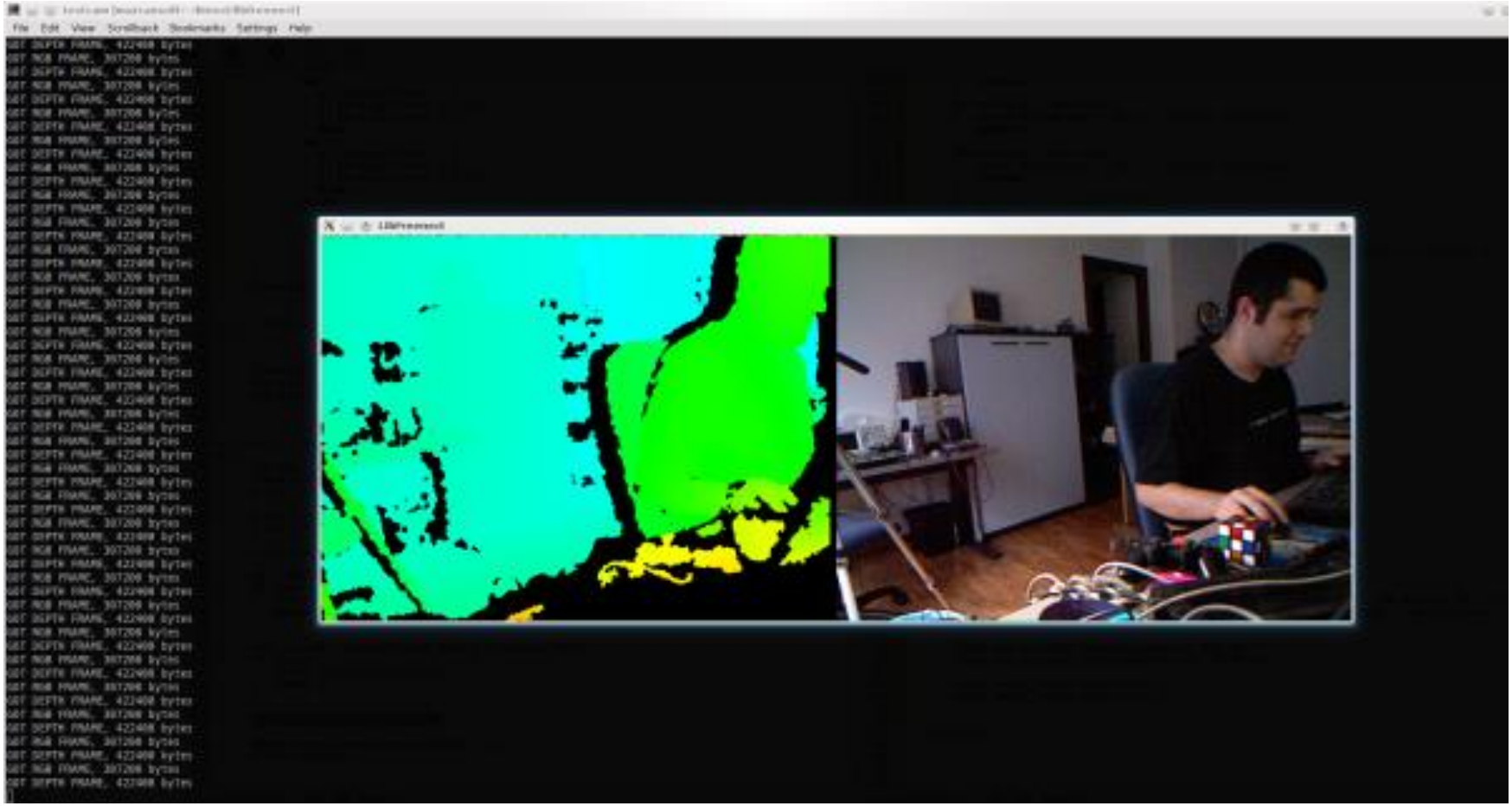
Typical structure light system



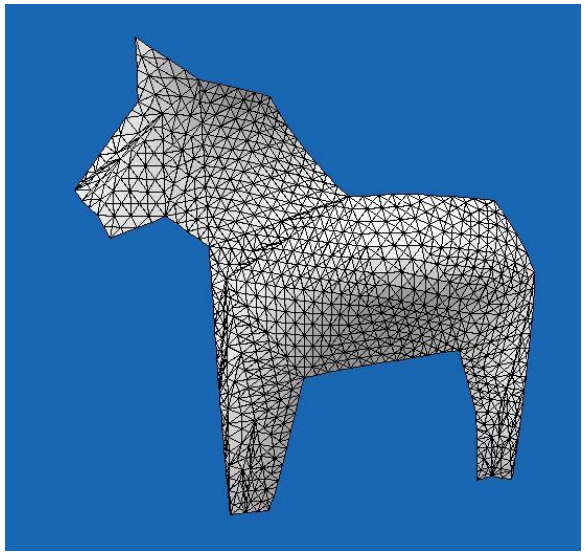
Kinect system



Kinect system



3D Reconstruction



Augmented Reality

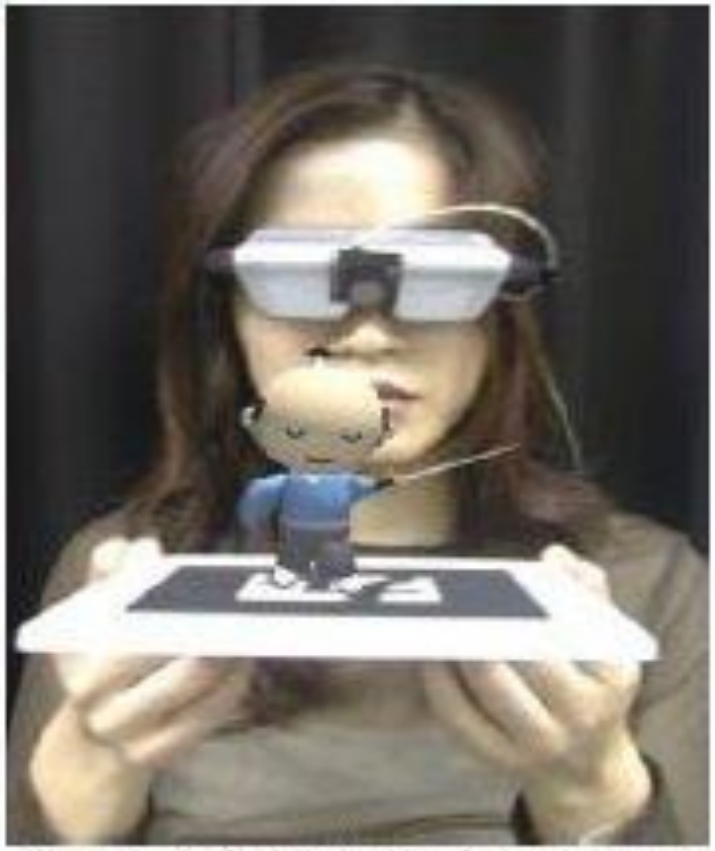
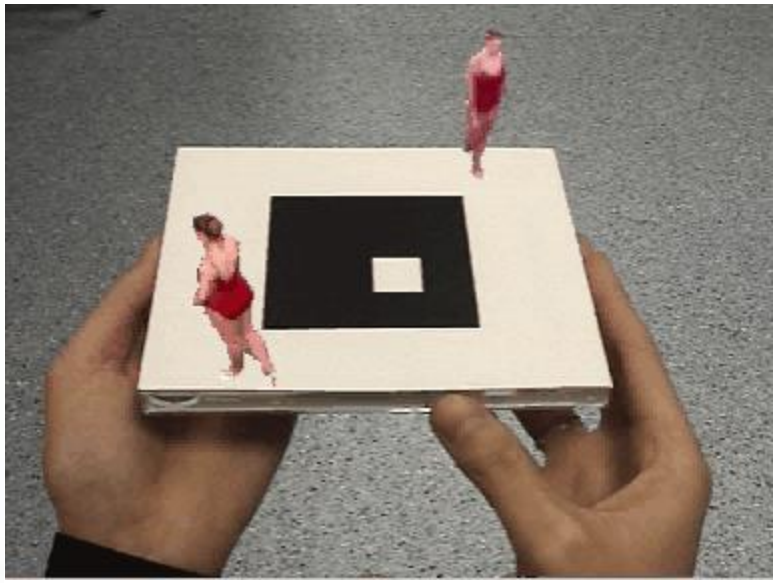


Fig. 2: A Virtual Object on a Card



Panoramic Mosaics

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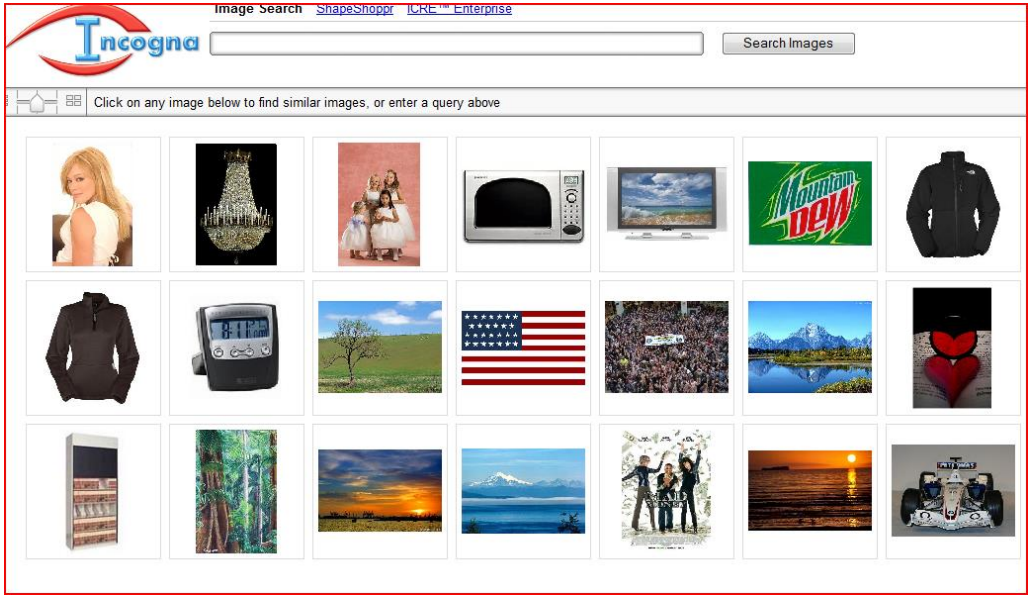
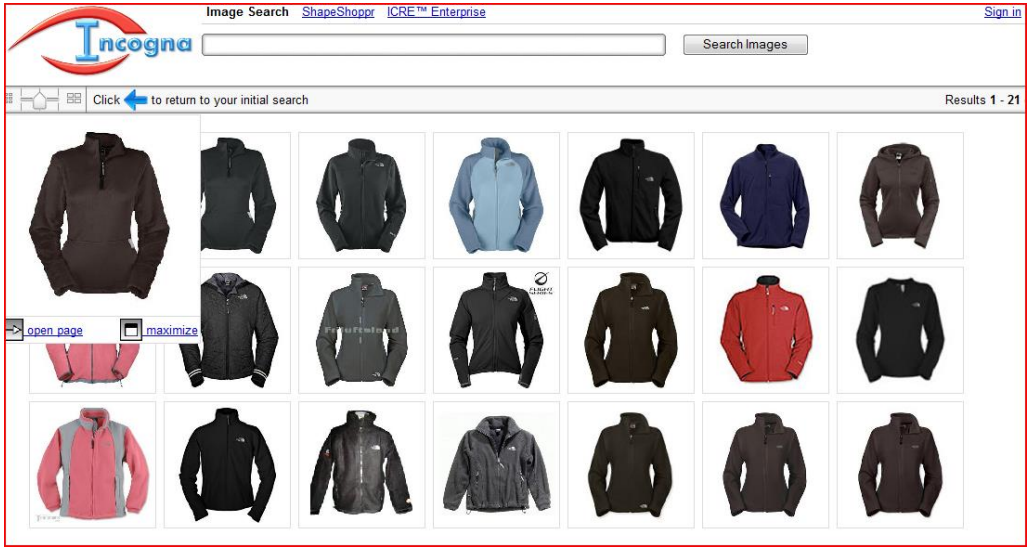
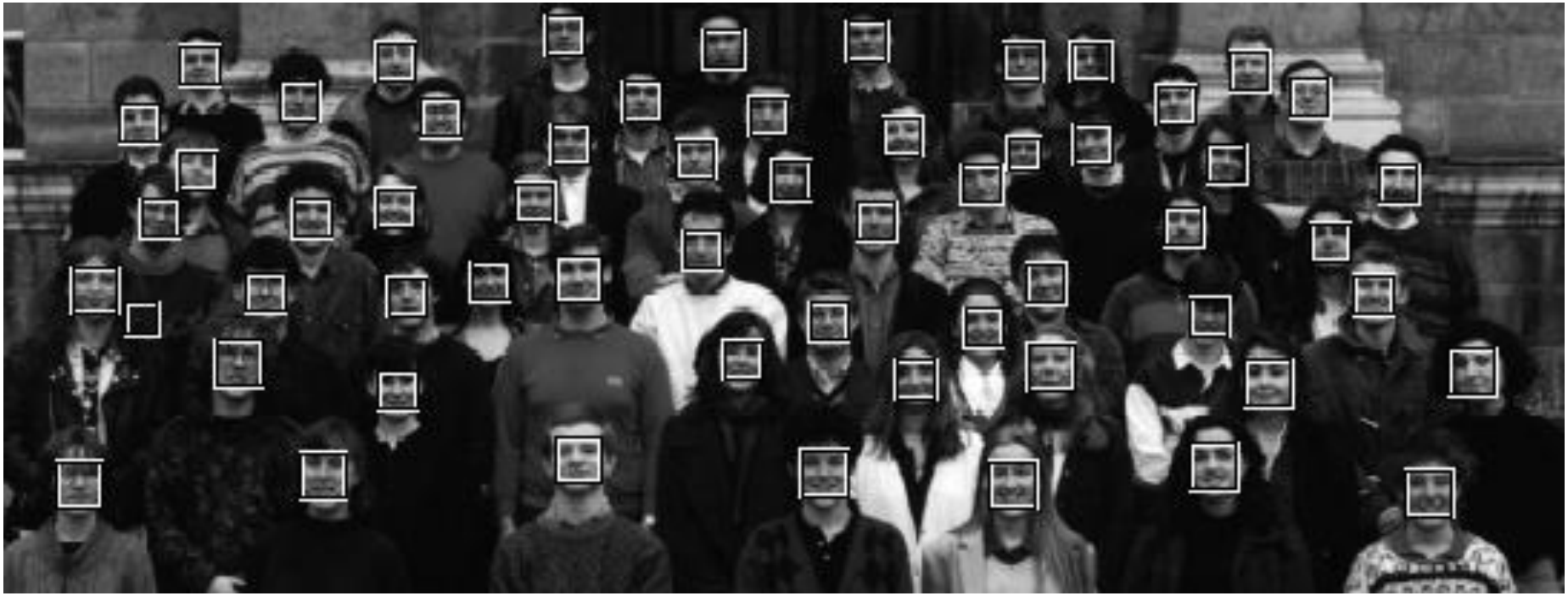
Image Search: www.incogna.com





Applications: Recognition



Applications: Special Effects

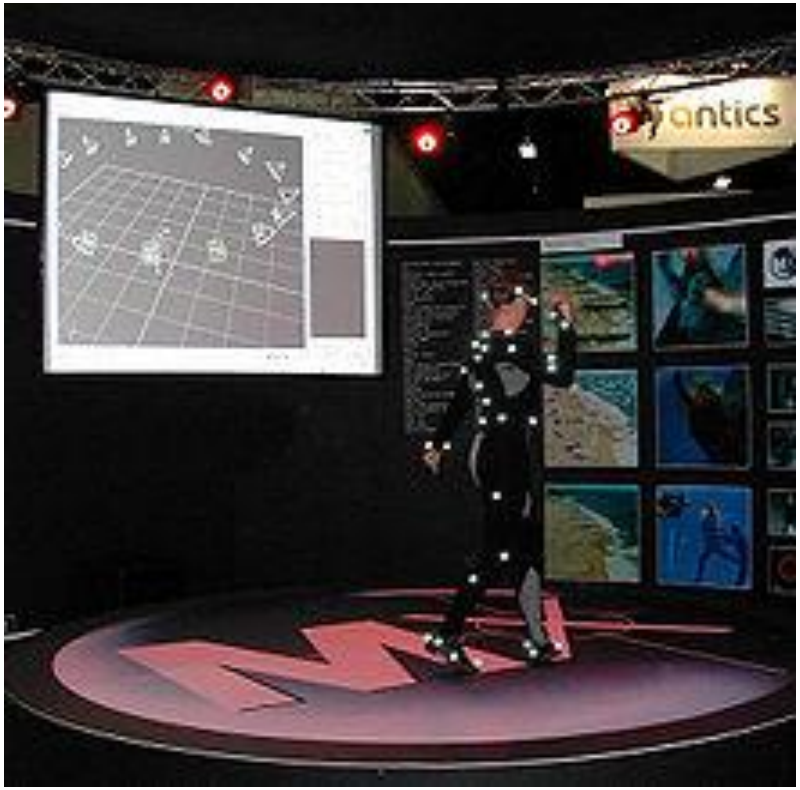
ESC Entertainment, XYZRGB, NRC

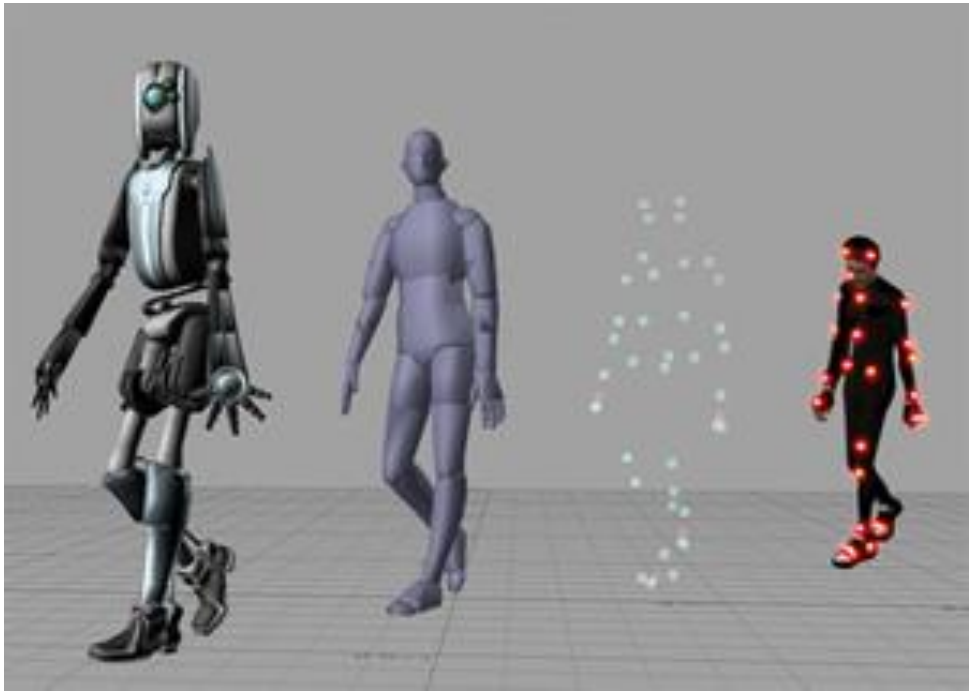
Applications: Special Effects

Andy Serkis, Gollum, Lord of the Rings

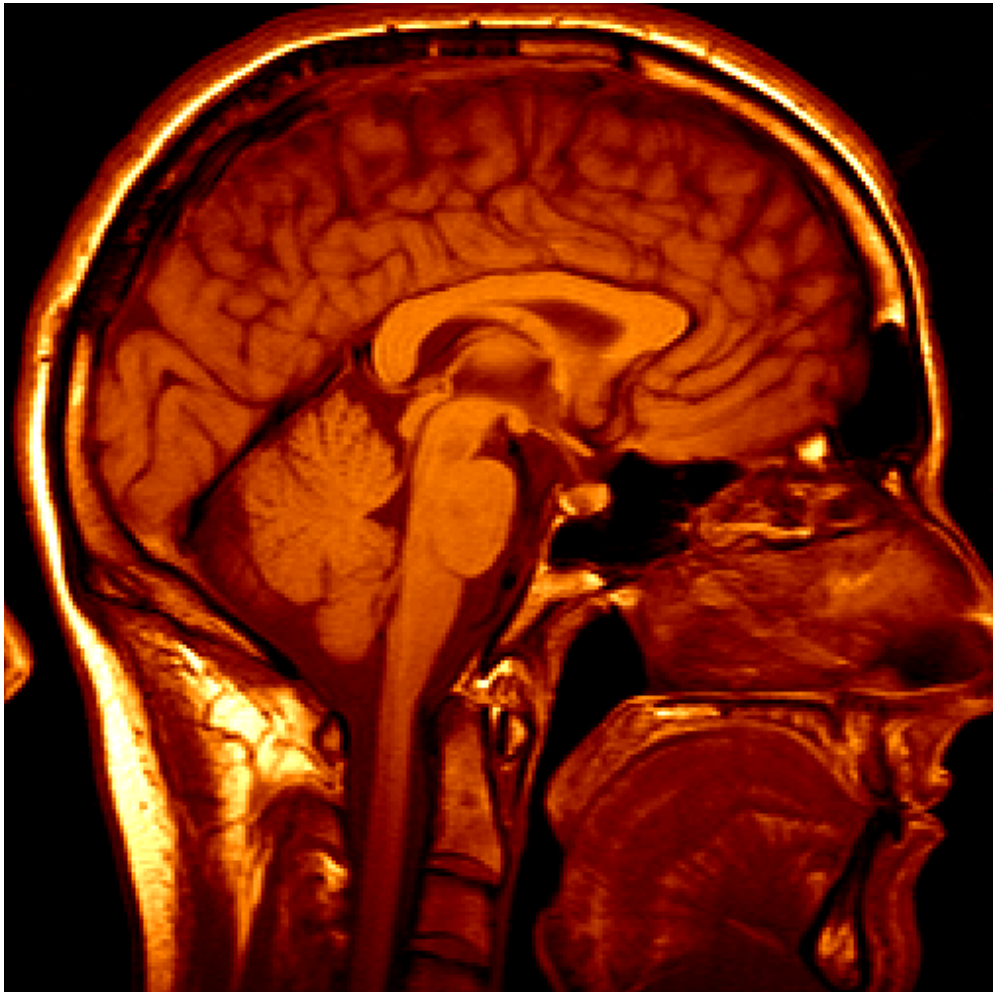
Motion capture systems

- Put retro-reflective balls everywhere
- Track these in real-time to get 3d positions

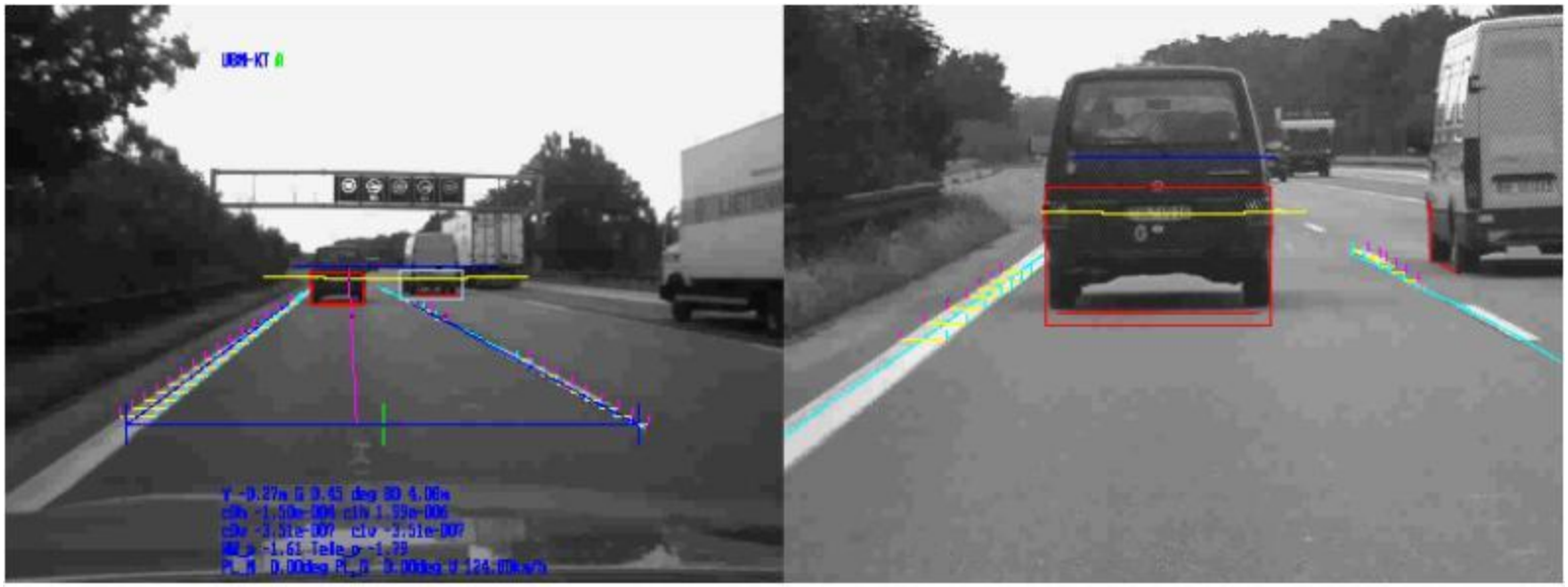




Applications: Medical Imaging

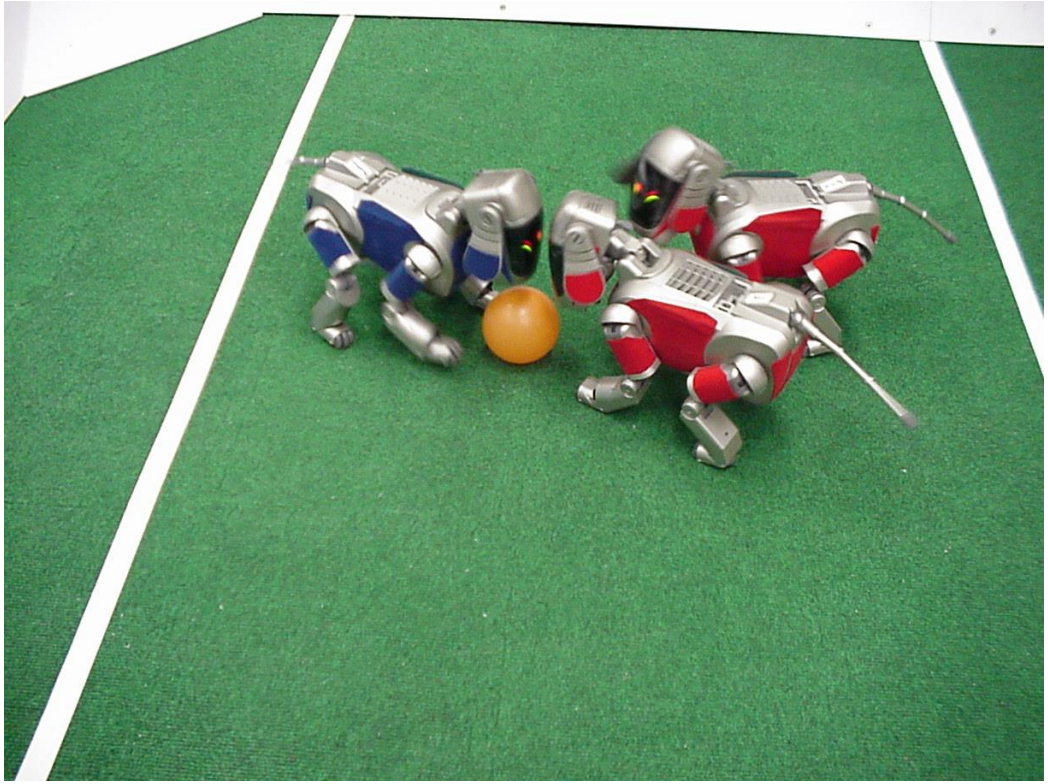


Autonomous Vehicle

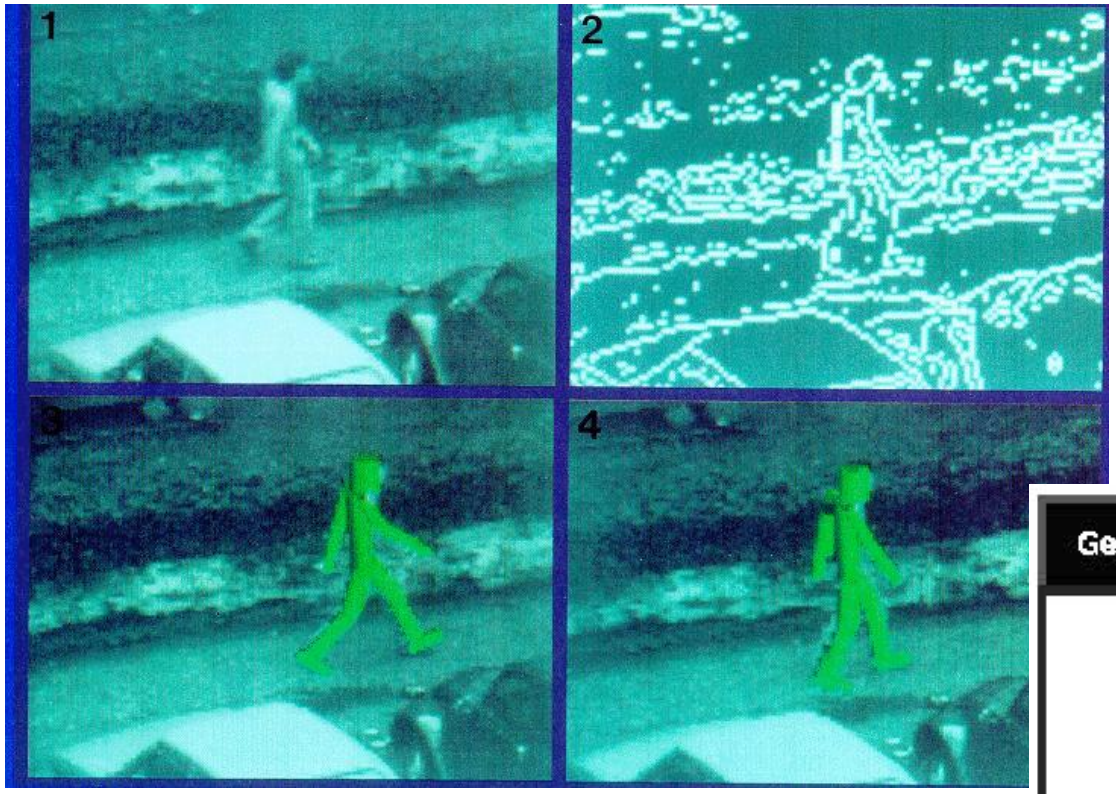


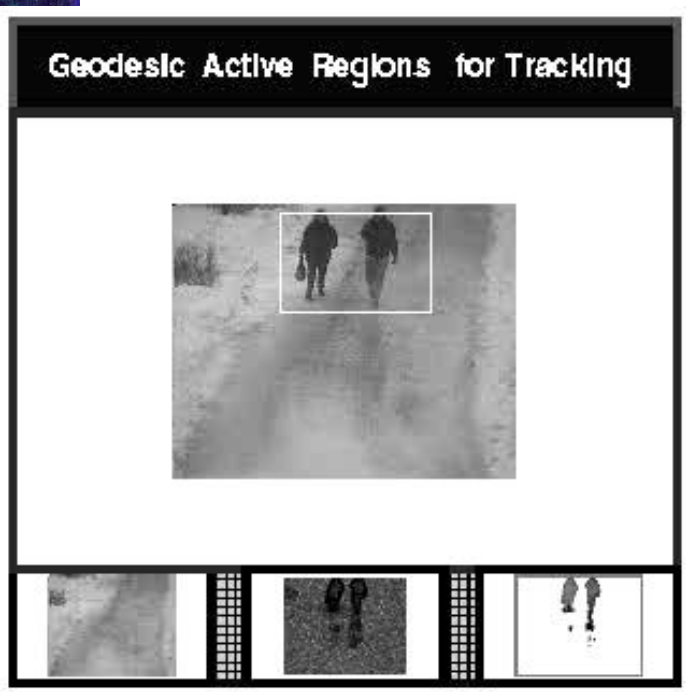
Flakey, SRI

Applications: Robotics

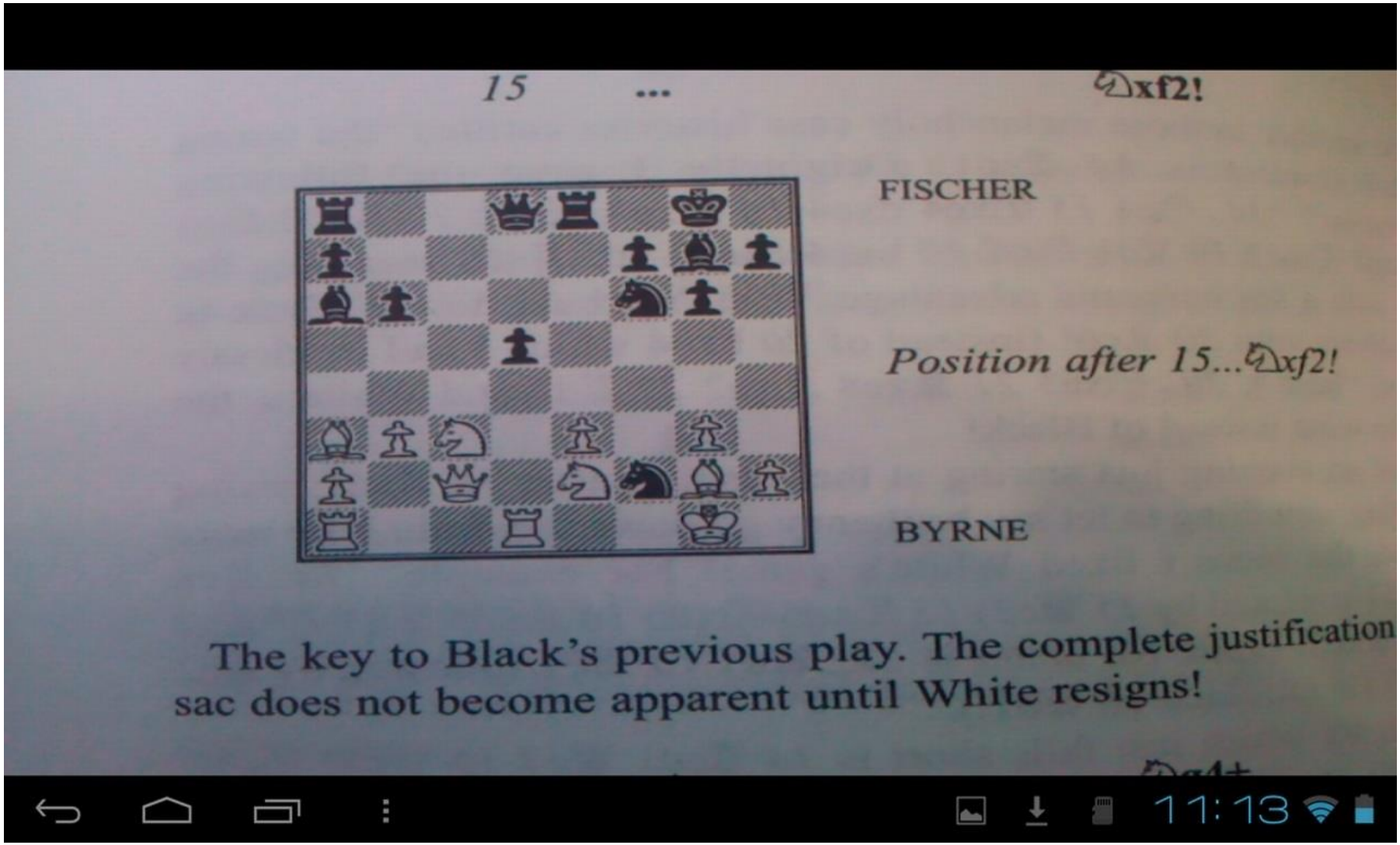


Applications: Surveillance

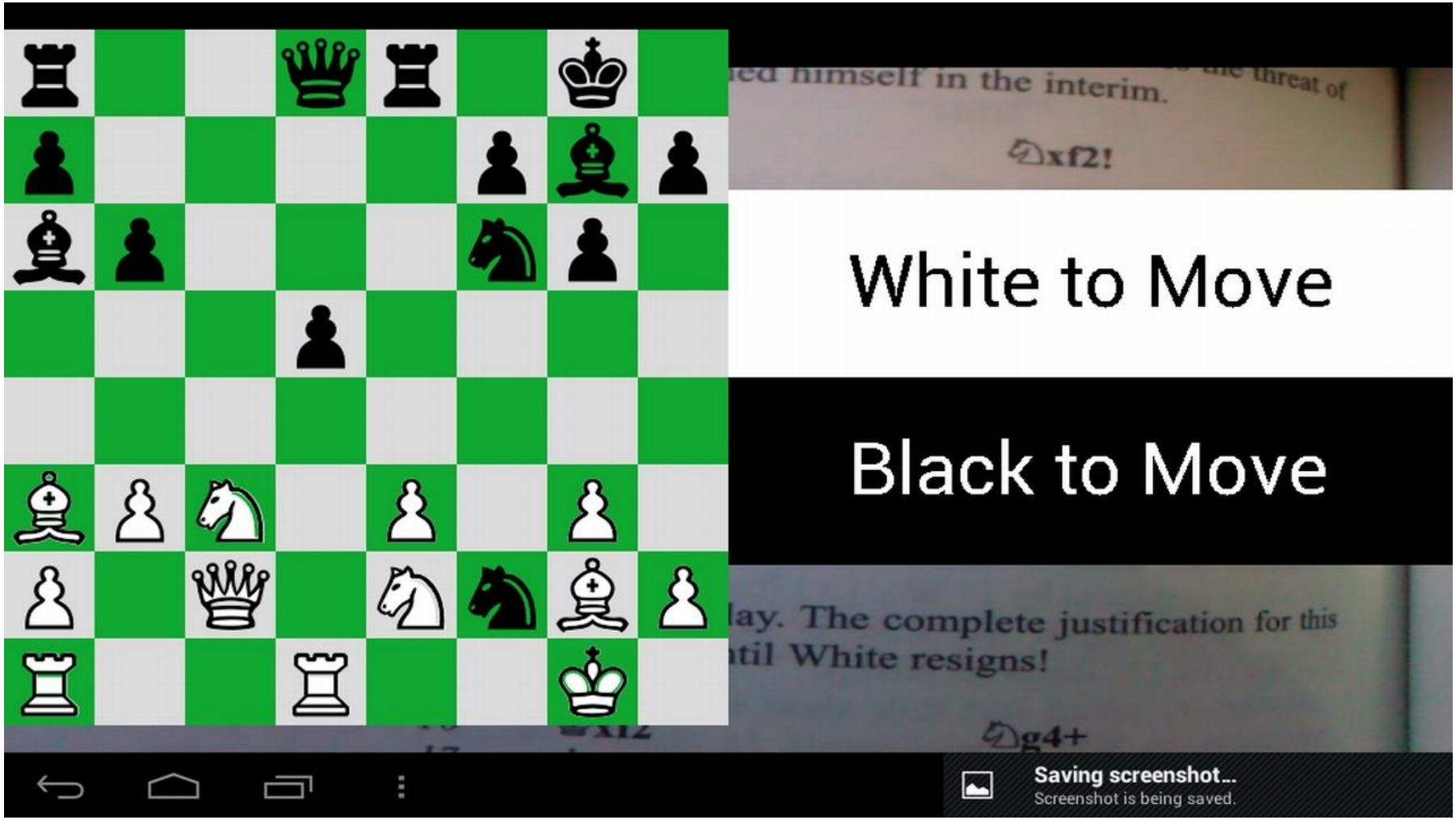




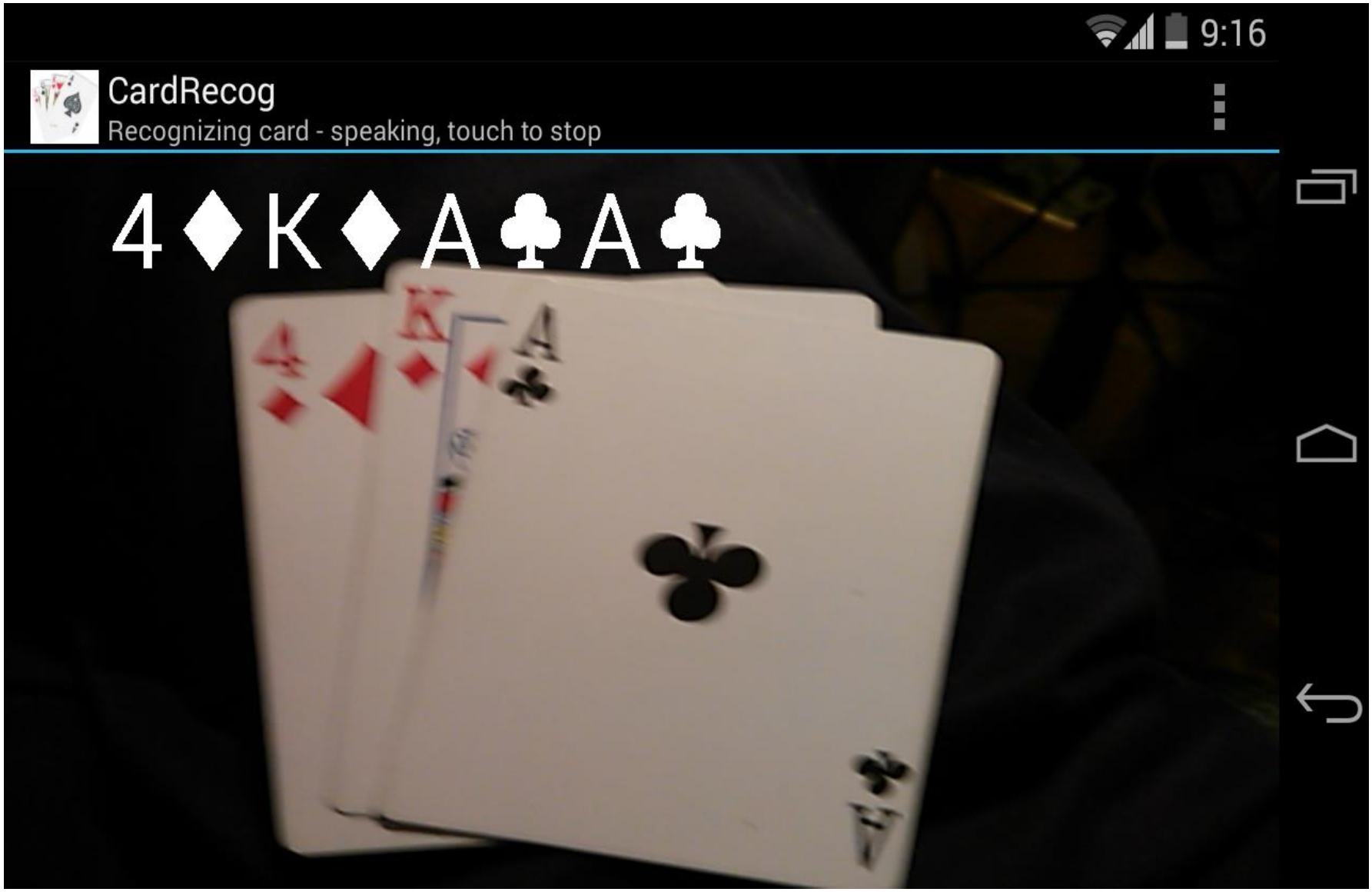
Applications: Mobile - ChessOcr



Applications: Mobile - ChessOcr



Applications: Mobile - CardRecog



Mathematical tools

- Linear algebra
- Vector calculus
- Euclidean geometry
- Projective geometry
- Differential geometry
- Differential equations
- Numerical analysis
- Probability and statistics

Programming tools

- OpenCV - http://opencv.org
  - A universal toolbox for research and development in the field of Computer Vision
  - Widely used OpenSource library written in C/C+
  - Capable of running in real-time applications
  - OS/hardware/window-manager independent
    - Simple Gui environment with sliders/mouse interaction
  - Routines for a large variety of computer vision algorithms
  - Works on Windows, Linux, Android, and IOS
  - In windows require Visual Studio environment (free for you!)
  - Easiest way to learn is to look at the sample code
  - OpenCV web site has documentation and tutorials
  - There are a number of different versions – I have included latest version on your DVD along with instructions

OpenCV Functionality

Image data manipulation

- allocation, release, copying, setting, conversion

Image and video I/O

- file and camera based input, image/video file output

Matrix and vector manipulation, and linear algebra routines

- products, solvers, eigenvalues, SVD

Various dynamic data structures

- lists, queues, sets, trees, graphs

Basic image processing

- filtering, edge detection, corner detection, sampling and interpolation, color conversion, morphological operations, histograms, image pyramids

OpenCV Functionality (*cont.*)

Structural analysis

- connected components, contour processing, distance transform, various moments, template matching, Hough transform, polygonal approximation, line fitting, ellipse fitting, Delaunay triangulation

Camera calibration

- finding and tracking calibration patterns, calibration, fundamental matrix estimation, homography estimation, stereo correspondence

Motion analysis

- optical flow, motion segmentation, tracking

Object recognition

- eigen-methods, HMM

Basic GUI

- display image/video, keyboard and mouse handling, scroll-bars

Image labeling

- line, conic, polygon, text drawing

OpenCV Modules

OpenCV Functionality

- more than 350 algorithms

Cxcore

- Data structures and linear algebra support.

cv

- Main OpenCV functions.

Cvaux

- Auxiliary (experimental) OpenCV functions.

Highgui

- GUI functions – works on Windows and Linux
- Very simple to understand and use
- On mobile devices you must make your own GUI

Course DVD – OpenCV plus lectures

- Contains OpenCV and an example program along with a copy of the course web site
  - But you should look at course web site for current updates
- http://opencv.org/ has latest version plus docu
  - But read my notes in the DVD to see easiest approach!
- Easiest approach is on Windows as below
  - Install some version of Visual Studio (Version 12 is best)
  - Install OpenCV (OpenCV3.0 Beta on DVD)
  - In directory OpenCV example open the sln project file
  - Use X86 or w32 mode, depending on your machine
  - To try out different example programs replace display_image.cpp with the other .cpp and .c files