Image Processing: Applications and Overview

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Part 1: Why take this course?

Why take this course?

- One of the important courses offered by the ViGIL group

- Soft/hard Pre-requisite for many courses offered in the Spring semester,
  - ✔ CS 763 (Computer Vision)
  - ✔ CS 736 (Medical Image Computing)
  - ✔ CS 754 (Advanced Image Processing)

Why take this course?

- Inherently interdisciplinary subject: numerous application areas

- A popular field of study in India: scope for R&D work in numerous research labs (In India:

✔ GE, Phillips, Siemens, Microsoft, HP, Texas Instruments, Samsung, Google, Facebook, Qualcomm, Intel, Nvidia, many startups

✔ DRDO, ICRISAT, ISRO

Why take this course?

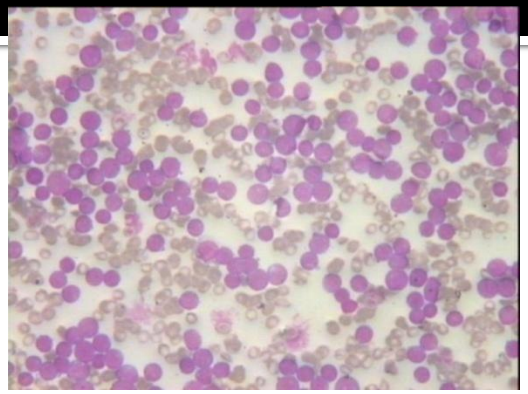
- Images are ubiquitous!
- Image processing is a field well in tune with the recent interest in big data, data science, machine learning, etc.
- You will learn lots of cool mathematical concepts on the way!

Part 2: Applications of Image Processing

Applications

- Medical image analysis
- Remote sensing (satellite images)
- Agriculture
- Machine design/testing (!)
- Surveillance
- Biometrics
- Archaeology (!)
- Computational photography, intelligent cameras
- Digital Forensics (!)

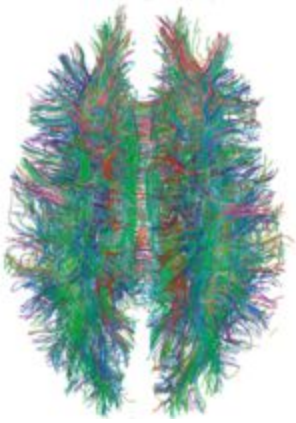
Medical image analysis



Automated pathology: cell counting, disease diagnosis/prediction

Disease detection, study of skeletal system, detection of organs

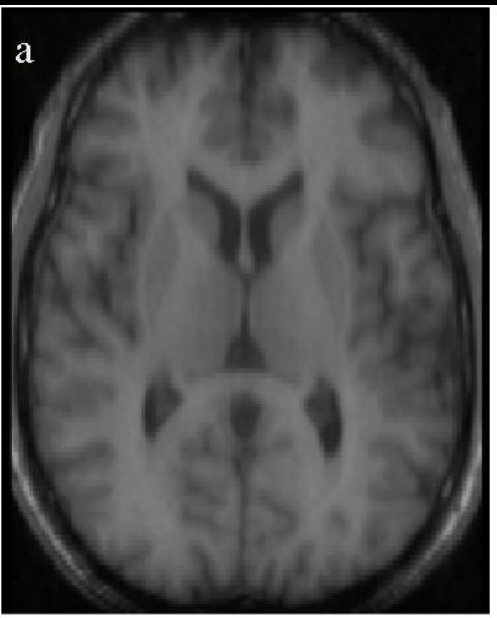
Tomography: creation of 3D models of organs

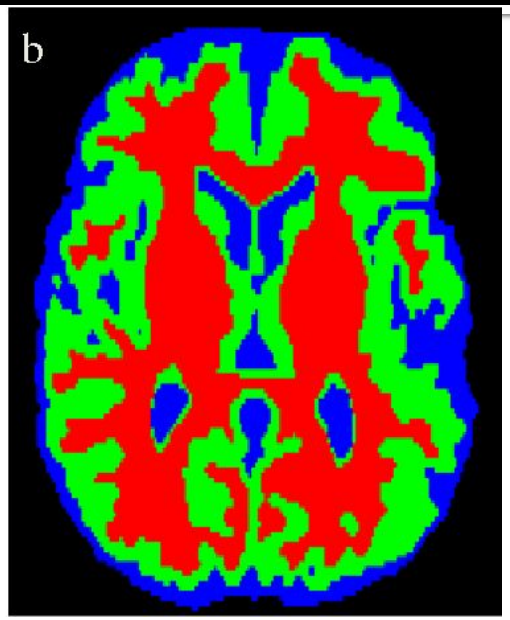


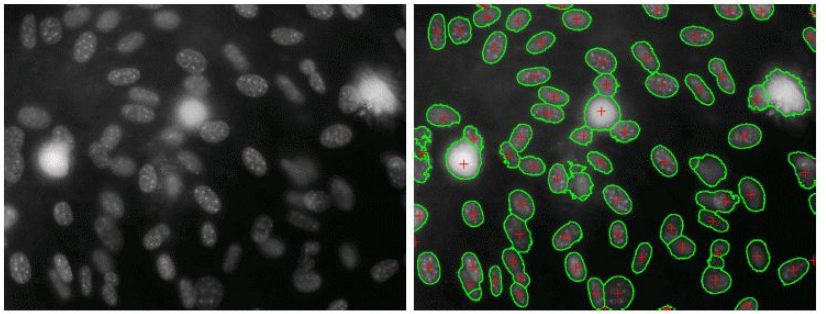
Connectome: maps of neuronal fibres from diffusion MRI images

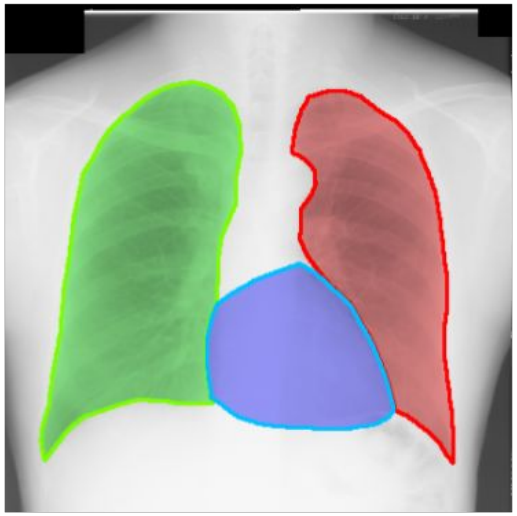
Many modalities: X-Ray, CT, MRI, diffusion MRI, electron microscopy, histopathology images, ultrasound, etc.

Medical image analysis: segmentation

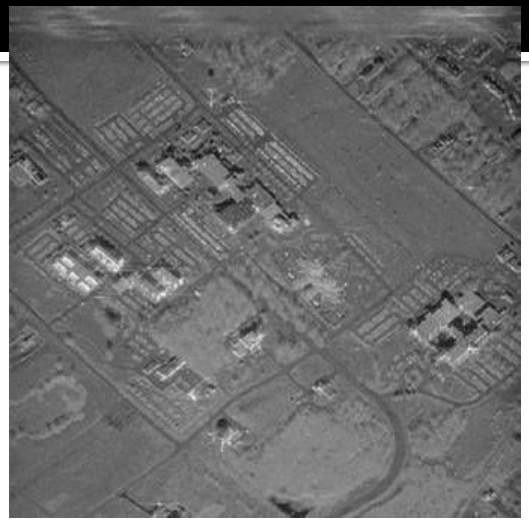


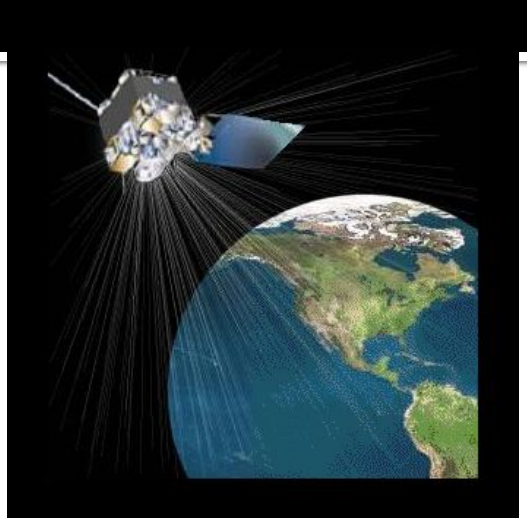


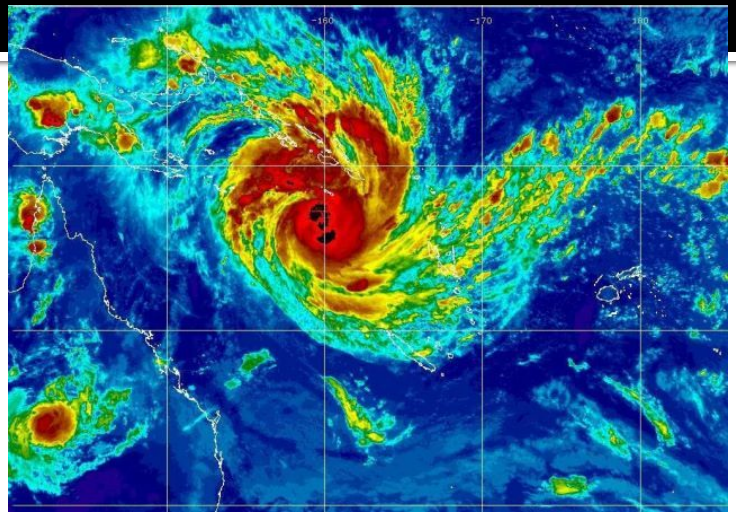




Remote Sensing







Analysis of satellite images: detection/quantification of water-body, forest, land-mass, urban settlement, landmines, etc.

Classification of materials: soil type/vegetation type etc.

Creation of detailed maps of various regions of the earth

Tracking changes in certain portions of surveyed land/water bodies (Defence/environmental engineering applications)

Analysis of weather patterns/predictions of natural disasters

Agriculture

Detection/classification of diseases in leaves or crops

Detection/counting of fruits in an orchard

Detection of animals/animal movement in crop-fields

Agriculture/Botany

(a) *Sanguisorba minor* (b) *Euphorbia cyparissias* (c) Pairs of different species with similar visual appearance

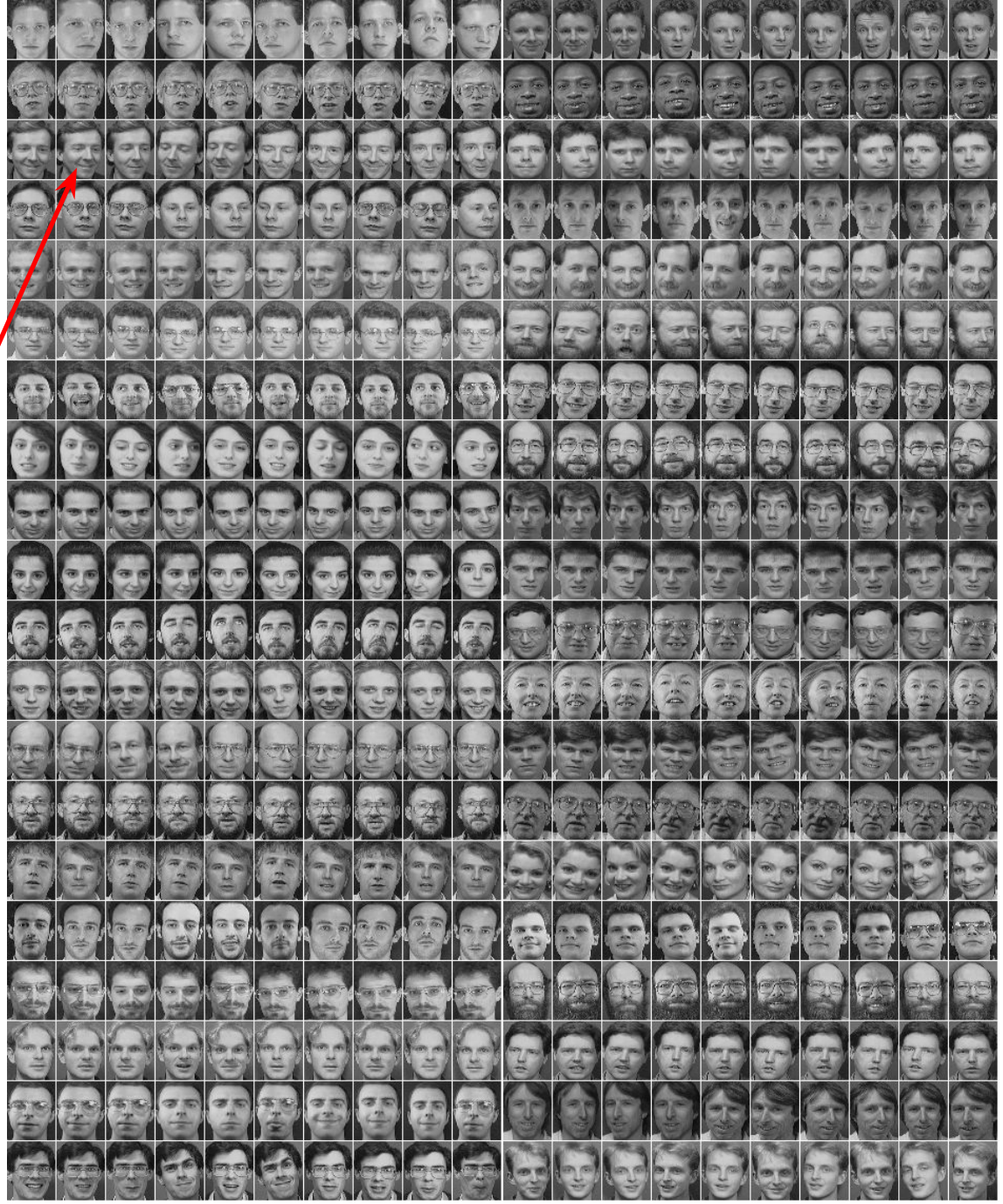
Leafsnap

Biometrics

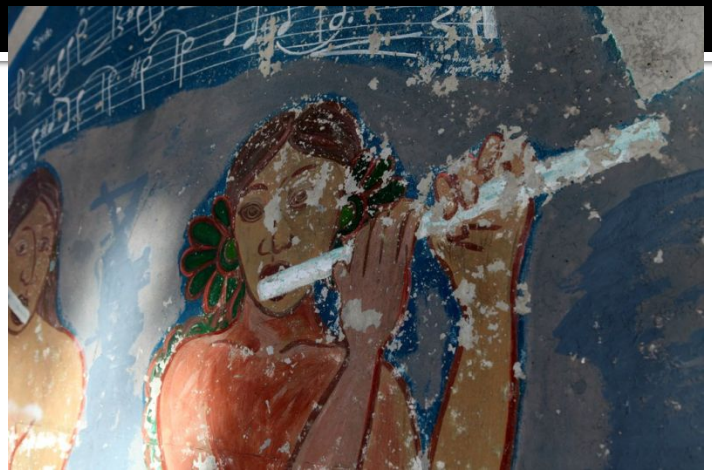
- Recognition of people from face images (2D or 3D or both), fingerprints, iris, palm-prints, dental X-rays, ears
- Face/fingerprint verification
- India's UID (Aadhaar) project!
- Human gait/motion analysis
- Challenging issues in face recognition: pose, illumination, expressions, age, plastic surgery, twins!

Face detection

Face recognition



Archaeology



Digital restoration of damaged paintings

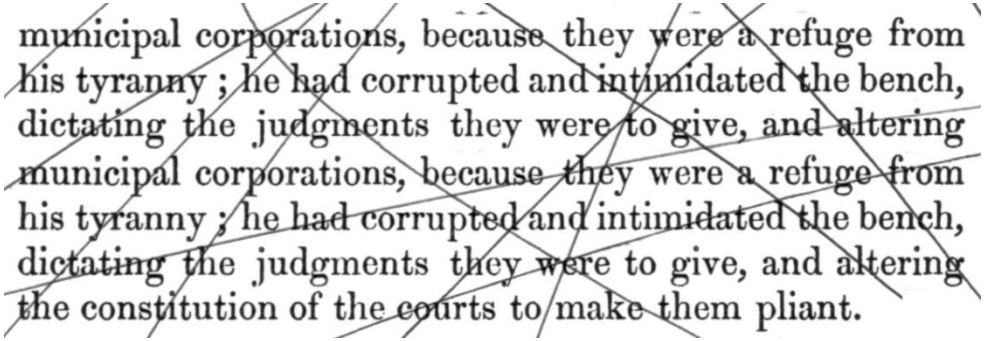
Creation of 3D models and virtual walkthroughs of monuments, archaeological sites.

Computer-aided techniques to restore ruins.

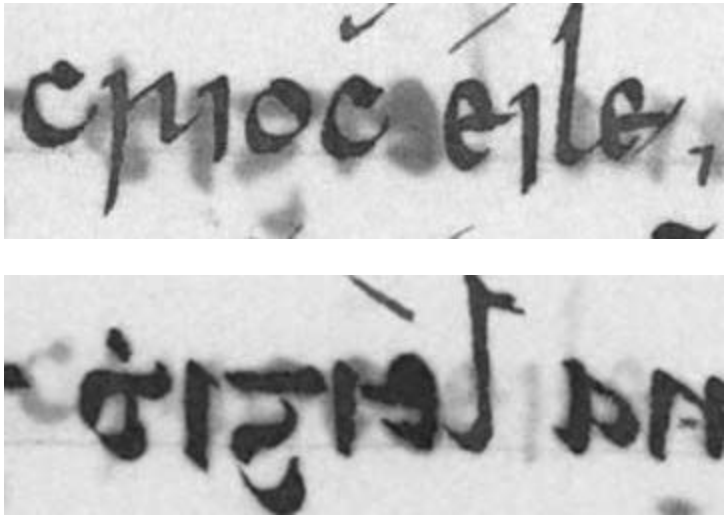
Automated analysis of old architectures.

Document image processing

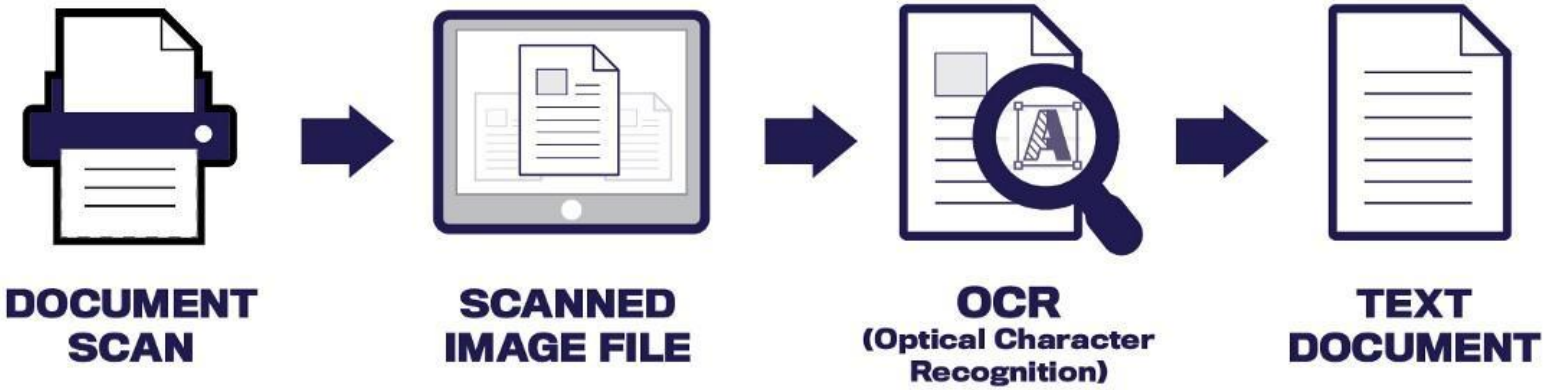
- Digital storage of handwritten/printed books (optical character/handwriting recognition)
- Digital restoration of images of manuscripts

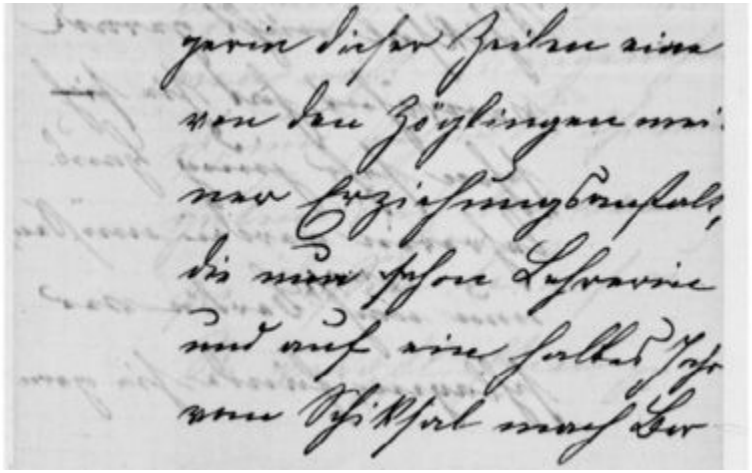

municipal corporations, because they were a refuge from his tyranny ; he had corrupted and intimidated the bench, dictating the judgments they were to give, and altering municipal corporations, because they were a refuge from his tyranny ; he had corrupted and intimidated the bench, dictating the judgments they were to give, and altering the constitution of the courts to make them pliant.

http://www.mee.tcd.ie/~sigmedia/pmwiki/uploads/Main.Publications/RRB_CVPR13final.pdf



Document image processing





Processing of Photographs

Noise removal

Motion/defocus blur removal

Inpainting

Super-resolution

Processing of photographs

Red eye removal

Embossing

Cinematography/Movie Restoration

Intensity Flicker Removal

Digital Image Forensics

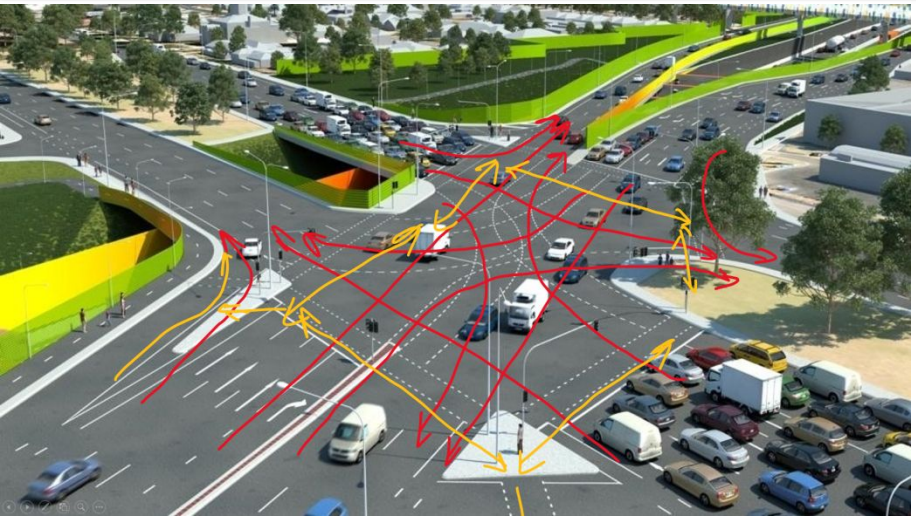
Real photo or computer manipulated?

Detecting image splicing

http://www.cs.dartmouth.edu/farid/Hany_Farid/Research/Entries/2011/6/3_Computer_Generated_or_Photographic.html

Surveillance: Person Re-identification

Surveillance: Traffic Monitoring

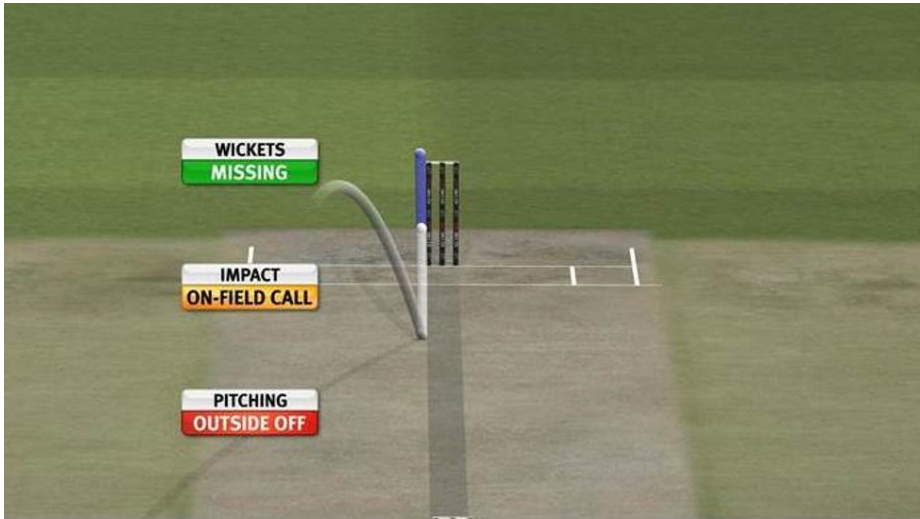


Sports!

Hawk-eye

Its major use in cricket broadcasting is in analysing leg before wicket decisions, where the likely path of the ball can be projected forward, through the batsman's legs, to see if it would have hit the stumps. Consultation of the third umpire, for conventional slow motion or Hawk-Eye, on leg before wicket decisions, is currently sanctioned in international cricket even though doubts remain about its accuracy.[9] The Hawk-Eye referral for an LBW decision is based on three criteria:

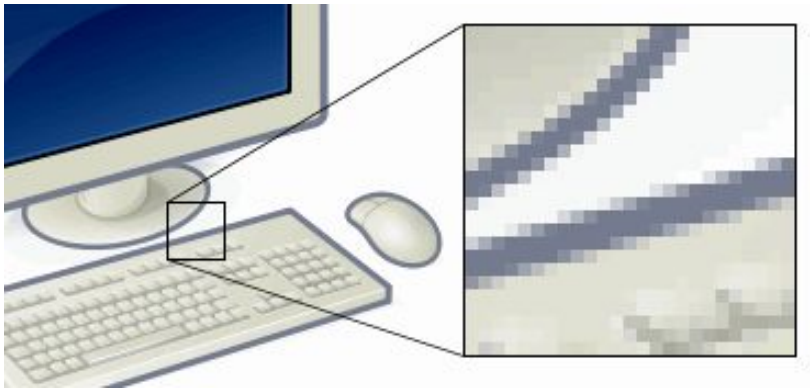
* Where the ball pitched
* The location of impact with the leg of the batsman
* The projected path of the ball past the batsman



Part 3: A few basics – what is an image?

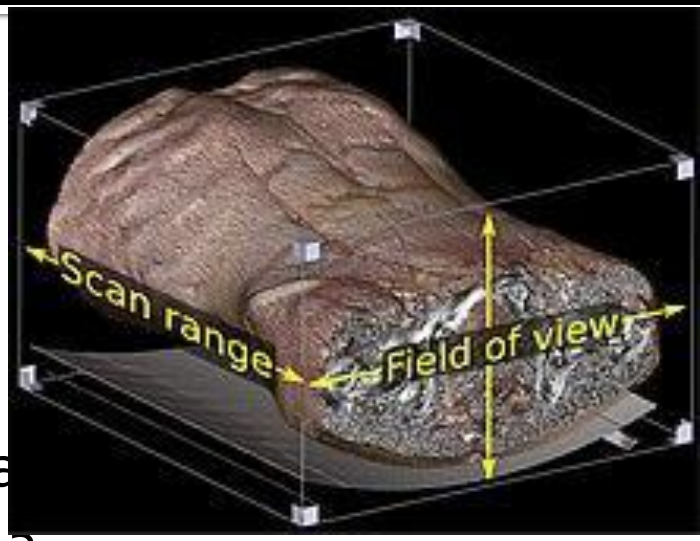
Part 3: A few basics

- Most digital images are **two-dimensional** and defined on a square or rectangular grid/array/domain.
- Each entry of the array is called a **pixel**, and contains a "**intensity**" value which tells you how bright that pixel is.
- This is for **grayscale** images.
- The intensity value is a real number.



A few basics

- Usually, pixels are **square** in shape.
- The smaller the physical size of a pixel, the greater the image resolution is.
- Images can sometimes also be defined on a three-dimensional domain – in such a case a pixel is replaced by a **voxel** (a small cube).
- This is common in medical imaging (MRI, CT, PET images)
- Each voxel again contains an intensity value.



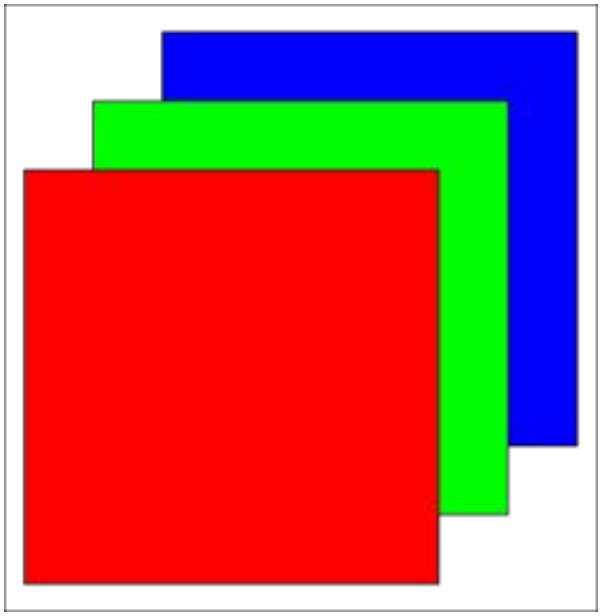
A few basics

- In this course, we will deal only with **digital** images – which are discrete (not continuous) entities

- We will **not** deal with continuous images which arise on photographic reels (infinite resolution)

A few basics

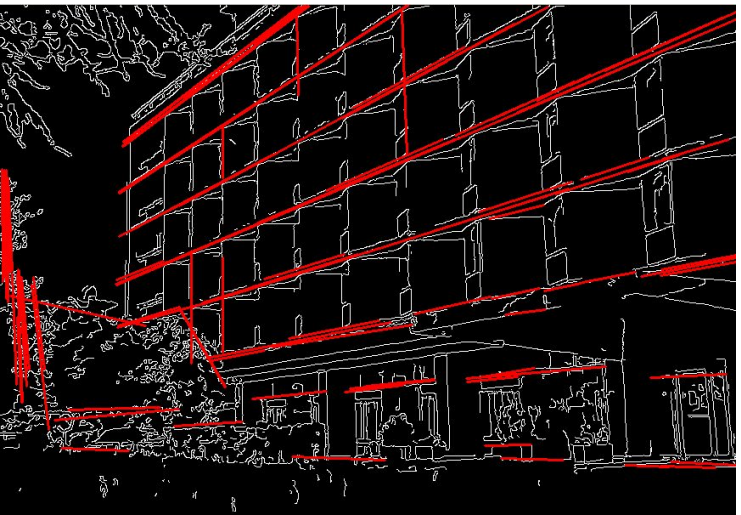
- In case of color images, each pixel contains three intensity values – one each denoting the strength of the Red (R), Green (G) and Blue (B) channels.

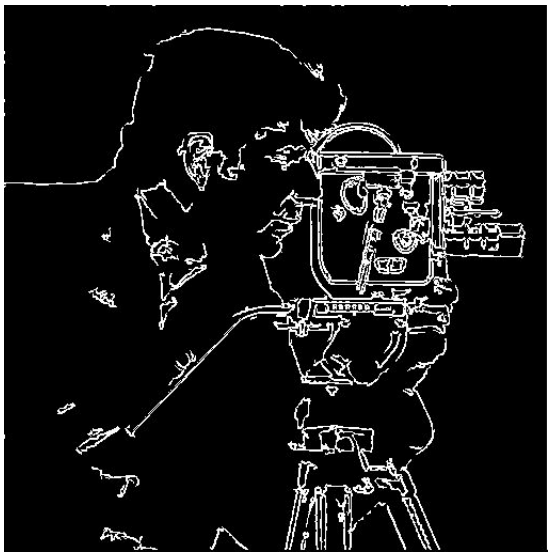


Part 4: Course syllabus

Course syllabus

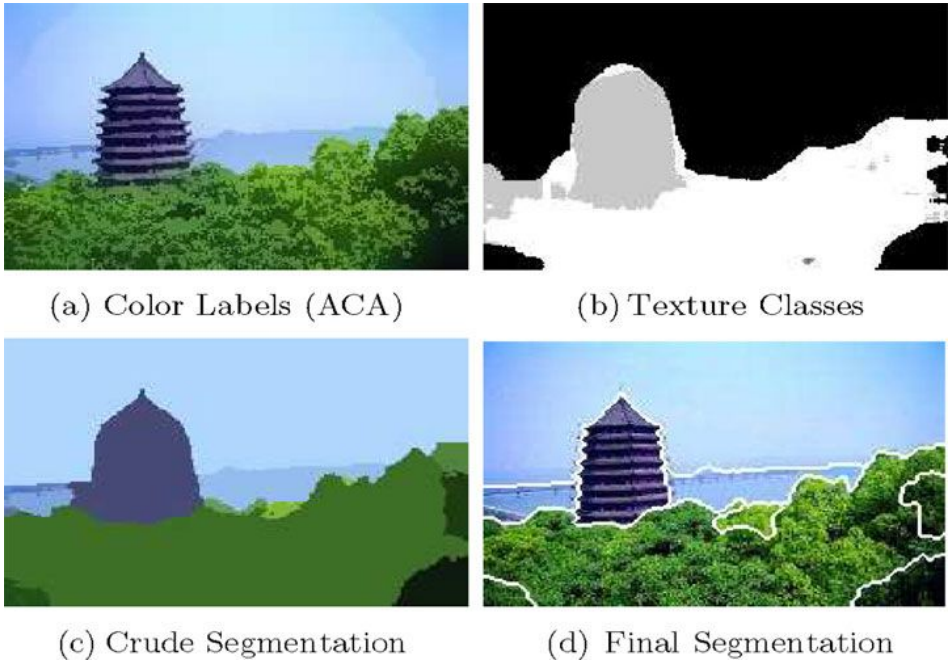
- Topic 1: Image alignment and warping
- Topic 2: Image filtering and enhancement methods
- ✔ Blurring, sharpening, edge detection, contrast enhancement





Course syllabus

- Topic 3: Image segmentation



(a) Color Labels (ACA)

(b) Texture Classes

(c) Crude Segmentation

(d) Final Segmentation

Course syllabus

- Topic 4: Fourier Transforms
- Topic 5: Face Recognition and associated Statistical Methods
- Topic 6: Image Restoration
- Topic 7: Image and Video Compression
- Topic 8: Color Image Processing
- Topic 9: Basics of tomography
- The topics won't necessarily be taught in this order, and some topics may be taught in a mixed fashion

Q = 100, compression rate = 1/2.6

Q = 10, compression rate = 1/46

Q = 50, compression rate = 1/15

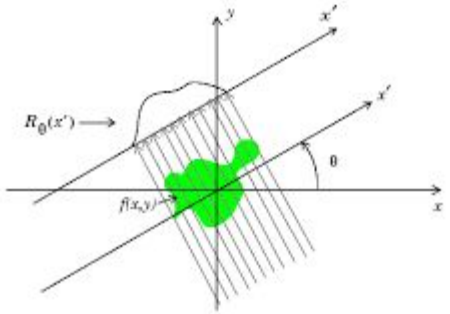
Q = 1, compression rate = 1/144

Q = 25, compression rate = 1/23

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

[Image deblurring]

Tomographic reconstruction



Mathematical tools for Image Processing

- Signal processing (Fourier transforms, wavelets, etc.)
- Statistical/basic probabilistic models, machine learning based methods, linear algebra

Programming tools

- MATLAB and associated toolboxes
- We will extensively use MATLAB for our course –
- ✔ it offers a convenient environment for numerical computations
- ✔ lots of in built functions
- ✔ Easy to debug
- MATLAB web version: https://matlab.mathworks.com/?s_tid=tah_po_start
- MATLAB at IITB: http://ftp.iitb.ac.in/ftp/IITB_private/Matlab/

- ITK (especially for medical imaging – InSight Toolkit)
- OpenCV

Part 5: Course policies

Grading policy

- Mid-semester exam: 20%
- End-semester exam: 30% (**cumulative** – will have the syllabus of the entire semester)
- Course project: 15%
- Homeworks: 35% (5 homeworks, including homework viva conducted along with project viva)
- The course project and homeworks will be done in groups of 3 students or less.
- In general, we expect the same group for homeworks and projects
- Homeworks will involve programming in MATLAB and some theory questions
- Course project is due in the week after the endsems, and will involve a group viva/demo
- Each student in the group is expected to contribute to every assignment and also the project.

Course textbooks and material

- Extensive lecture slides will be provided
- MATLAB for programming available on the IITB CC website – a web version also available via your IITB LDAP id.
- Textbook 1: "Digital Image Processing", Rafael and Woods, 3rd edition or any edition after that
- Textbook 2: "Fundamentals of Digital Image Processing", Anil K. Jain, any edition
- Both books available online

Other course policies

- Intended audience: 3rd/4th/5th year undergrads+ masters and PhD students (2nd year undergrads **ARE NOT** allowed, 2nd year masters or PhD student ARE allowed)
- Lecture slot: slot 14 (Tue and Fri 5:30 to 7 pm)
- Students who still have doubts are encouraged to email the instructor
- Office hours: 7 to 7:30 pm (in class, after the lecture)

Attendance Policy

- In general, each student should attend all the lectures
- Attendance less than 85% could invite a DX grade

Academic Honesty

- Each student should adhere to all principles of academic honesty during homeworks, exams and projects
- Avoid plagiarism or result fabrication at all costs
- Penalty for violation of these principles could be severe.

Course websites

- https://www.cse.iitb.ac.in/~ajitvr/CS663_Fall2024/
- We will use moodle extensively