Introduction
Vision

- “to know what is where, by looking.” (Marr).
- Where
- What
What is Computer Vision?

• *Vision* is about discovering from images what is present in the scene and where it is.

• In *Computer Vision* a camera (or several cameras) is linked to a computer. The computer interprets images of a real scene to obtain information useful for tasks such as navigation, manipulation and recognition.
Applications

- Intelligent machines (AI)
- Industrial inspection
e.g. light bulbs, electronic circuits
- Automotive
e.g. Ford, GM, DARPA Grand Challenge
- Security
e.g. facial recognition in airports
- Toys (Aibo dog)
- Image/video retrieval

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Computer Vision

- Digital cameras are everywhere now….
Vision is inferential: Light

Checker-shadow illusion:
The squares marked A and B are the same shade of gray.

(http://www-bcs.mit.edu/people/adelson/checkershadow_illusion.html)
Vision is Inferential: Prior Knowledge
Computer Vision

- Inference $\rightarrow$ Computation
- Building machines that see
- Modeling biological perception
The Human Eye

- Retina measures about $5 \times 5$ cm and contains $10^8$ sampling elements (rods and cones).
- The eye's spatial resolution is about 0.01° over a 150° field of view (not evenly spaced, there is a fovea and a peripheral region).
- Intensity resolution is about 11 bits/element, spectral range is 400–700nm.
- Temporal resolution is about 100 ms (10 Hz).
- Two eyes give a data rate of about 3 GB/s!
Human visual system

- Vision is the most powerful of our own senses.
- Around 1/3 of our brain is devoted to processing the signals from our eyes.
- The visual cortex has around $O(10^{11})$ neurons.

[Thorpe et. al.]
Why is Vision “Interesting”?

• Psychology
  – ~ 35% of cerebral cortex is for vision.
  – Vision is how we experience the world.
• Engineering
  – Want machines to interact with world.
  – Digital images are everywhere.
Computer Vision: A whole series of problems

- What is in the image?
  - Object recognition problem
- Where is it?
  - 3D spatial layout
  - Shape
- How is the camera moving?
- What is the action?
A Quick Tour of Computer Vision
Boundary Detection

http://www.robots.ox.ac.uk/~vdg/dynamics.html
Boundary Detection

Finding the Corpus Callosum

(G. Hamarneh, T. McInerney, D. Terzopoulos)
Tracking
Tracking
Tracking
Tracking
Tracking

AVERAGE QUEUE LENGTH - SITE1, JULY 2001

Queue 1

Queue 2

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Computer Vision
Application: Assisted driving

Pedestrian and car detection

Lane detection

• Collision warning systems with adaptive cruise control,
• Lane departure warning systems,
• Rear object detection systems,
Stereo
Stereo

http://www.magiceye.com/
Motion

Motion - Application

(www.realviz.com)
Pose Determination

Visually guided surgery

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Computer Vision

January 2004
Recognition - Shading

Lighting affects appearance
Classification

3D Model Search Engine

Keywords:

Find similar shape
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Computer Vision
January 2004
(Funkhauser, Min, Kazhdan, Chen, Halderman, Dobkin, Jacobs)
Application: Improving online search

Query: STREET

Organizing photo collections
Vision depends on:

- Geometry
- Physics
- The nature of objects in the world (This is the hardest part).
Approaches to Vision
Modeling + Algorithms

- Build a simple model of the world (eg., flat, uniform intensity).
- Find provably good algorithms.
- Experiment on real world.
- Update model.

*Problem*: Too often models are simplistic or intractable.
Bayesian inference

• Bayes law: \( P(A|B) = P(B|A) \cdot P(A)/P(B) \).
• \( P(\text{world}|\text{image}) = P(\text{image}|\text{world}) \cdot P(\text{world})/P(\text{image}) \)
• \( P(\text{image}|\text{world}) \) is computer graphics
  – Geometry of projection.
  – Physics of light and reflection.
• \( P(\text{world}) \) means modeling objects in world.
  Leads to statistical/learning approaches.

Problem: Too often probabilities can’t be known and are invented.
Engineering

• Focus on definite tasks with clear requirements.
• Try ideas based on theory and get experience about what works.
• Try to build reusable modules.

Problem: Solutions that work under specific conditions may not generalize.
The State of Computer Vision

• Science
  – Study of intelligence seems to be hard.
  – Some interesting fundamental theory about specific problems.
  – Limited insight into how these interact.
Related Fields

- Graphics. “Vision is inverse graphics”.
- Visual perception.
- Neuroscience.
- AI
- Learning
- Math: eg., geometry, stochastic processes.
- Optimization.