CS231A

Computer Vision:

From 3D Reconstruction to Recognition

Class Time

M-W; 11:30—12:50PM

CS231A

Instructors

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- Office hour: Friday 2-3pm or by appointment

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- Office hour: Friday 1-2pm or by appointment

CAs:

- Andrey Kurenkov, Kuan Fang, Brent Yi, Krishnan Srinivasan

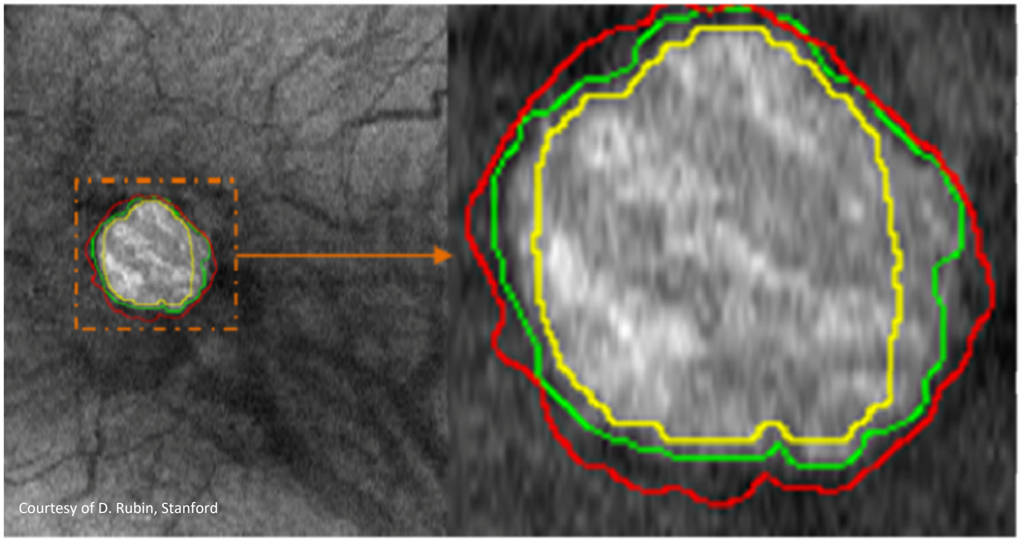
Lecture 1
Introduction

- An introduction to computer vision
- Course overview

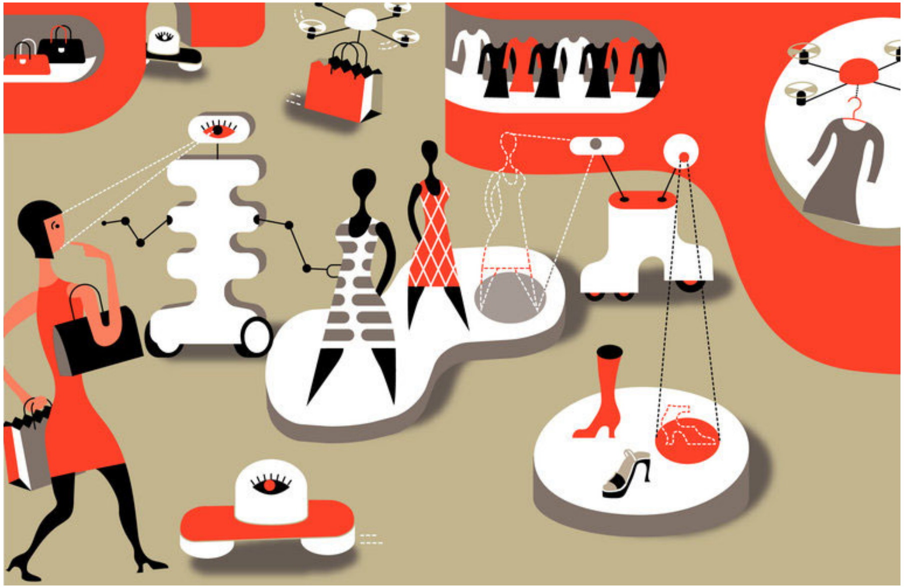
AI is a propelling force of today's technology

Smart Agriculture

Health care



Retail



From Imagining the Retail Store of the Future - The New York Times, April 12, 2017

Manufacturing

Courtesy of ITRI, 2017

Transportation and Logistics

Construction Management

Why is this acceleration happening now?

Enabling factors

- Big data

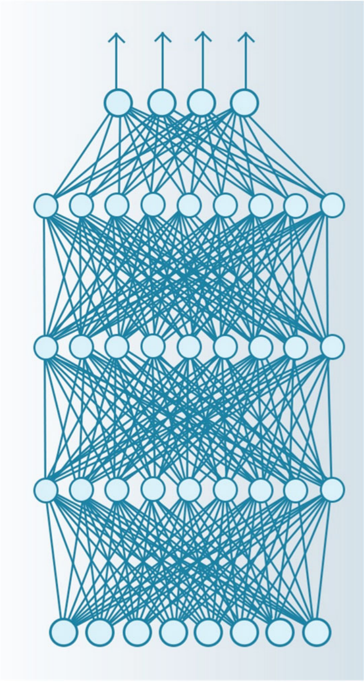
ImageNet, 2009
ShapeNet, 2015

Enabling factors

- Big data
- Faster hardware

Enabling factors

- Big data
- Faster hardware
- New algorithms
  - Representation learning
  - Neural networks
  - Inject learning to deterministic reasoning



Computer vision

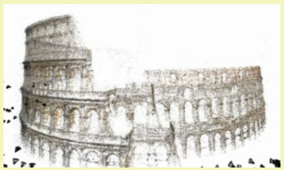
Sensing device

Computational device

- **Information extraction**
- **Interpretation**

1. **Information extraction:** features, 3D structure, motion flows, etc…
2. **Interpretation:** recognize objects, scenes, actions, events

Major areas in Computer Vision



Space/Geometry

- Object shape recovery
- Depth estimation
- 3D scene reconstruction

Semantics/Learning

- Object detection and pose estimation
- Object tracking
- Scene understanding

Major areas in Computer Vision

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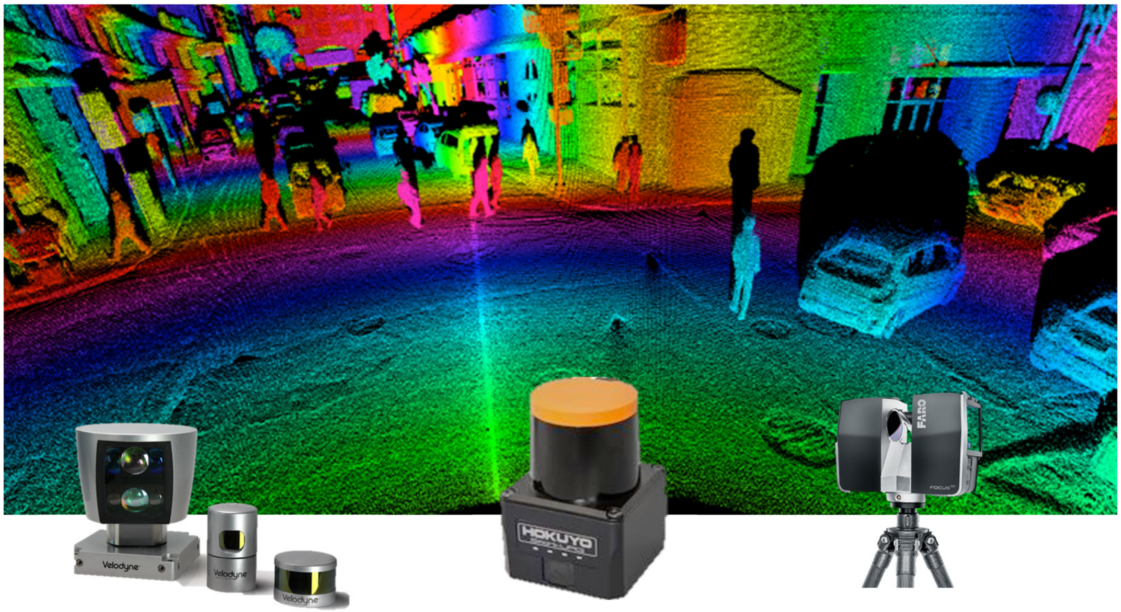
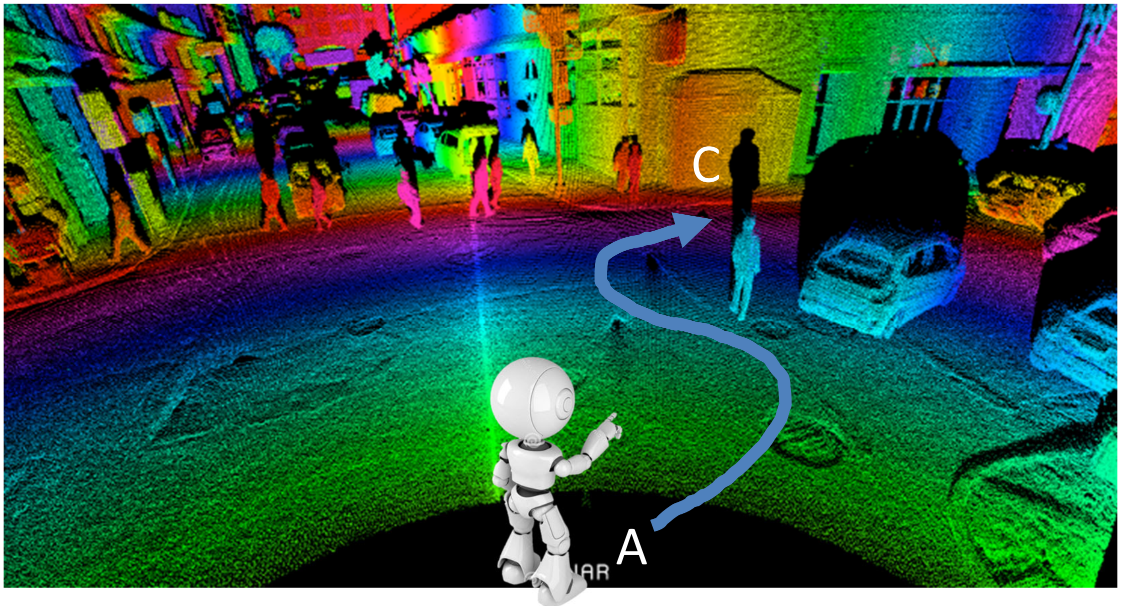
Recovering 3D models of the environments

Armeni et al. 2016

Recovering 3D models of the environments



This is critical for autonomous driving or navigation!



Major areas in Computer Vision

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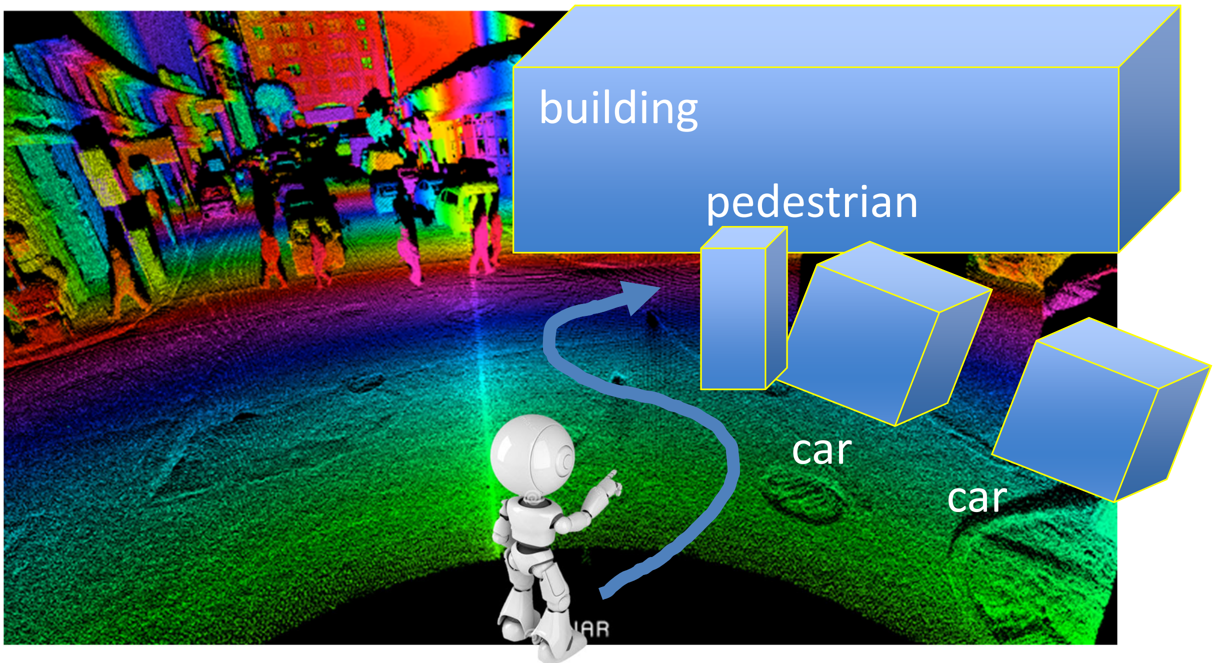
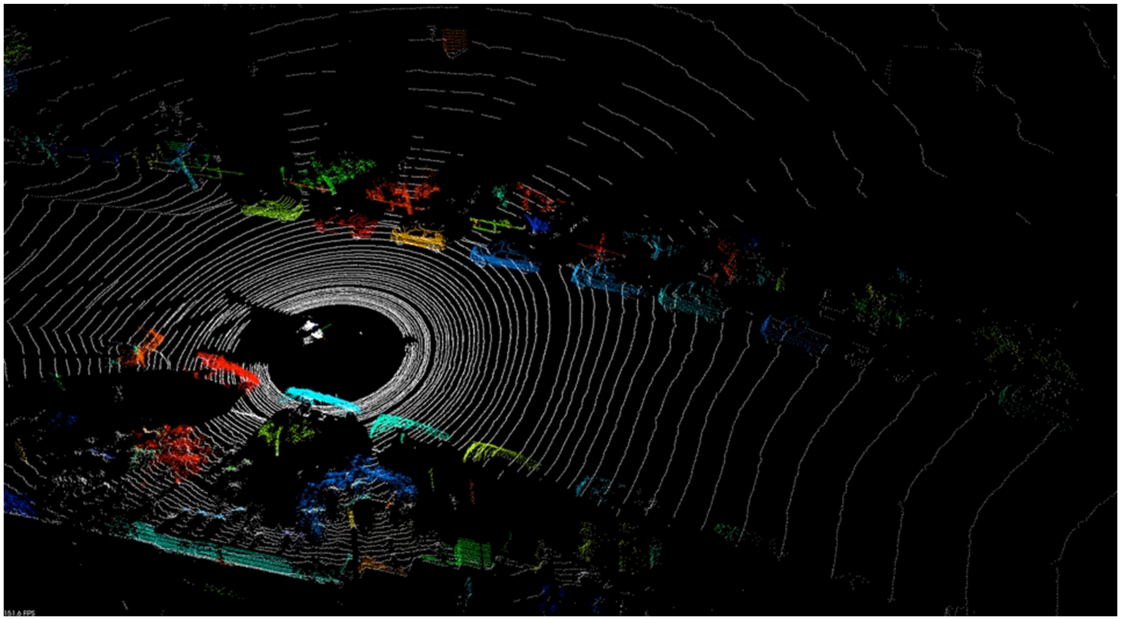
Detecting and tracking objects in the environments



3D Scene Parsing

Held, Thrun, Savarese, 2016-206



Major areas in Computer Vision

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CS 231A course overview

1. Space/Geometry

   Estimating spatial properties of objects and scene from images through geometrical methods

2. Semantics/Learning

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Camera systems

Establish a mapping from 3D to 2D

How to calibrate a camera

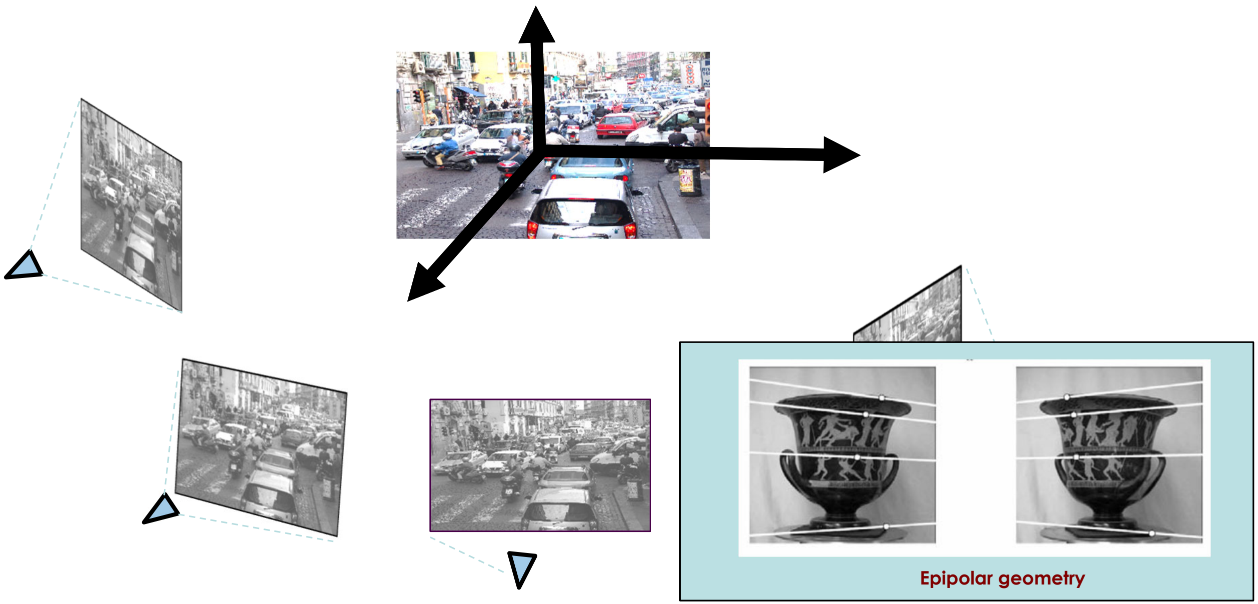
Estimate camera parameters such pose or focal length

Single view metrology

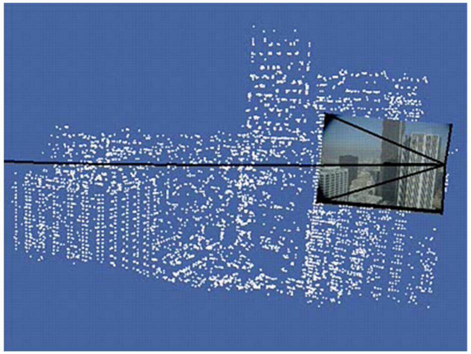
Estimate 3D properties of the world from a single image

Multiple view geometry

Estimate 3D properties of the world from multiple views

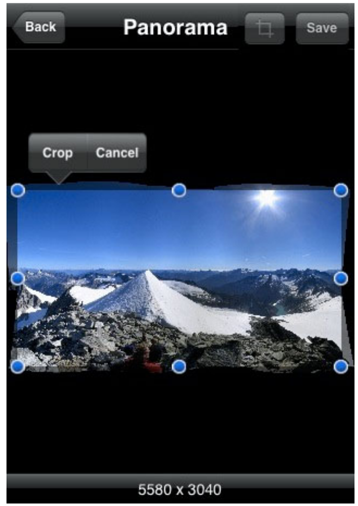


Structure from motion



Courtesy of Oxford **Visual Geometry Group**

Panoramic Photography

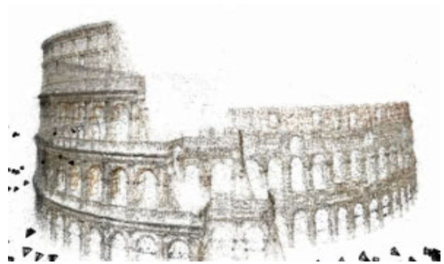


Cloudburst RESEARCH

HumanEyes
Print Out of the Box

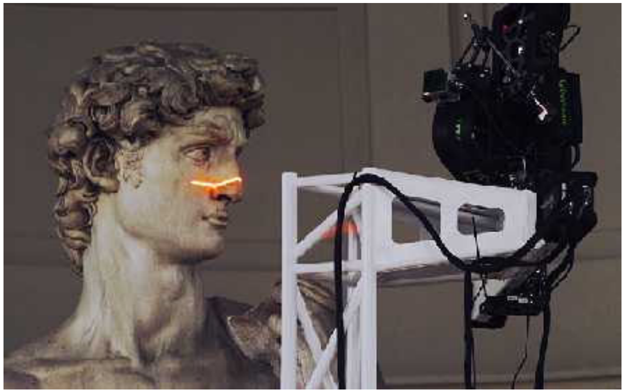
kolor

3D Modeling of landmarks



Microsoft® Photosynth™

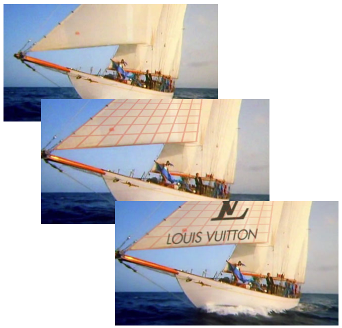
Accurate 3D Object Prototyping



Scanning Michelangelo's *"The David"*

- The Digital Michelangelo Project
  - http://graphics.stanford.edu/projects/mich/
- 2 BILLION polygons, accuracy to .29mm

Augmented Reality



Mirriad
Advertising for the Skip Generation

AUGMENT

- Magic leap
- Daqri
- Meta
- Etc…

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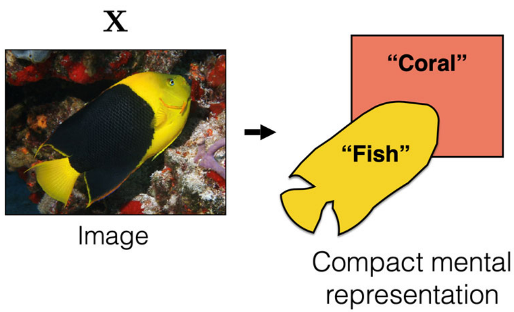
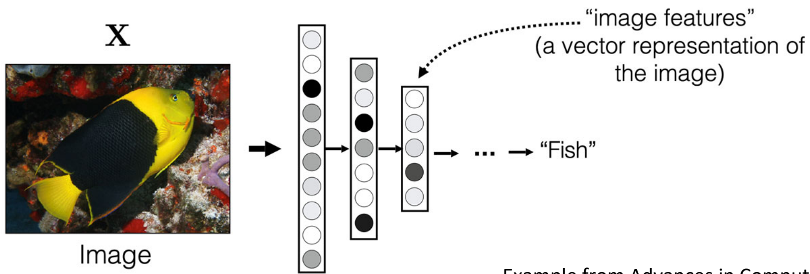
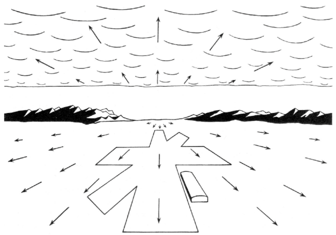
Representations and Representation Learning



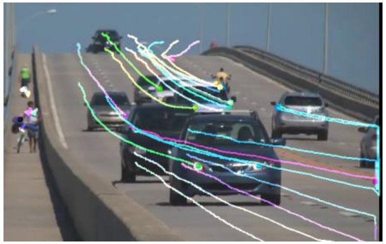


Example from Advances in Computer Vision – MIT – 6.869/6.819

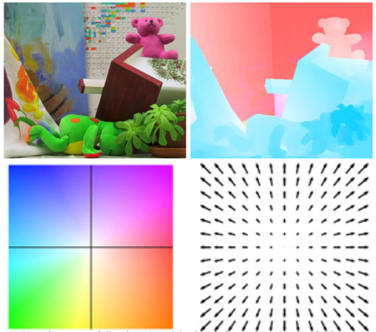
Feature Tracking and Flow



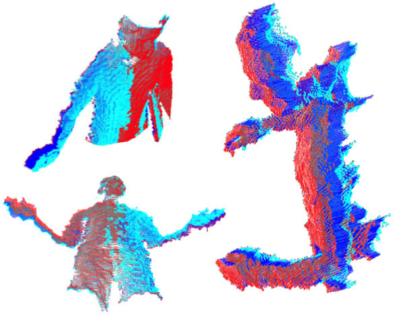
J. J. Gibson, The Ecological Approach to Visual Perception



Lucas-Kanade Feature Tracking over multiple frames. Picture adopted from OpenCV Webpage.

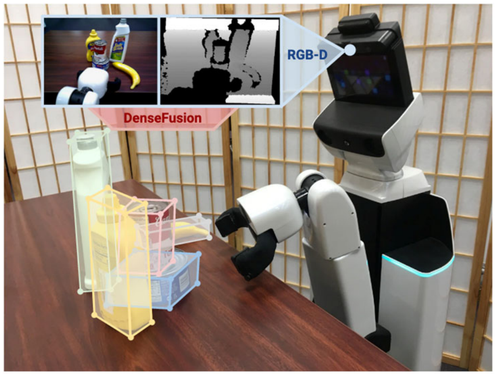


A Database and Evaluation Methodology for Optical Flow. Baker et al. IJCV. 2011



A Primal-Dual Framework for Real-Time Dense RGB-D Scene Flow. Jaimez at al. ICRA, 2015.

Object Pose Estimation and Tracking



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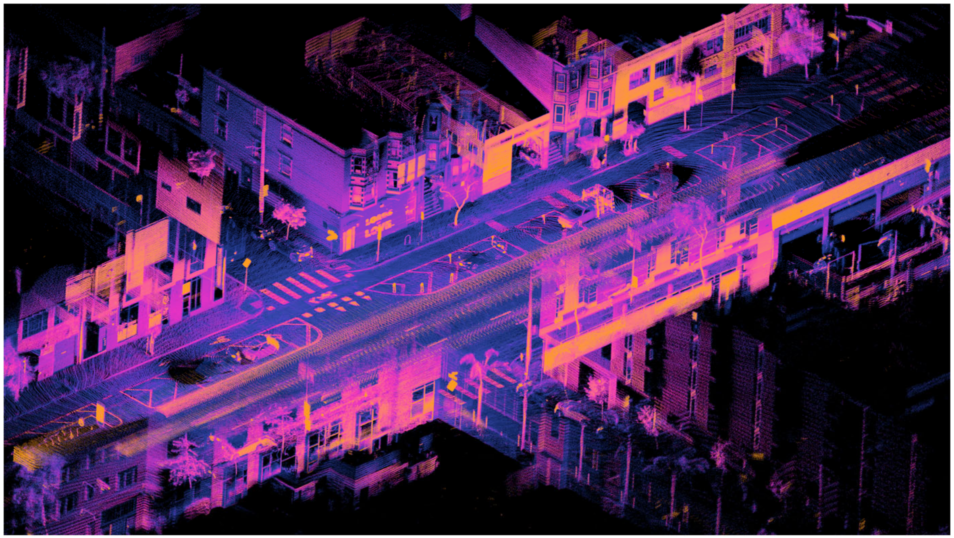
SLAM and Localization



Accumulated registered point cloud from lidar SLAM.

Autonomous navigation and safety

[Mobileye](): Vision systems in high-end BMW, GM, Volvo models

But also, Toyota, Google, Apple, Tesla, Nissan, Ford, etc….

Source: A. Shashua, S. Seitz

Personal robotics

jibo

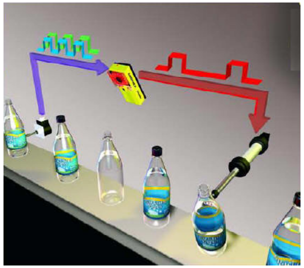
FIVE ELEMENTS ROBOTICS

a

ECOVACS

BLUE FROG robotics

More Applications



Factory inspection

Assistive technologies

Surveillance

Exploration and remote operations

Syllabus

Lecture	Topic
1	Introduction
2	Camera models
3	Camera calibration
4	Single view metrology
5	Epipolar geometry
6	Multi-view geometry
7	Structure from motion/ SLAM
8	Volumetric stereo
9	Fitting and Matching
10	Low Level Representations
11	Depth Estimation, Low Level Tracking
12	Optical and Scene Flow
13	6D pose Estimation, Object Tracking
14	Object Tracking Continued
15	SLAM
16	Guest

Project presentations

January

February

March

Geometry

Learning

Proposal due

Mid term

Final projects

Prerequisites

- This course requires knowledge of linear algebra, probability, statistics, machine learning and computer vision, as well as decent programming skills.
- Though not an absolute requirement, it is encouraged and preferred that you have at least taken either CS221 or CS229 or CS131A or have equivalent knowledge.
- We will leverage concepts from low-level image processing (CS131A) (e.g., linear filters, edge detectors, corner detectors, etc…) and machine learning (CS229) (e.g., **SVM, basic Bayesian inference, clustering**, neural networks, etc…) which we won't cover in this class.
- We will provide links to background material related to CS131A and CS229 (or discuss during TA sessions) so students can refresh or study those topics if needed.

Text books

Required:

- [FP] D. A. Forsyth and J. Ponce. *Computer Vision: A Modern Approach* (2nd Edition). Prentice Hall, 2011.
- [HZ] R. Hartley and A. Zisserman. *Multiple View Geometry in Computer Vision*. Academic Press, 2002.

Recommended:

- R. Szeliski. *Computer Vision: Algorithms and Applications*. Springer, 2011.
- D. Hoiem and S. Savarese. *Representations and Techniques for 3D Object Recognition and Scene Interpretation*, Synthesis lecture on Artificial Intelligence and Machine Learning. Morgan Claypool Publishers, 2011
- Learning OpenCV, by Gary Bradski & Adrian Kaehler, O'Reilly Media, 2008.

Course assignments

- 1 warm up problem set (HW-0)
- 4 problem sets
- 1 mid-term exam
- 1 project

- Look up class schedule for release and due dates.
- Problems will be released through the schedule page and must be submitted through Gradescope.

Midterm Exam

- The exam will be on 02/22. It will be released on Canvas and be available for 48 hours. You will have 2 hours to complete it once you start.

- You will be updated with more details, e.g., material to be covered, review sessions etc., as we approach the midterm.

Course Projects

- Replicate an interesting paper
- Comparing different methods to a test bed
- A new approach to an existing problem
- Original research

- Write a 10-page paper summarizing your results
- Release the final code
- Give a final in-class presentation
- SCPD students can send videos instead.

- We will introduce projects in 1-2 weeks
- Important dates: look up class schedule

Course Projects

- Form your team:
  - 1-3 people
  - The larger is the team, the more work we expect from the team
  - Be nice to your partner: do you plan to drop the course?
- Evaluation
  - Quality of the project (including writing)
  - Final project in-class presentation (~ TBA minutes spotlight presentations)

Grading policy

- Homeworks: 37%
  - 1% for HW0
  - 9% for HW1, HW2, HW3, HW4 (each)
- Mid term exam: 20%
- Course project: 38%
  - Project proposal 1%
  - mid term progress report 5%
  - final report 25%
  - presentation 7%
- Attendance and class participation: 5%
  - Questions, answers, remarks, piazza posts,…
  - Class participation are waived for SCPD students. For the project presentation, SCPD students can send videos instead.

Grading policy (HWs)

- 25% will be deducted per day late.
- Two 48-hours one-time late submission "bonuses" are available; that is, you can use this bonus to submit your HW late after at most 48 hours. This is one time deal: After you use all your bonuses, you must adhere to the standard late submission policy.
- No exceptions will be made.

Grading policy (project)

- If 1 day late, 25% off the grade for the project
- If 2 days late, 50% off the grade for the project
- Zero credits if more than 2 days
- No "late submission bonus" is allowed when submitting your progress report or project report

CS231

Introduction to Computer Vision

Next lecture: Camera systems