DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF COPENHAGEN

Vision and Image Processing: Introductory lecture

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The teachers

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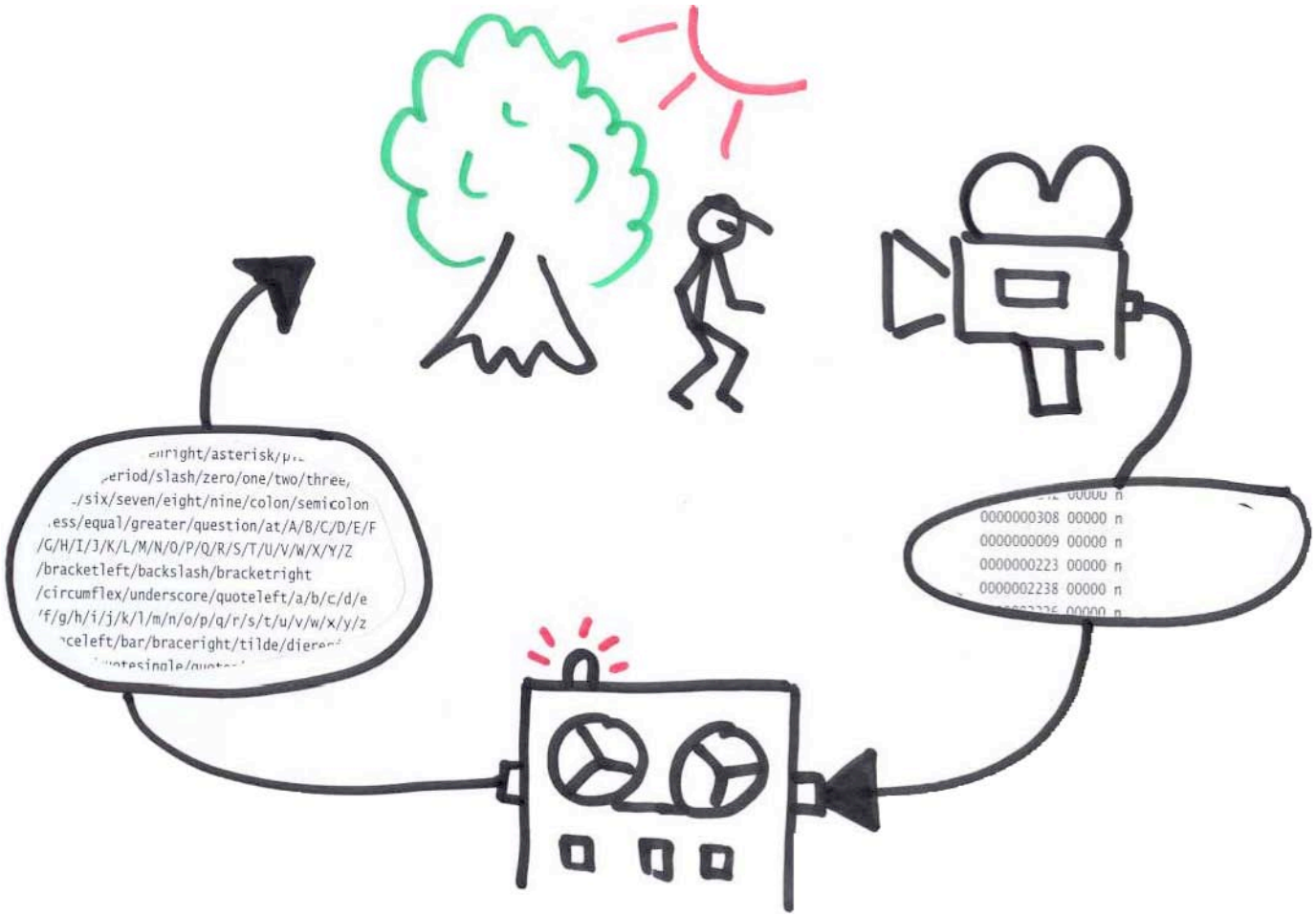
- Jan Kremer, jan.kremer@diku.dk, DIKU Image Group (TA)

What is this course about?

Computer Vision



Definitions of Computer Vision

- **My definition:** The design of algorithms for interpreting visual data by mimicking (and surpassing) the human visual perceptual system.

Alternatives:

- **McGraw-Hill Science & Technology Dict.:** The use of digital computer techniques to extract, characterize, and interpret information in visual images of a three-dimensional world.
- **Wikipedia:** As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner.
- **thefreedictionary.com:** Field of robotics in which programs attempt to identify objects represented in digitized images provided by video cameras, thus enabling robots to “see.”

Tentative plan for lectures

Week	Content
47	Features
48	Features
49	Content-Based Image Retrieval (CBIR)
50	Object detection and recognition
51	Segmentation
2	Optic flow and tracking
3	Camera models and stereo vision

Format

- This course consists of:
  - Lectures on Mondays
  - A mix of lectures and exercise class on Wednesdays (bring your laptop)

- You will work with selected methods in the mandatory assignments.

- We suggest that you try to implement and experiment with other methods not covered in the assignments.

Schedule: When and where?

Lectures:

- Mondays 13:15 – 15:00 in room 2-0-25 (Biocenter)

- Wednesdays 13:15 – 16:00 in room 2-0-25 (Biocenter)

Mandatory assignments

The course includes 4 mandatory assignments:

- A mix of theoretical and practical problems
- You have two weeks to solve each of them
- Necessary theory will be presented at lectures
- The solutions must be made individually and some in groups
- You can get help during the lectures and exercise class
- You are also welcome to contact the lecturers and TA for help
- You are encouraged to use the discussion forum

Students Prerequisites

- This course is offered on the M.Sc. educations in It & Cognition and Computer Science.

We assume that you know:

- Programming at a basic level (either Python, Matlab, or C/C++)

Be aware:

• You are a mixed crowd with different backgrounds!

• There might be parts you will find trivial and other parts you won't.

Relation to other DIKU courses

- Signal and image processing, Q1
  - Extremely useful, but not a requirement for this course
- Statistical methods for machine learning, Q3
  - Excellent companion course
- Advanced topics in data modeling, Q4
  - Good companion course
- Medical image analysis, Q2
  - Related topic
- Constrained continuous optimization, Q2
  - Gives a good foundation in optimization techniques relevant for Computer Vision

How do I pass this course?

- You have to pass the 4 mandatory assignments in order to pass this course.
- Assignment 1 must be solved individually, but we encourage you to discuss it with your fellow students.
- Other assignments are either group or individual.
- In case you do not pass an assignment the first time you will be given a second chance to submit a new solution (Assuming that you have made a SERIOUS attempt the first time).
- Final grading for the course is: Pass / Fail based on the assignments.

How much time should I spend on this course?

- KU expect that you to use 23 hours / week for a 7.5 ECTS course. Approx. 46 hours/wk for full time study.
  (Yes, it is more than the 37.5 hours/wk common out in real life, i.e. according to Danish union agreements)
- How should I spend my time:
  - Lectures and exercise classes = 2 + 3 = 5 hours/wk
  - Preparation and assignment = 23 – 5 = 18 hours/wk

- We recommend that you prepare by reading the current weeks material and doing some research on your own, ideally prior to each lecture (approx. 9 hours/wk)
- Work on the assignment at home (approx. 9 hours/wk)

Course material

- We will use a mix of research papers and chapters from selected books.

- All material will be made available in Absalon under the Course material menu item.

Relevant software

- Matlab is available from KUnet software library for installation on your laptop

- You can get quite far in Python using:
  - Numpy
  - Scipy
  - Python Image Library (PIL)

- If you prefer C / C++ (or Python), we recommend these libraries:
  - OpenCV http://opencv.willowgarage.com/wiki/
  - VLFeat http://www.vlfeat.org/

How to get help

- We use Absalon (access via your KUnet account)
  - You will find latest lecture plan
  - Links to lecture slides (usually after the lecture)
  - Course material (reading material)
  - Exercise material
  - Links to additional material (reading, programming, etc.)
- Discussion board in Absalon for course related topics
- Talk with the teachers at class, per e-mail, or try to catch us at our offices

Enough about the formalities!

What do you see in this image?

- Low level cues: Texture, shading, shadows, occlusion boundaries
- High level interpretation: Objects, foreground-background, 3D perception, object affordances
- And we did not include motion!

A couple of examples of interesting problems in Computer Vision

Example: Object recognition and detection

What is in this image?

And where?

Cars

House

Lamp post

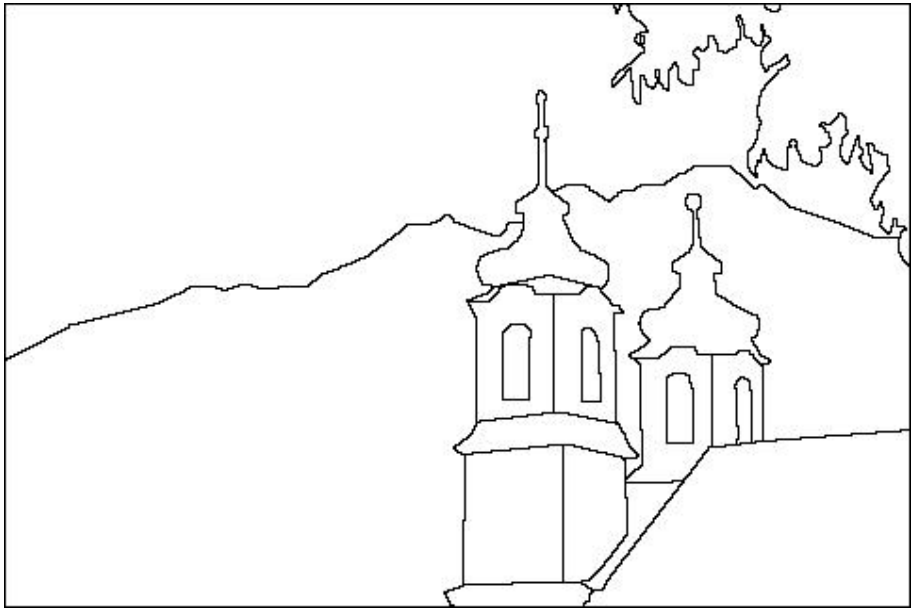
Example: Content-Based Image Retrieval

Please return all image that are similar to my query image

Query image

Search result

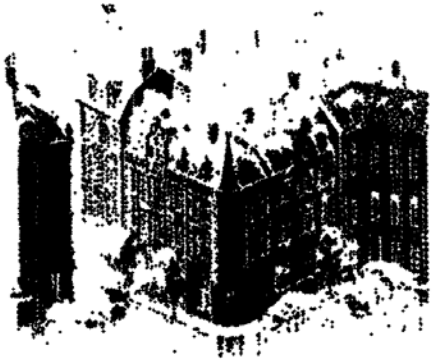
Example: Image Segmentation
Information on object boundaries and parts



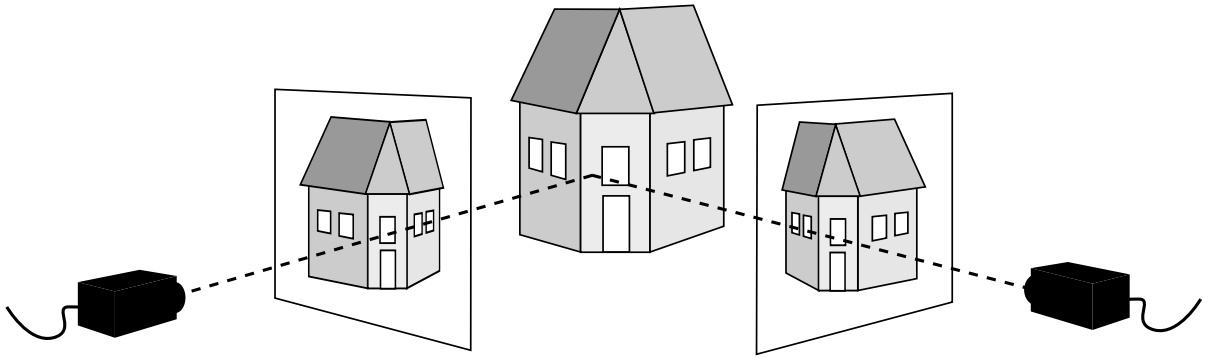
Example: 3D reconstruction
Stereo or multi-view

(a)

(b)



(c)



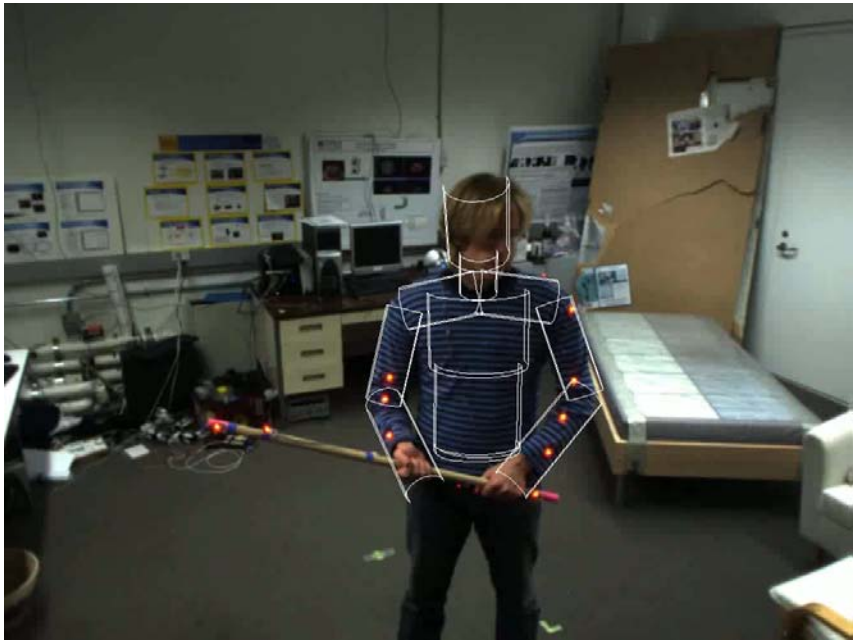
(d)

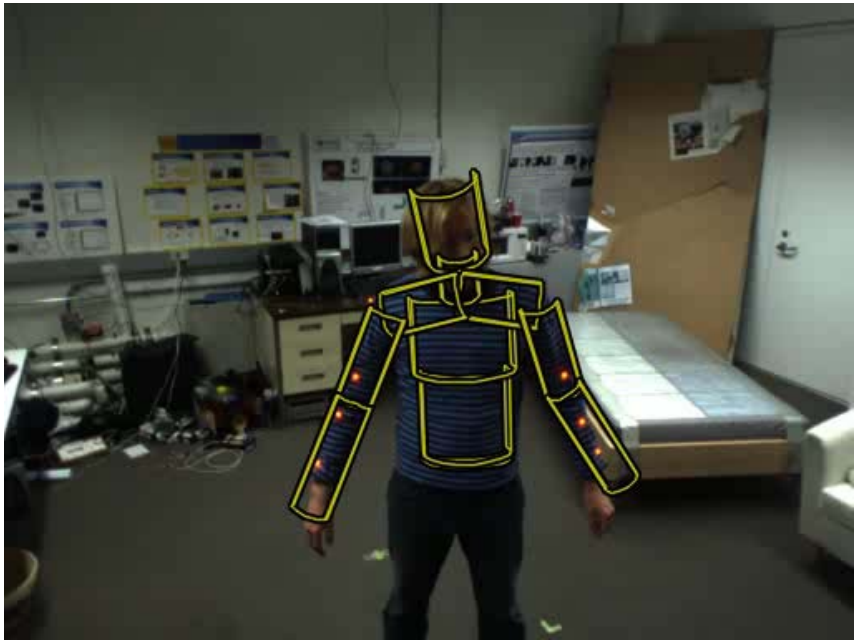
Example: 2D tracking of objects

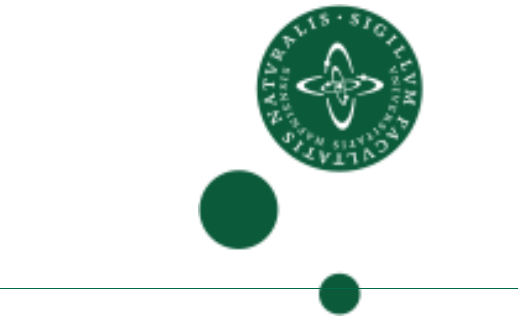
Estimate an objects 2D trajectory in the image over time

Example: 3D articulated human tracking

Estimate 3D pose over time





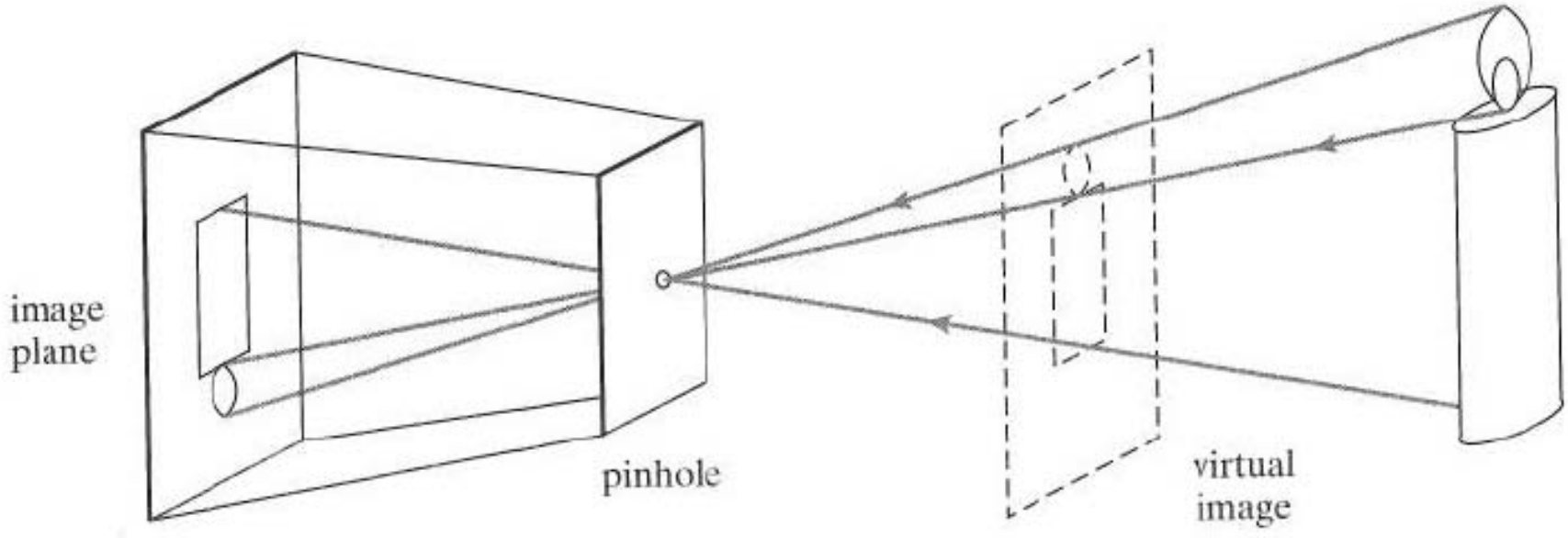


Lets start from the bottom and go up

Our input data consists of images – so what is an image?

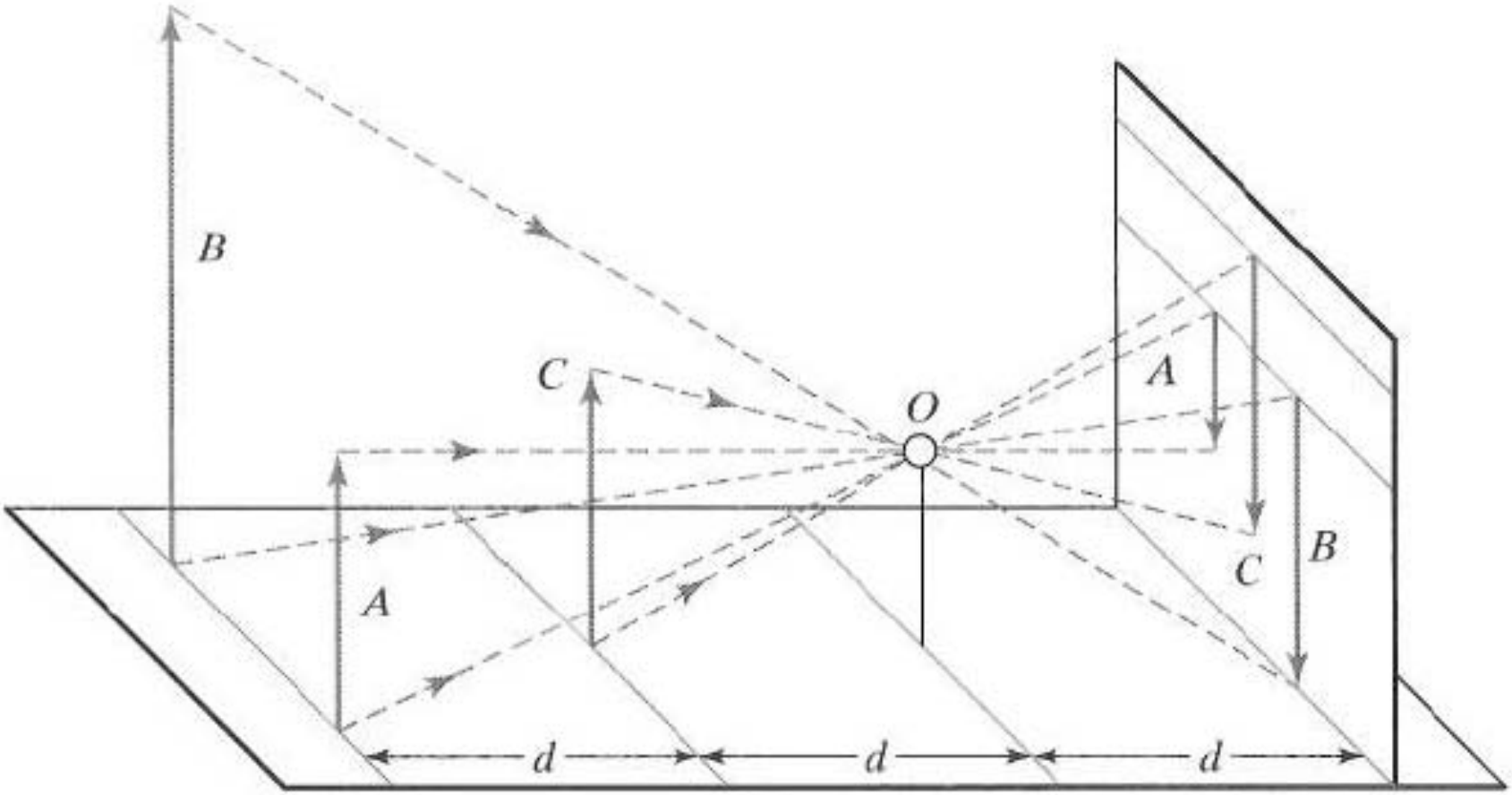
Image formation:
Camera obscura / pinhole camera

Image formation:
Camera obscura / pinhole camera



Notice: An image is a 2D projection of the 3D world through a perspective projection

Image formation:
Some effects of perspective projection



Objects far away appear smaller than close by objects

Image formation:
Some effects of perspective projection

Parallel lines appear to cross in the image plane (vanishing point)

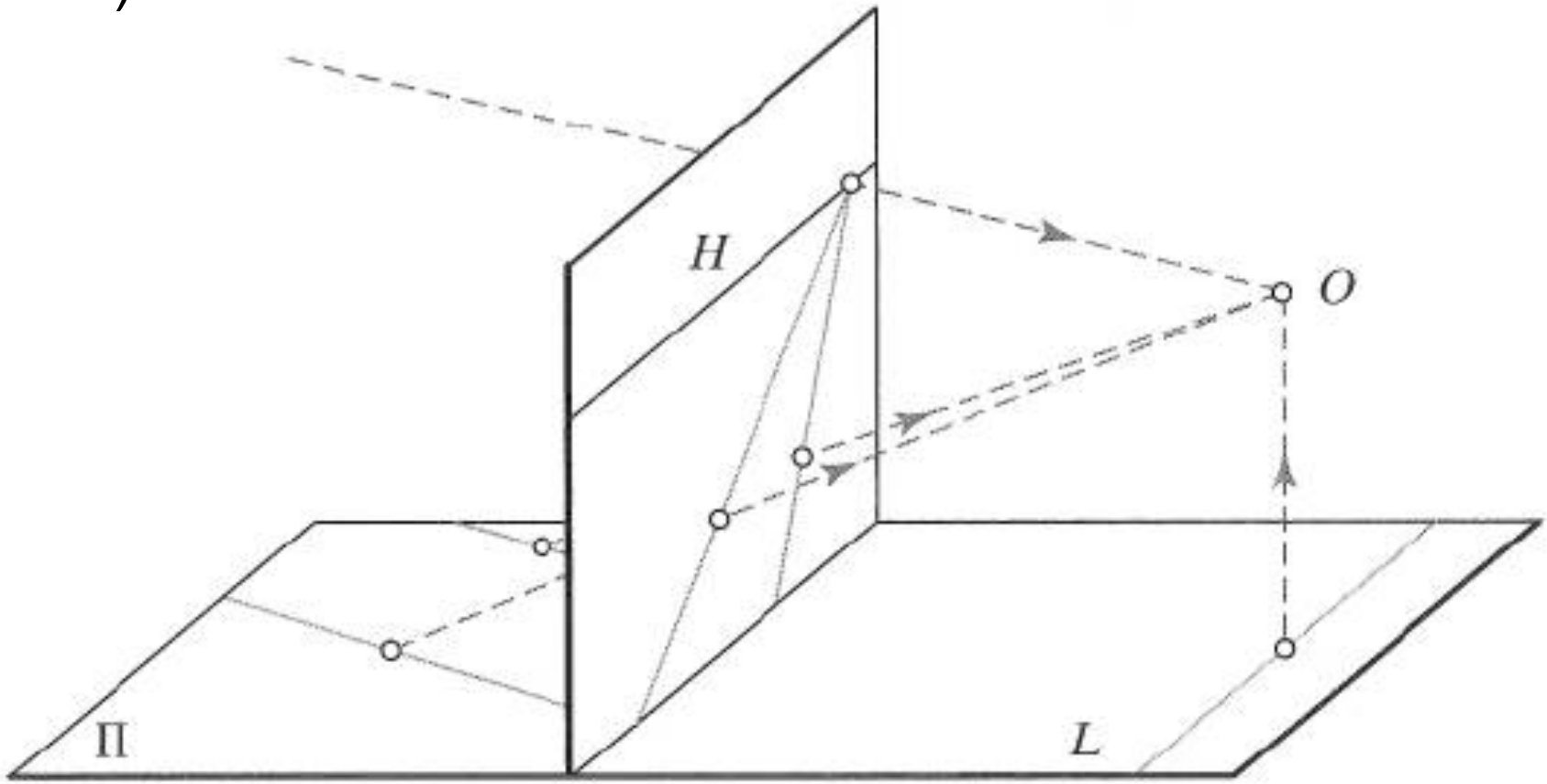
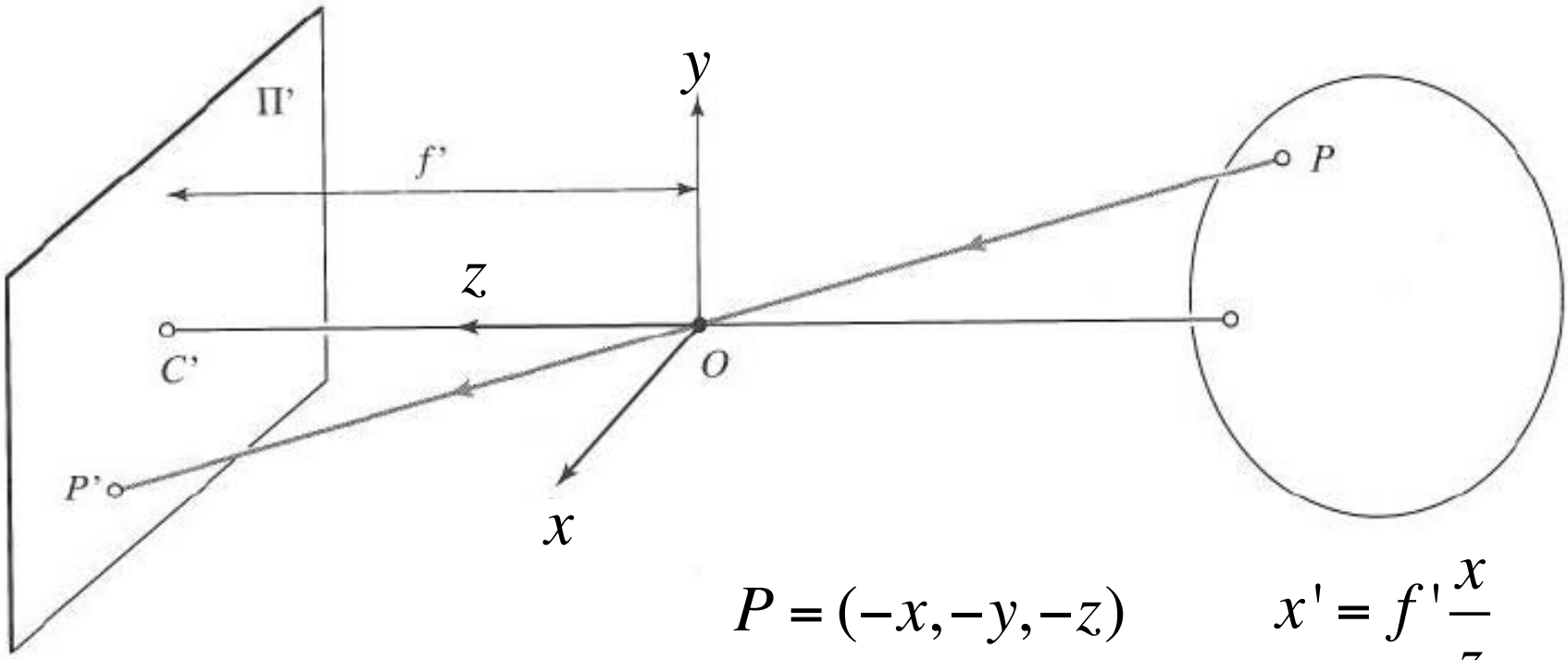


Image formation:
The pinhole camera model



$$P = (-x, -y, -z)$$

$$P' = (x', y', z')$$

$$C' = (0, 0, f')$$

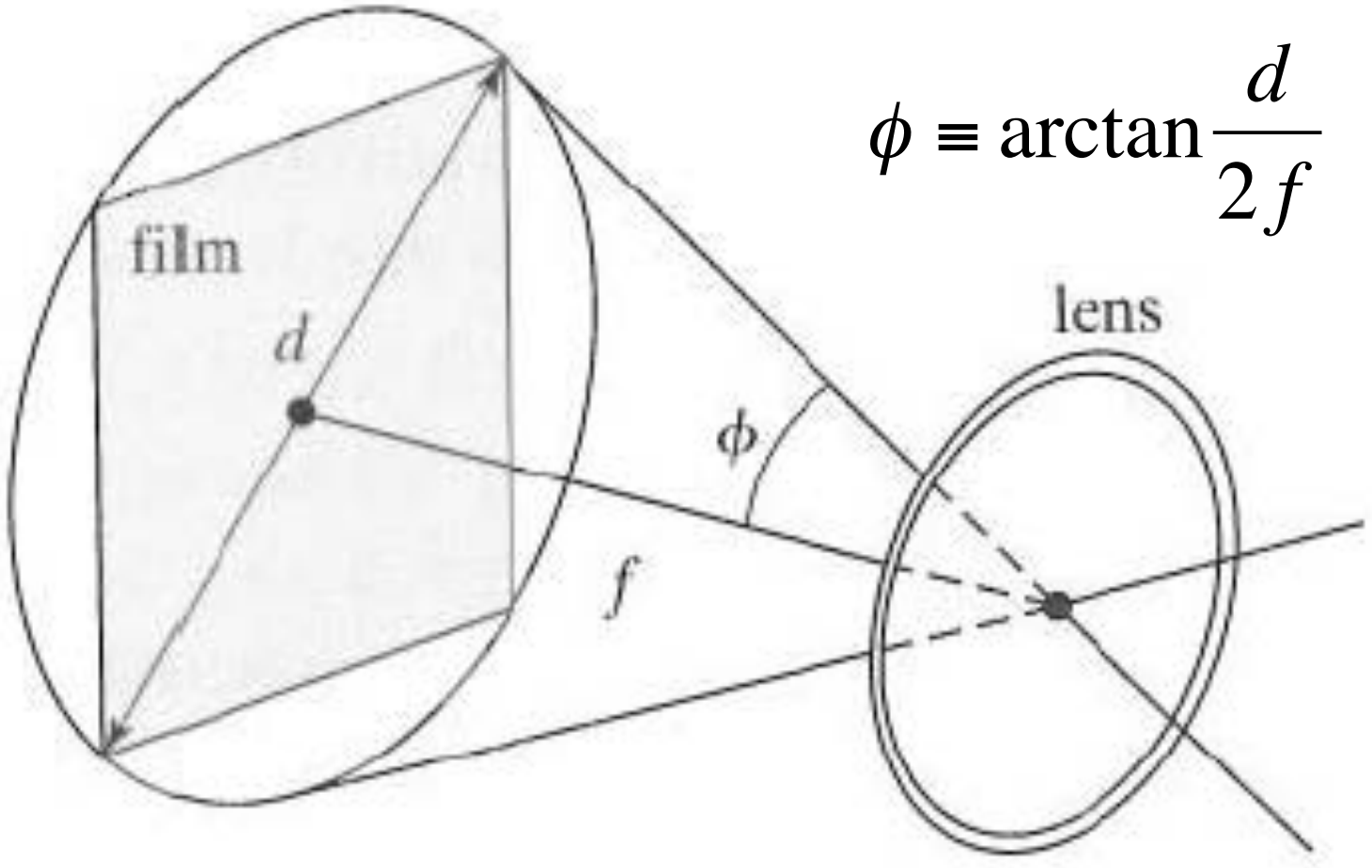
$$x' = f' \frac{x}{z}$$

$$y' = f' \frac{y}{z}$$

$$z' = f'$$

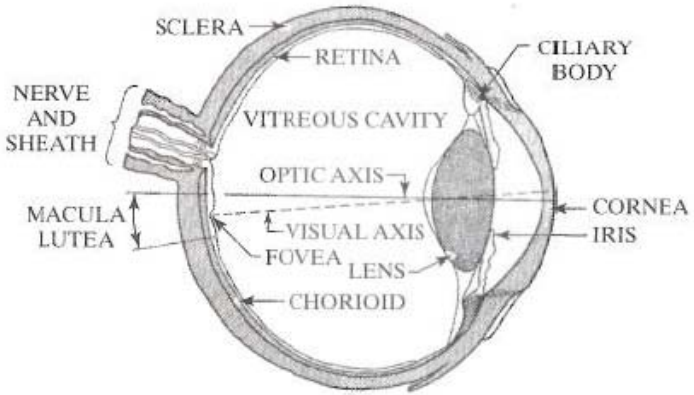
O : optical center / pinhole
k : optical axis
C' : image center
f' : focal length

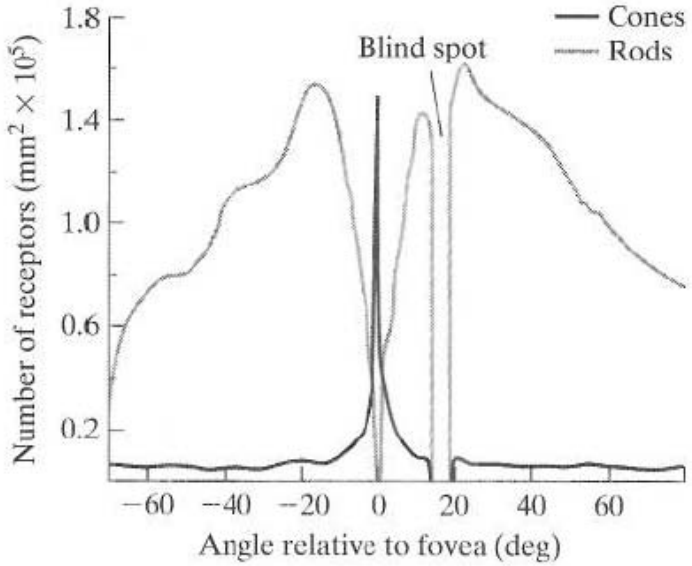
Image formation:
Field of view of the camera is 2ϕ



$$\phi \equiv \arctan\frac{d}{2f}$$

Image formation: The human eye





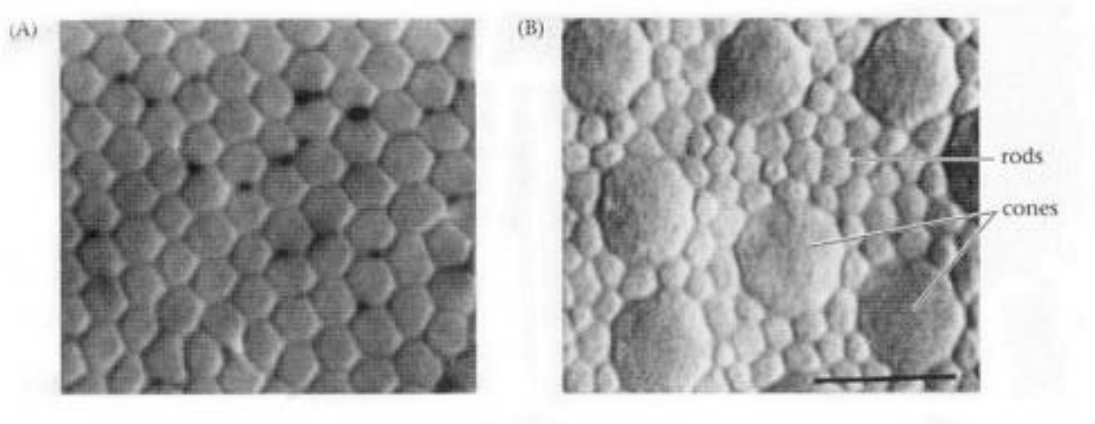
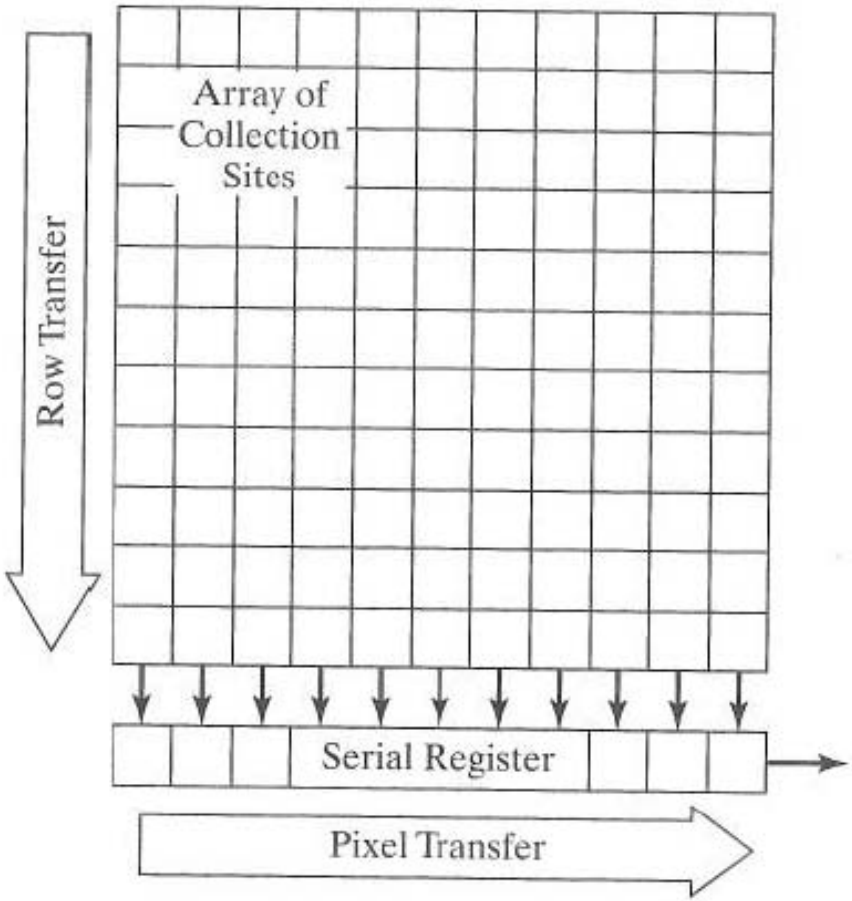
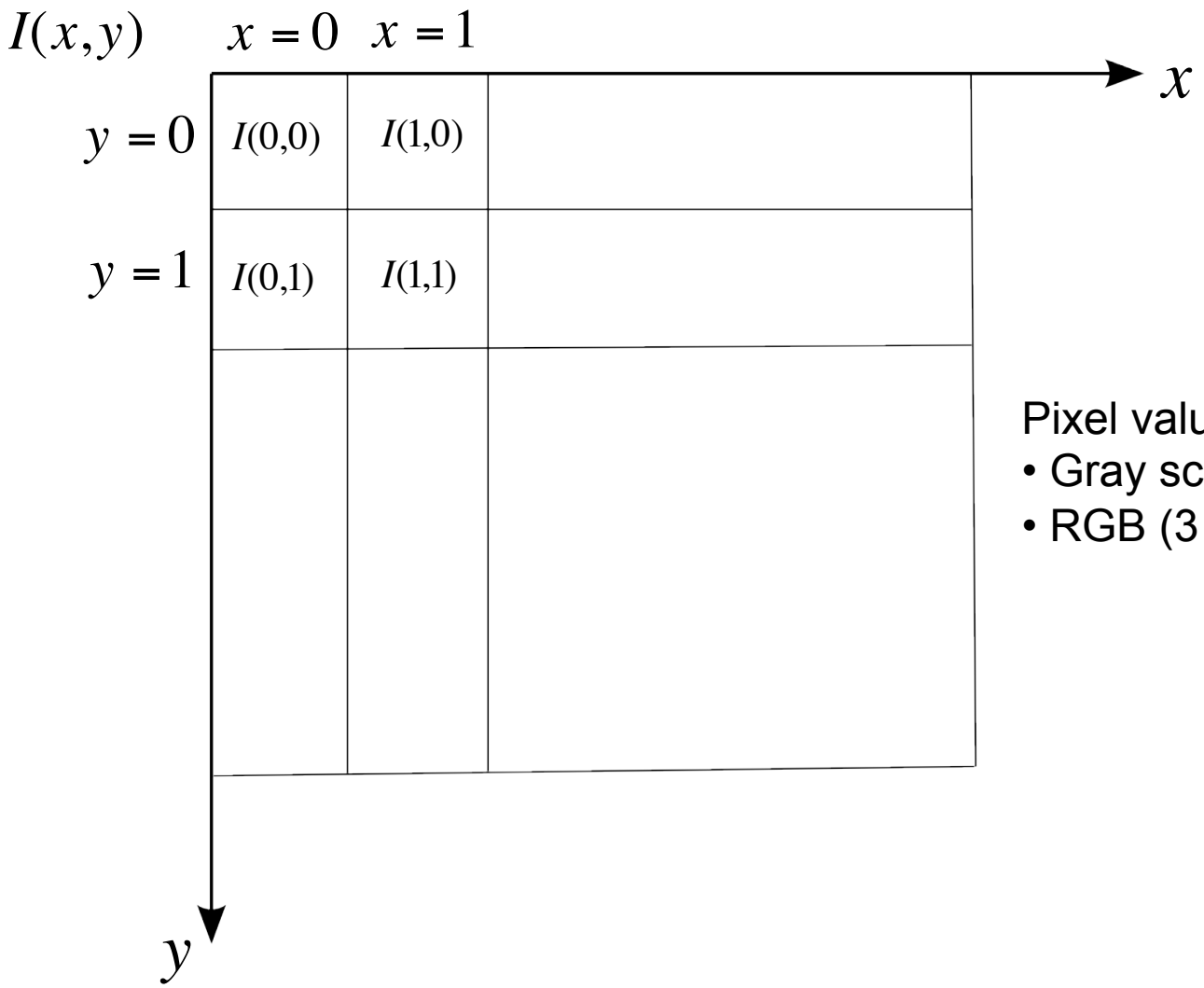


Image formation:
The digital camera



- Most cameras use charge coupled device (CCD) chip

Image representation: An array of pixels



Pixel values:
- Gray scale (1 integer)
- RGB (3 integers vector)

Image representation:
An array of pixels (picture elements)

R:255 G:213 B:227	R:255 G:170 B:194	R:255 G:162 B:181	R:255 G:159 B:172	R:255 G:143 B:159	R:255 G:138 B:151	R:255 G:121 B:132	R:255 G:113 B:121	R:255 G:102 B:108	R:255 G: 99 B:109
R:255 G:190 B:206	R:255 G:162 B:181	R:255 G:160 B:174	R:255 G:148 B:159	R:255 G:134 B:146	R:255 G:126 B:136	R:255 G:117 B:125	R:255 G:114 B:117	R:255 G:100 B:102	R:255 G: 89 B: 89
R:255 G:187 B:203	R:255 G:158 B:177	R:255 G:148 B:162	R:255 G:144 B:155	R:255 G:134 B:146	R:255 G:121 B:131	R:255 G:108 B:116	R:255 G:103 B:106	R:255 G: 91 B: 93	R:255 G: 86 B: 86
R:255 G:165 B:180	R:255 G:139 B:154	R:255 G:126 B:142	R:255 G:125 B:139	R:255 G:128 B:138	R:255 G:116 B:124	R:255 G:109 B:111	R:255 G: 98 B: 95	R:255 G: 84 B: 76	R:255 G: 84 B: 75
R:255 G:148 B:163	R:255 G:130 B:145	R:255 G:116 B:132	R:255 G:114 B:128	R:255 G:124 B:134	R:255 G:112 B:120	R:255 G:107 B:109	R:255 G: 96 B: 93	R:255 G: 87 B: 79	R:255 G: 85 B: 76
R:255 G:131 B:147	R:255 G:121 B:134	R:255 G:111 B:125	R:255 G:114 B:126	R:255 G:113 B:123	R:255 G:110 B:108	R:255 G:104 B: 97	R:255 G: 87 B: 77	R:255 G: 83 B: 76	R:255 G: 82 B: 78
R:255 G:129 B:145	R:255 G:119 B:132	R:255 G:113 B:127	R:255 G:112 B:124	R:255 G:108 B:118	R:255 G:103 B:101	R:255 G: 94 B: 87	R:255 G: 85 B: 75	R:255 G: 84 B: 77	R:255 G: 77 B: 73

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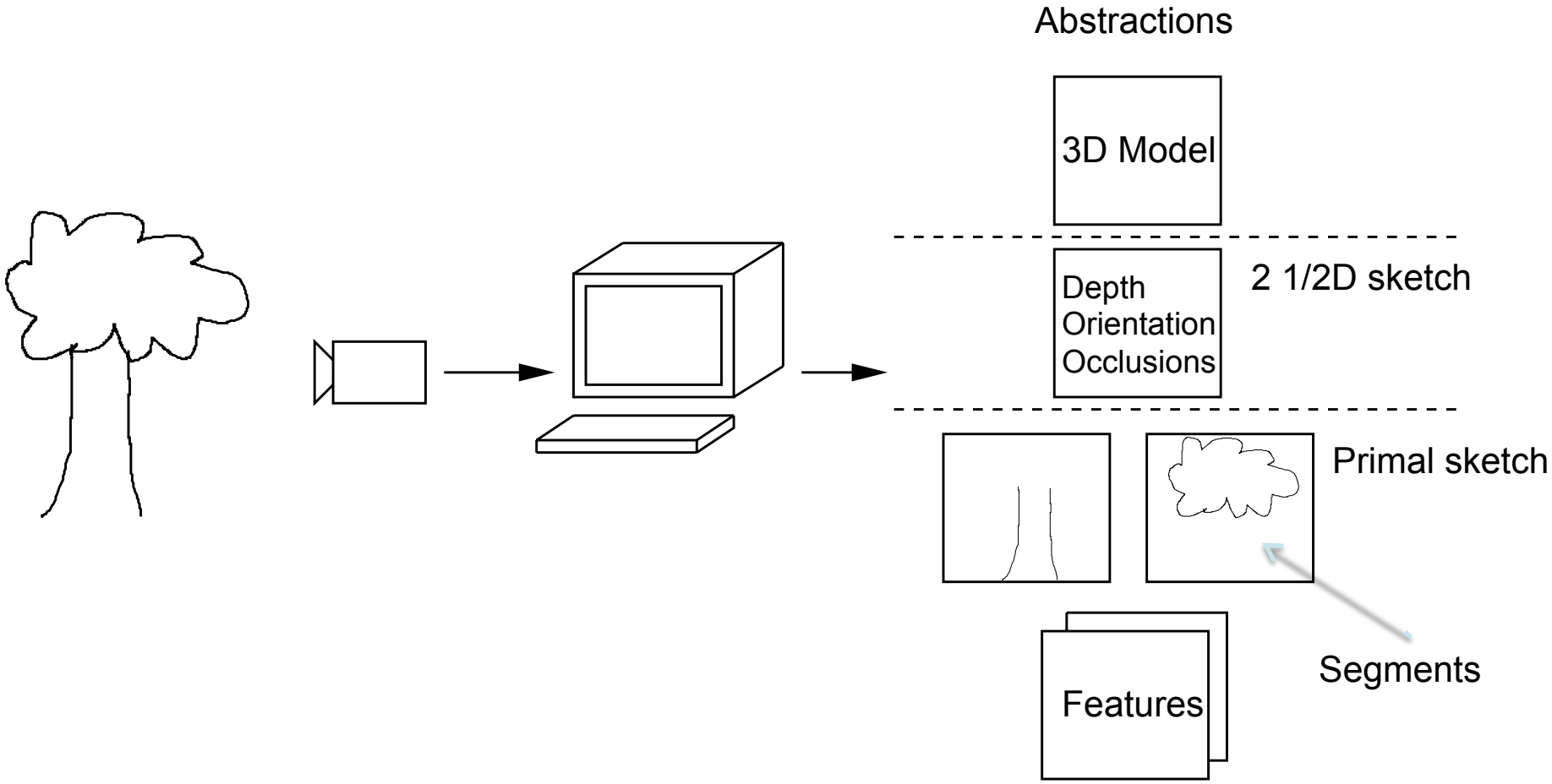
:100 23 15	R: 98 G: 23 B: 17	R: 98 G: 23 B: 17	R:101 G: 24 B: 18	R:102 G: 25 B: 19	R: 98 G: 25 B: 19	R: 98 G: 25 B: 19	R: 97 G: 24 B: 18	R: 98 G: 25 B: 19	R: 97 G: 26 B: 20	R: 98 G: 27 B: 21

A bunch of numbers in a table is not enough!

Image representation: Marr's layers of abstraction



Color, Shading and Shadows also concerns us

(a)

(b)

(c)

(d)

We need to refine this hierarchy of abstractions!

That is the topic of this course

Mandatory assignment 1: Feature extraction

- Build and experiment with interest point detectors
- Find matching points between two images

Summary

- Examples of computer vision problems
- Image formation:
  - Pinhole camera model
  - We skip models for lenses
  - The human eye is a “camera”
- Image representation:
  - At the bottom: Digital images as an array of pixels
  - Marr’s layers of abstraction

Literature

Reading material:

- Forsyth and Ponce: Ch. 1

Additional material:

- David Marr: Vision. W. H. Freeman & Company, 1982