# Computer Vision in Robotics

## EE366/CE366/CS380: Introduction to Robotics

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2 Field of Computer Vision

3 Big picture of vision in this class

4 Image Formation

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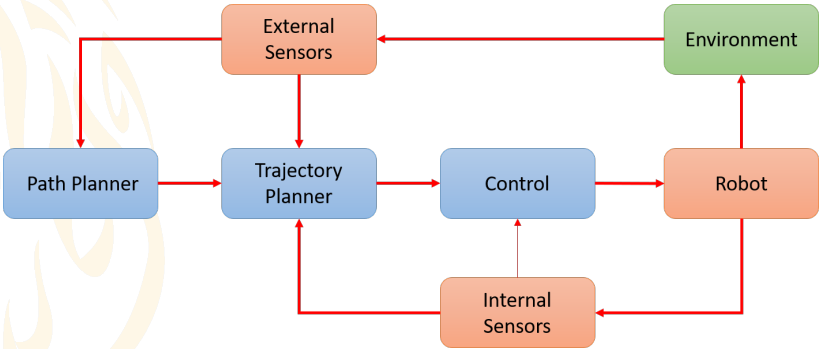
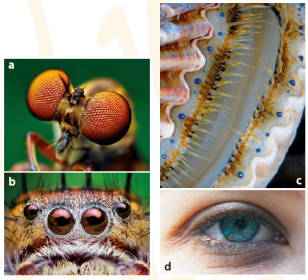
# Overview of a robot



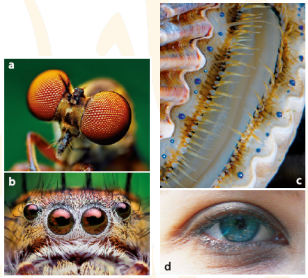
# Why Vision?




- Vision problems are notoriously hard. They're inverse problems.
- Evolution has not only preserved the eye, but most animals have more than one despite biological cost.
  - Almost one-third of brain is used for vision.

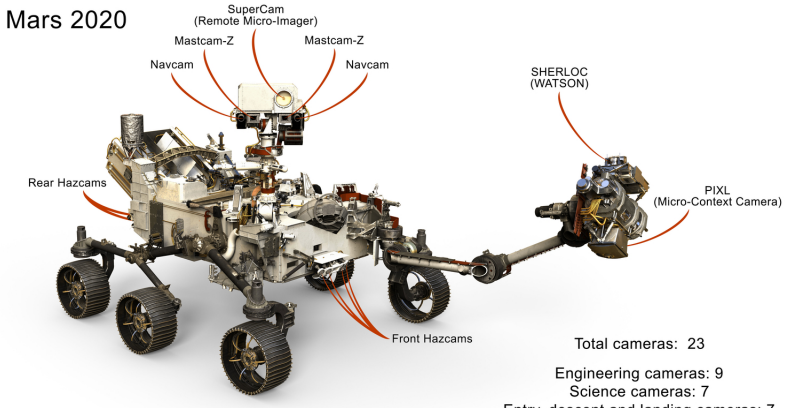
**Development of the eye.** It is believed that all animal eyes share a common ancestor in a proto-eye that evolved 540 million years ago. However major evolutionary advances seem to have occurred in just the last few million years. The very earliest eyes, called eyespots, were simple patches of photoreceptor protein in single-celled animals. Multi-celled animals evolved multi-cellular eyespots which could sense the brightness of light but not its direction. Gradually the eyespot evolved into a shallow cup shape which gave a limited ability to discriminate directional brightness according to which cells were illuminated. The pit deepened, the opening became smaller, and the number of photoreceptor cells increased, forming a pin-hole camera that was capable of distinguishing shapes. Next came an overgrowth of transparent cells to protect the eyespot which led to a filled eye chamber and eventually the eye as we know it today. The lensed eye has evolved independently seven different times across species. Nature has evolved ten quite distinct eye designs including those shown above.

# Why Vision?




- Vision provides
  - long-range sensing
  - rich information – shape, color
  - motion
- Eyes very effective for obstacle avoidance, manipulation, recognition, navigation.
- Practical sensor today, because of cheap sensor, new algorithms, accessibility to high computing power.

# Vision is useful!



# Computer Vision - What information can you get?

Figure: Source: Dr. Lazebnik-UIUC

Make computers understand images, videos, or any visual data.

# Computer Vision - What information can you get?

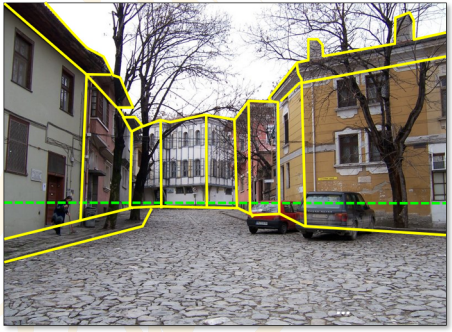


Figure: Source: Dr. Lazebnik-UIUC

Make computers understand images, videos, or any visual data.

- Geometric Information

# Computer Vision - What information can you get?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Make computers understand images, videos, or any visual data.

- Geometric Information
- Semantic Information

# Computer Vision - What information can you get?


Figure: Source: Dr. Lazebnik-UIUC

Make computers understand images, videos, or any visual data.

- Geometric Information
- Semantic Information
- Affordances

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# A timeline of Computer Vision

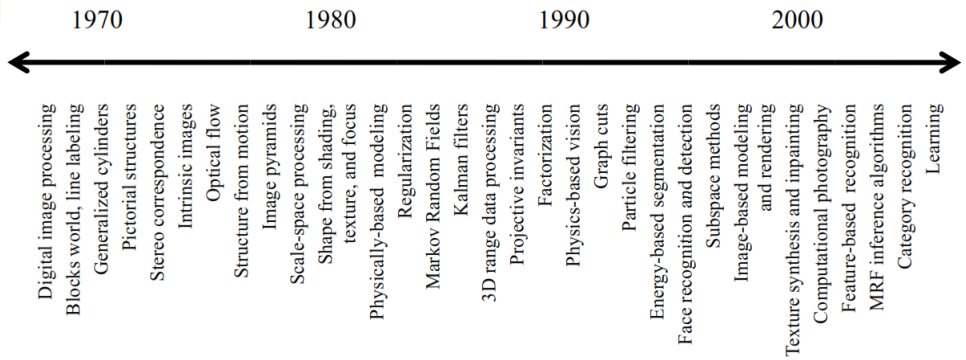
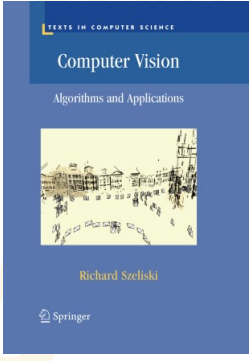
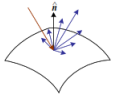



Figure: Brief history of computer vision. Source: [2]

# We'll look at some topics in pre-historic computer vision.

# Even pre-historic computer vision is vast. [2]



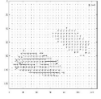


2. Image Formation

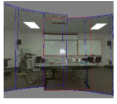

3. Image Processing

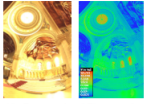

4. Features


5. Segmentation


6-7. Structure from Motion

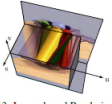

8. Motion


9. Stitching

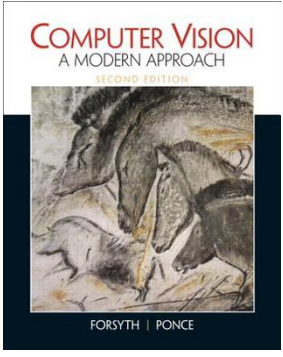

10. Computational Photography


11. Stereo

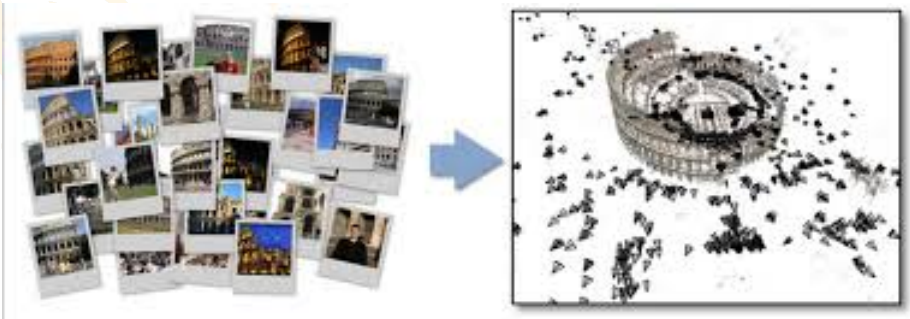

12. 3D Shape


13. Image-based Rendering


14. Recognition



# 3D Reconstruction



- Project Page: `https://grail.cs.washington.edu/projects/sq_rome_g1/`
- YouTube: `https://youtu.be/NdeD4cjLI0c`

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# How does the robot know where the box is?

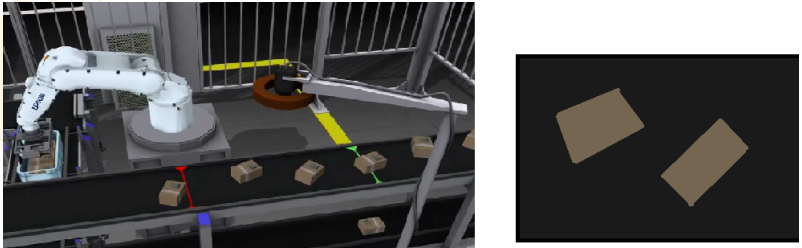

Figure: Left: Pick and place robot; Right: Image from camera

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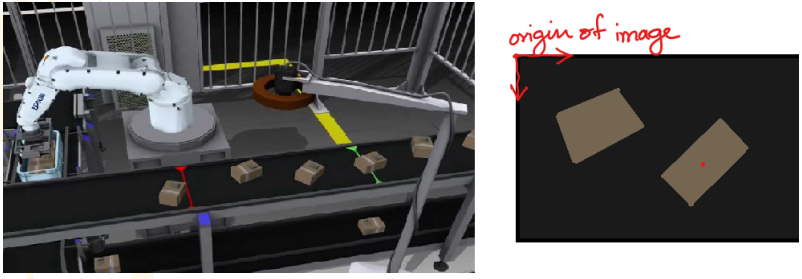


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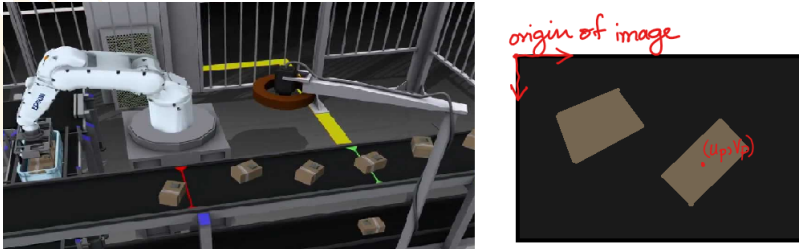


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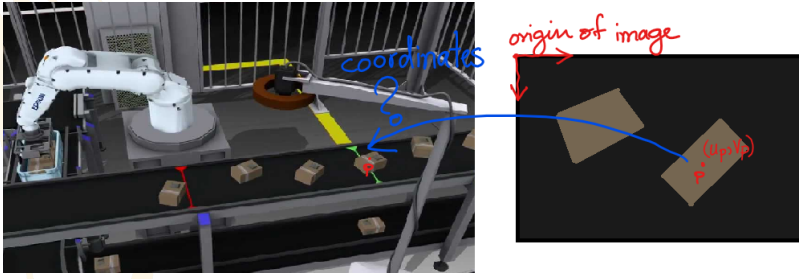


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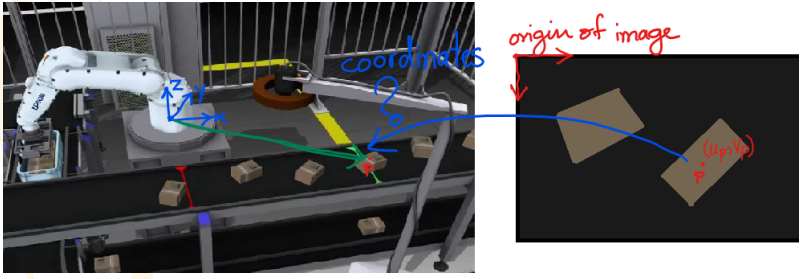
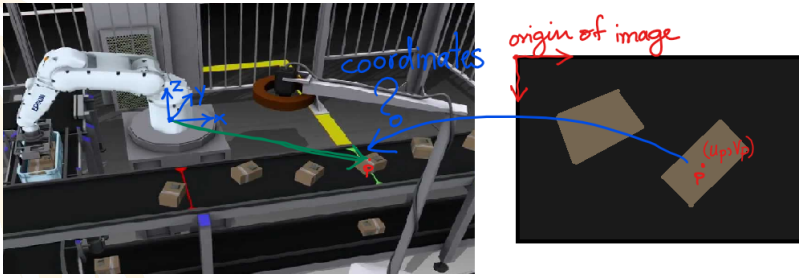



Figure: Left: Pick and place robot; Right: Image from camera

# We need to understand geometry of image formation.




- What is the relationship between image plane and real world?
  - Is it even possible to determine these coordinates?
- How do you choose point $p$ identifying box in image, automatically?
  - Does computer understand color?
  - How do we distinguish between different colored objects?

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# We'll be unable to study all parts. [1]

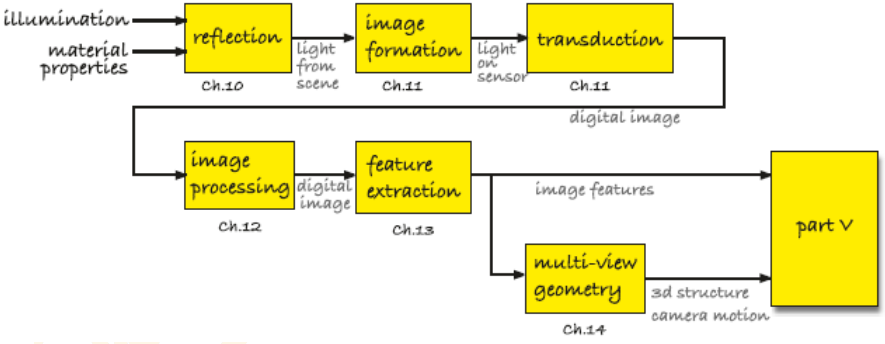


Fig. IV.3.
Steps involved in image processing

Figure: Source: Robotics, Vision, and Control – Peter Corke

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[1] **Peter I Corke and Oussama Khatib.**
**Robotics, vision and control: fundamental algorithms in MATLAB, volume 73.**
**Springer, 2011.**

**[2] Richard Szeliski.**
**Computer vision: algorithms and applications.**
**Springer Science & Business Media, 2010.**