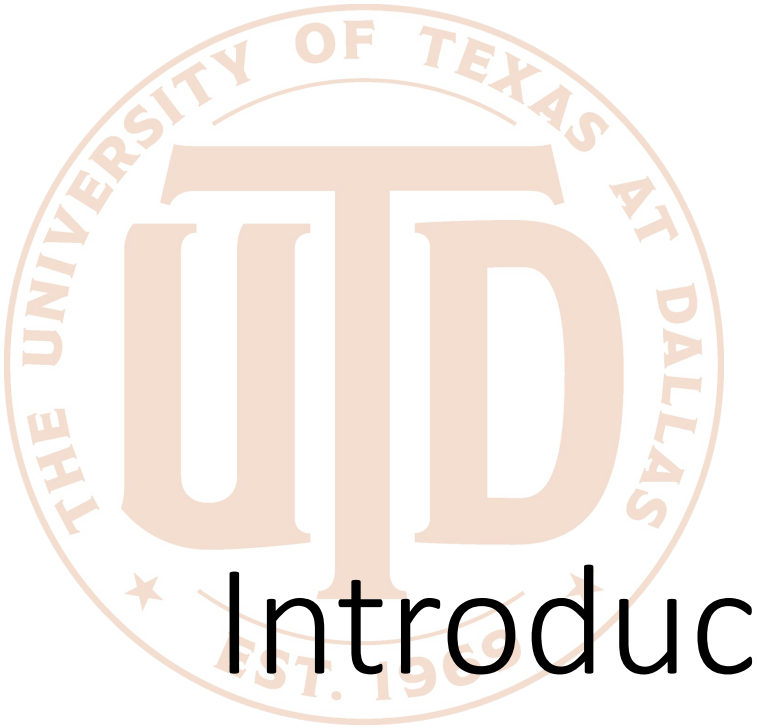


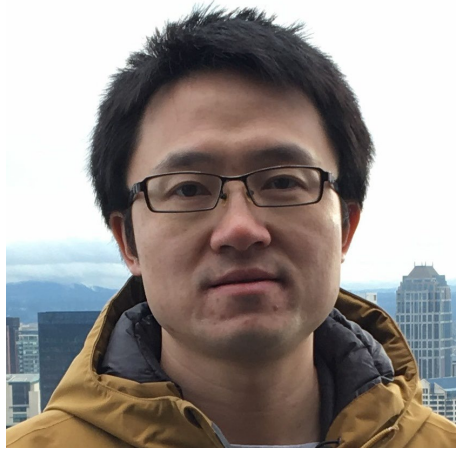
Introduction to Computer Vision

CS 6384 Computer Vision

Professor Yu Xiang

The University of Texas at Dallas

Who am I?

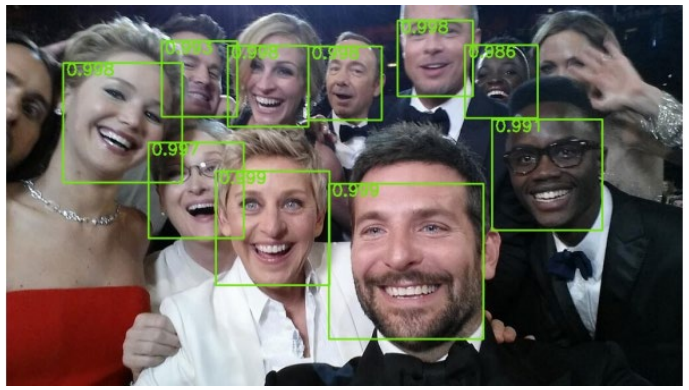


- Assistant Professor in CS at UTD (joined Fall 2021)
  - Research area: robotics and computer vision
- Senior Research Scientist at NVIDIA (2018 – 2021) Robotics
- Postdoc at Stanford, University of Washington, NVIDIA (2016 – 2018)
- Ph.D., Electrical and Computer Engineering, University of Michigan, 2016
- Master, CS, Fudan University, China, 2010
- Bachelor, CS, Fudan University, China, 2007

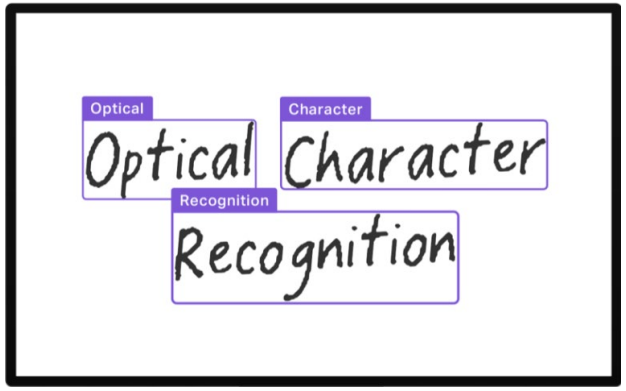
Introduce yourself

- Name
- Major program
- Which year in the program?
- Why are you interested in computer vision?

What is Computer Vision?



Face Detection



Optical Character Recognition (OCR)

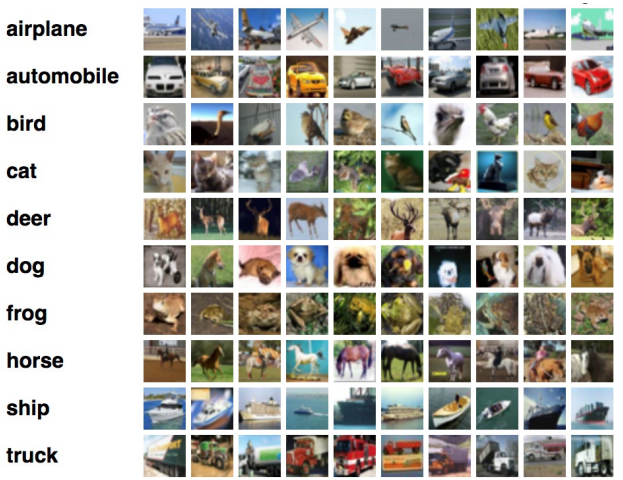
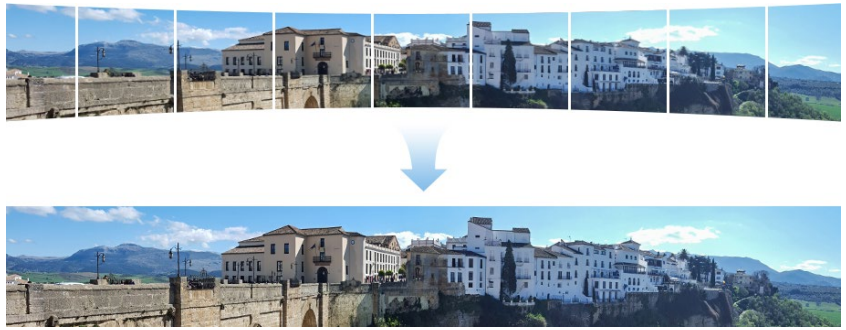
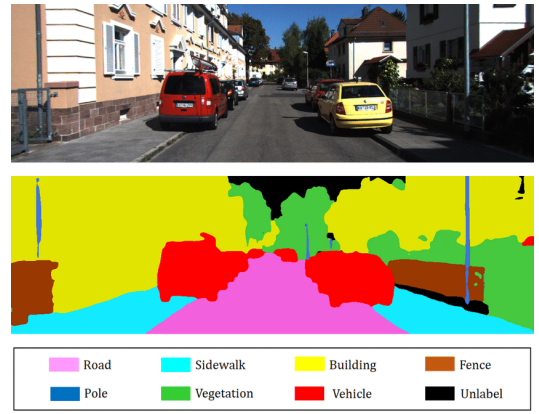


Image Classification



Panorama Stitching

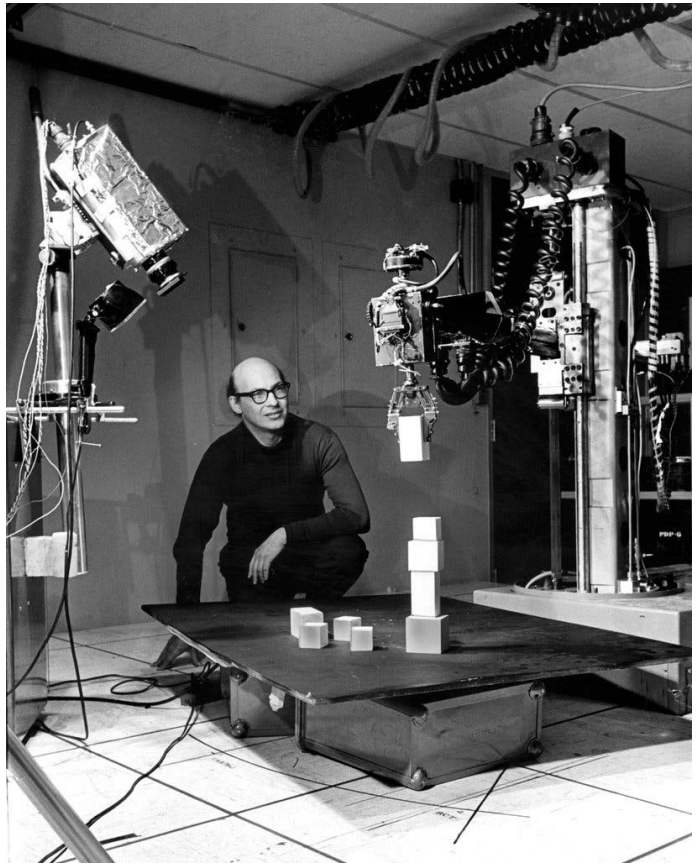
Surveillance



Semantic Segmentation

Computer vision is much more beyond image classification and processing

The Origin of Computer Vision



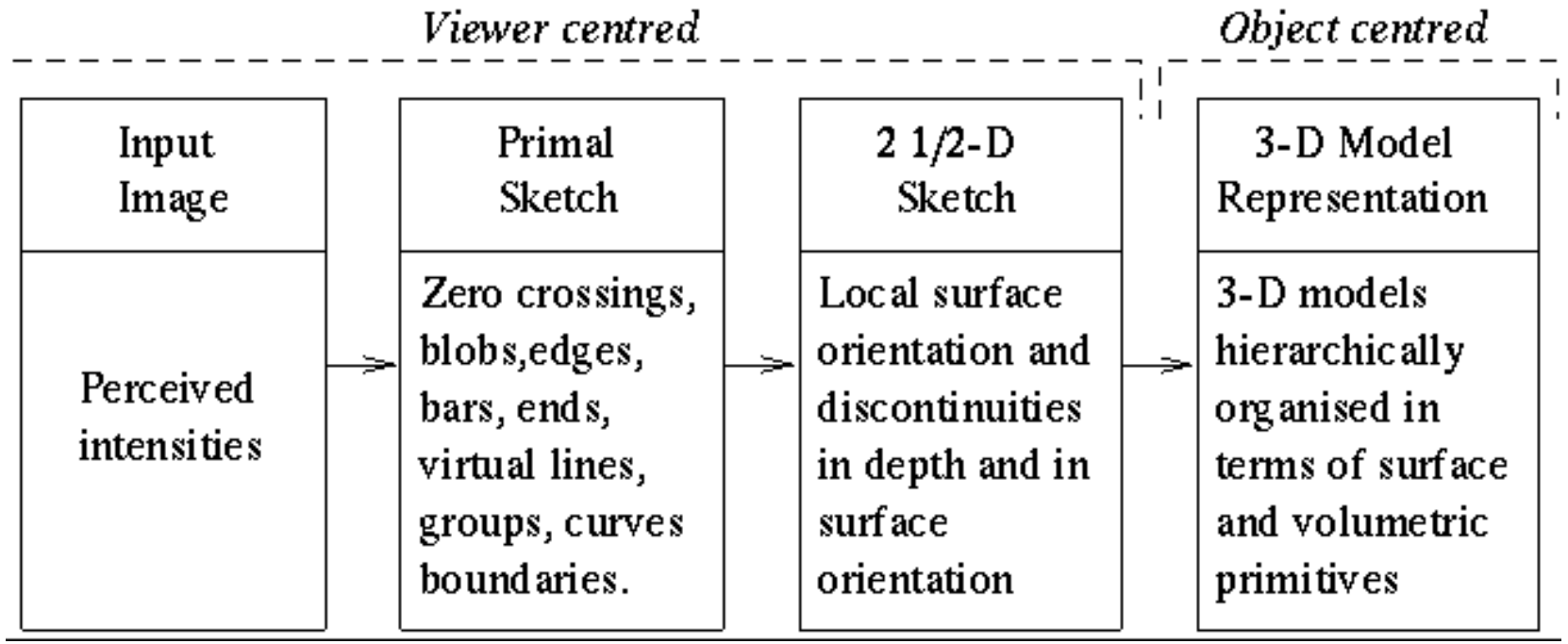
Marvin Minsky in a lab at MIT in 1968

An undergraduate project assigned by Marvin Minsky in 1966

“spend the summer linking a camera to a computer and getting the computer to describe what it saw”

Understand the 3D world from 2D images like humans

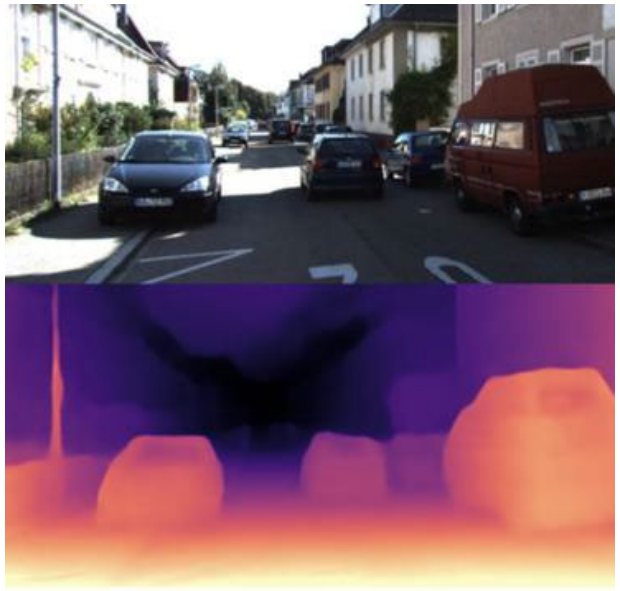
David Marr's Theory of Vision (Neuroscientist)



https://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/GOMES1/marr.html

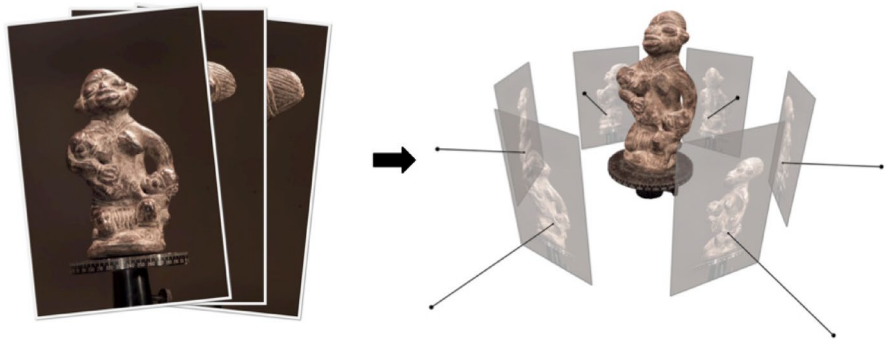
D. Marr. Vision. W. H. Freeman and Co., 1982.

What is Computer Vision?

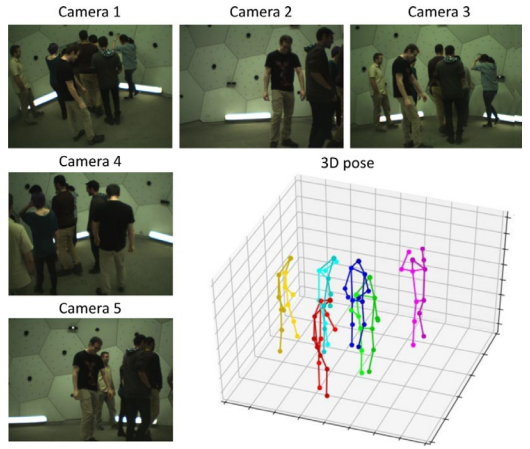


Depth Estimation

Structure from Motion



3D Reconstruction

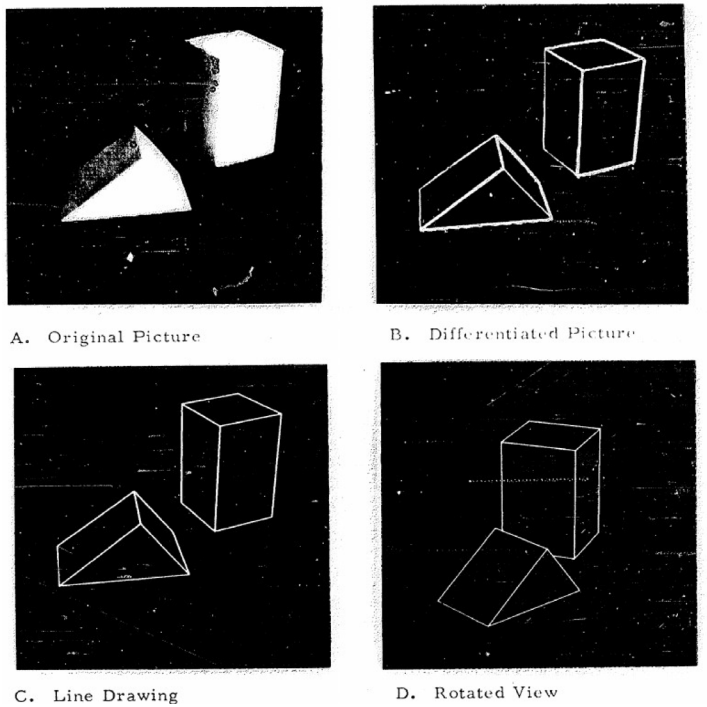


3D Human Pose Estimation
Dong et al. CVPR'19

Understand the 3D world from 2D images

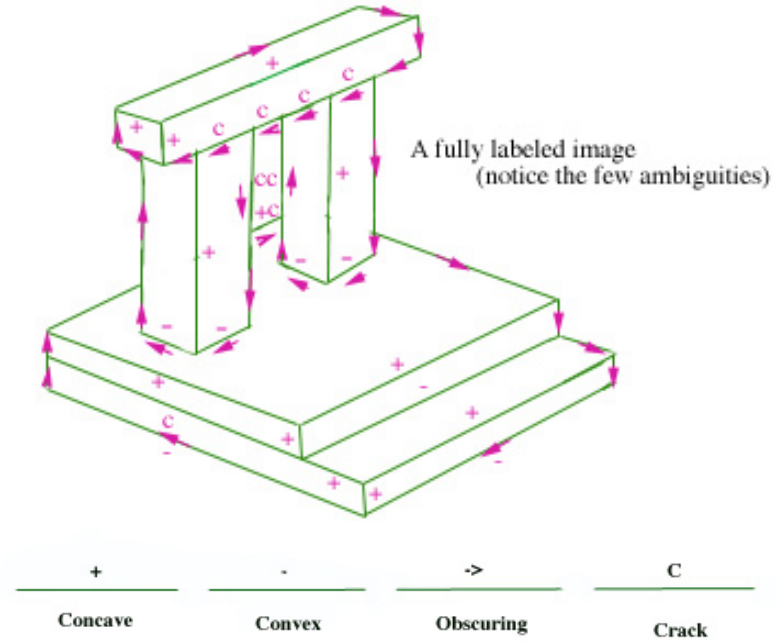
A Brief CV History and My Chosen Milestones

- 1970s
  - Recover 3D structure of the world from images

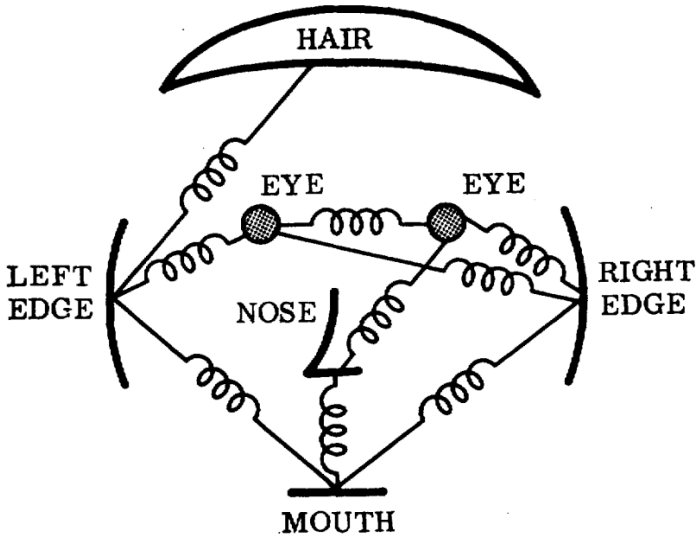


Blocks World

Roberts: Machine perception of three-dimensional solids. PhD Thesis, 1963



Line Labeling

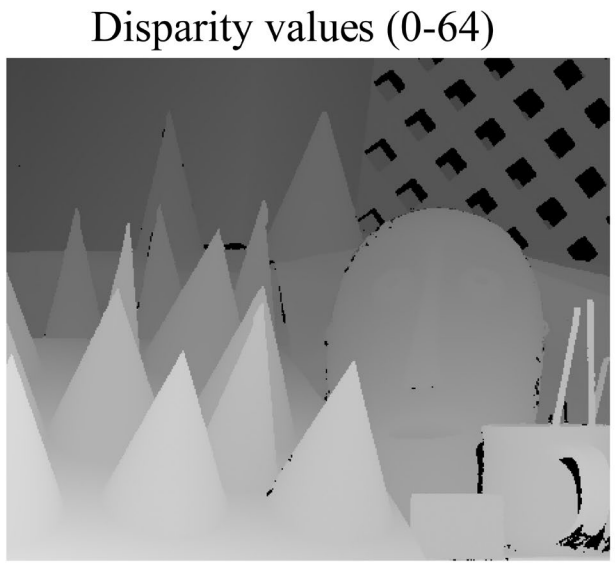


Pictorial Structure

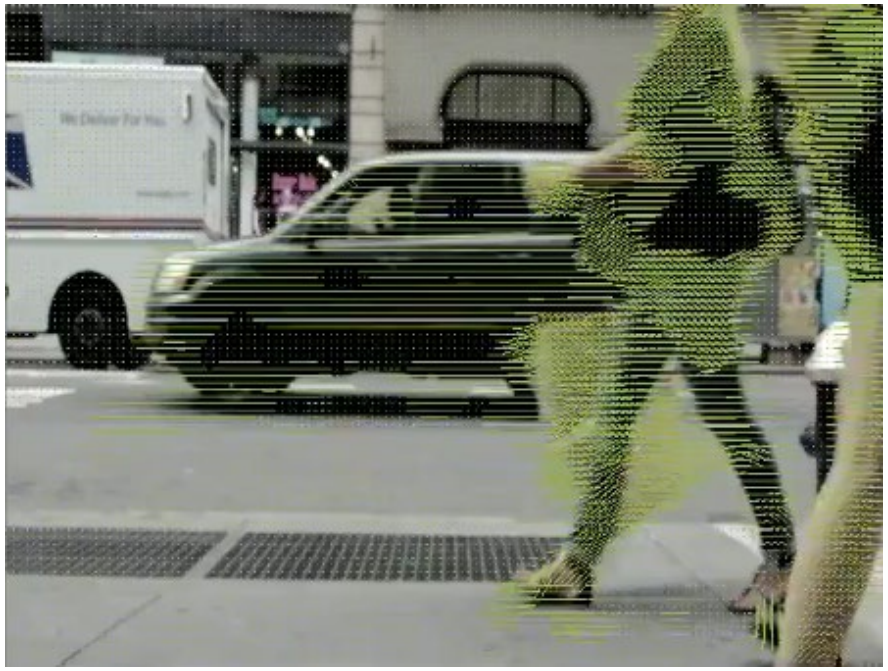
Fischler and Elschlager 1973

A Brief CV History and My Chosen Milestones

- 1980s
  - Stereo correspondence algorithms and optical flow algorithms



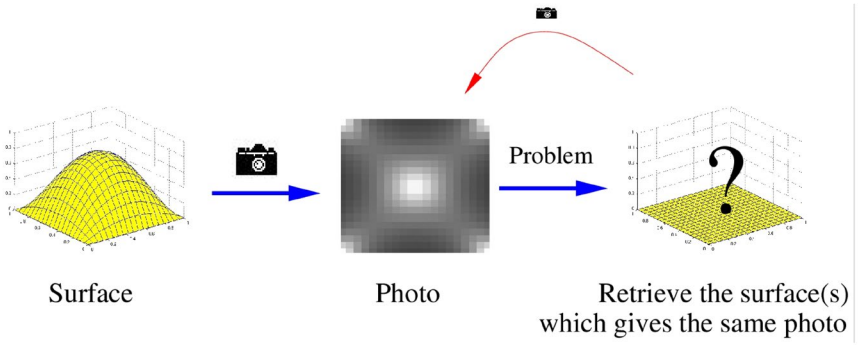
Stereo Correspondence



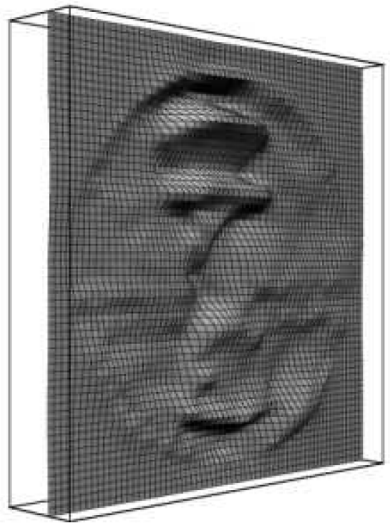
Optical Flow

A Brief CV History and My Chosen Milestones

- 1980s
  - Shape from X techniques (shape from shading, shape from texture, shape from shadows)
  - Edge and contours



Shape from shading



Freeman and Adelson 1991

Canny edge detector. Canny, 1986

A Brief CV History and My Chosen Milestones

- 1980s
  - Markov Random Fields (MRFs)

$$E(x) = \sum_i \underbrace{\Psi_i(x_i)}_{\text{Unary}} + \sum_{i \sim j} \underbrace{\Psi_{i,j}(x_i, x_j)}_{\text{Pairwise}}$$

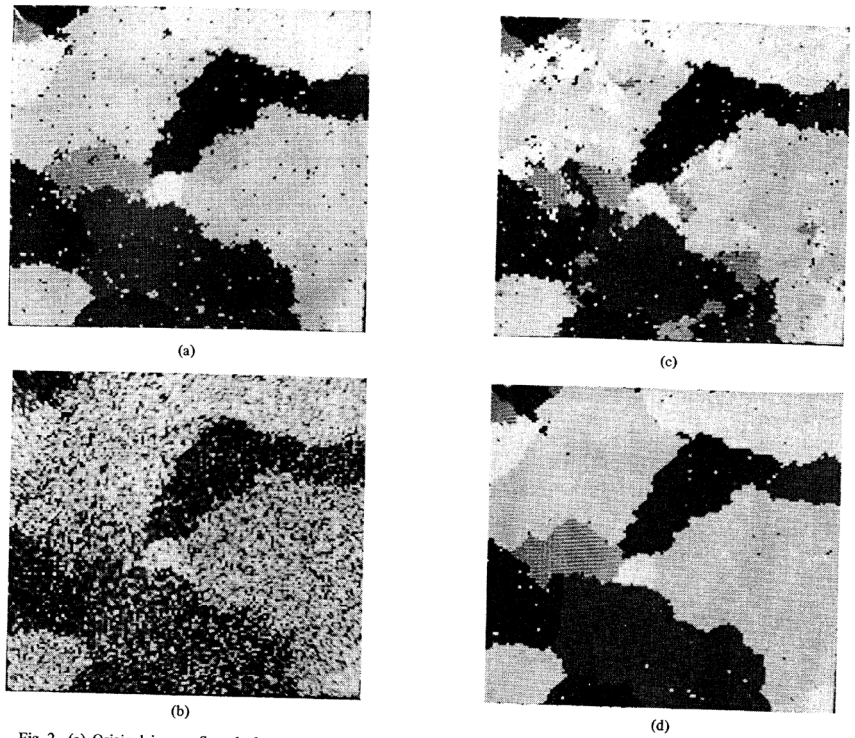
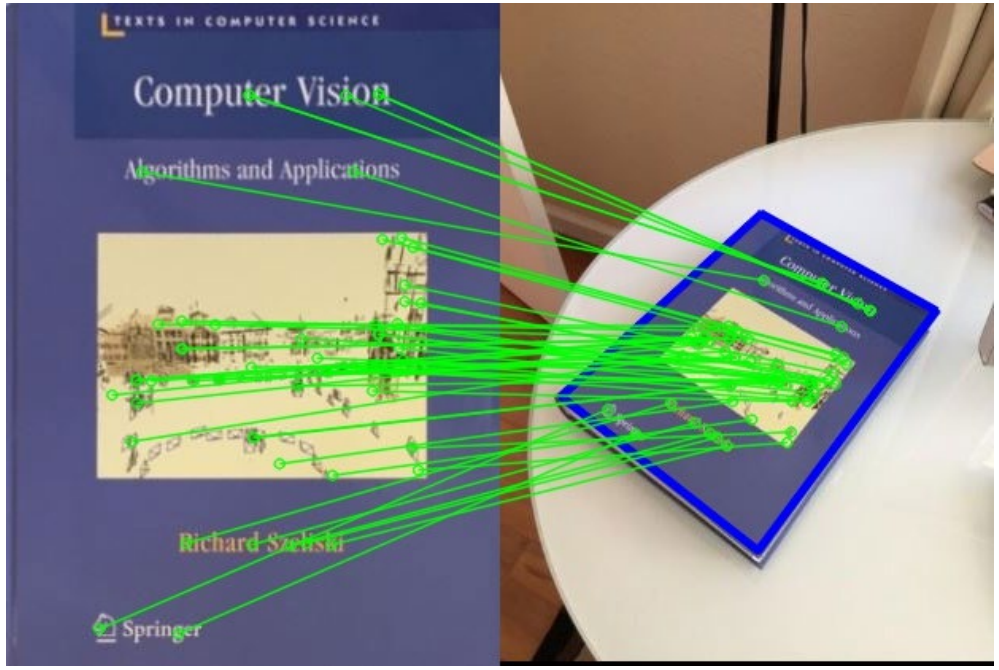


Fig. 2. (a) Original image: Sample from MRF. (b) Degraded image: Additive noise. (c) Restoration: 25 iterations. (d) Restoration: 300 iterations.

Geman and Geman: Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images. PAMI, 1984

A Brief CV History and My Chosen Milestones

- 1990s
  - Structure from Motion and Multi-view Reconstruction
  - Scale Invariance Feature Transform (SIFT)



David Lowe: Object recognition from local scale-invariant features. ICCV, 1999.

A Brief CV History and My Chosen Milestones

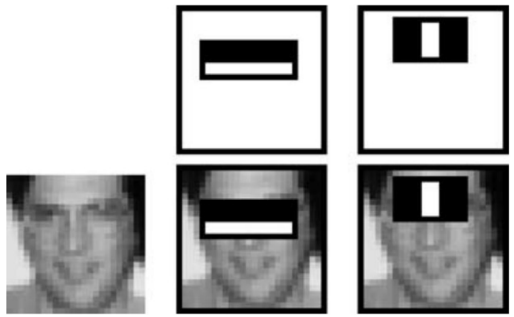
- 1990s
  - Statistical learning techniques started appearing

Eigenfaces

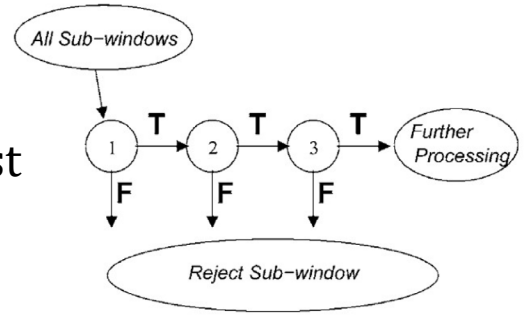
Turk and Pentland: Face recognition using Eigenfaces. CVPR, 1991

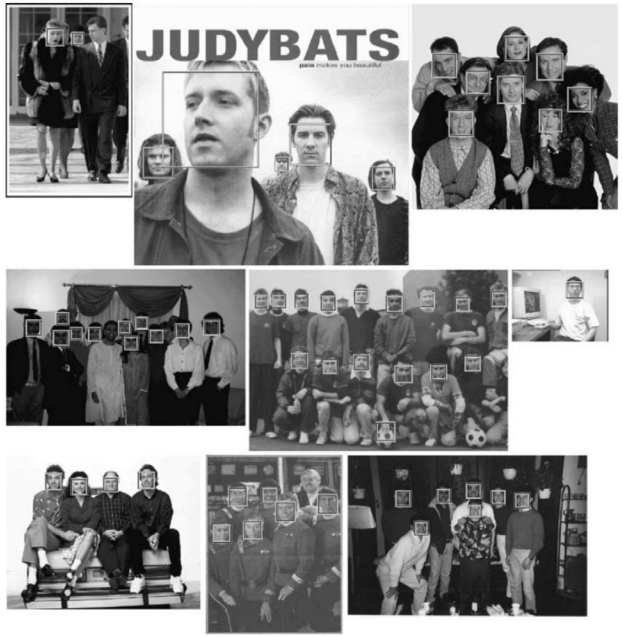
A Brief CV History and My Chosen Milestones

- 2000s
  - Data-driven and learning approaches
  - Cascaded classifiers for object detection



AdaBoost

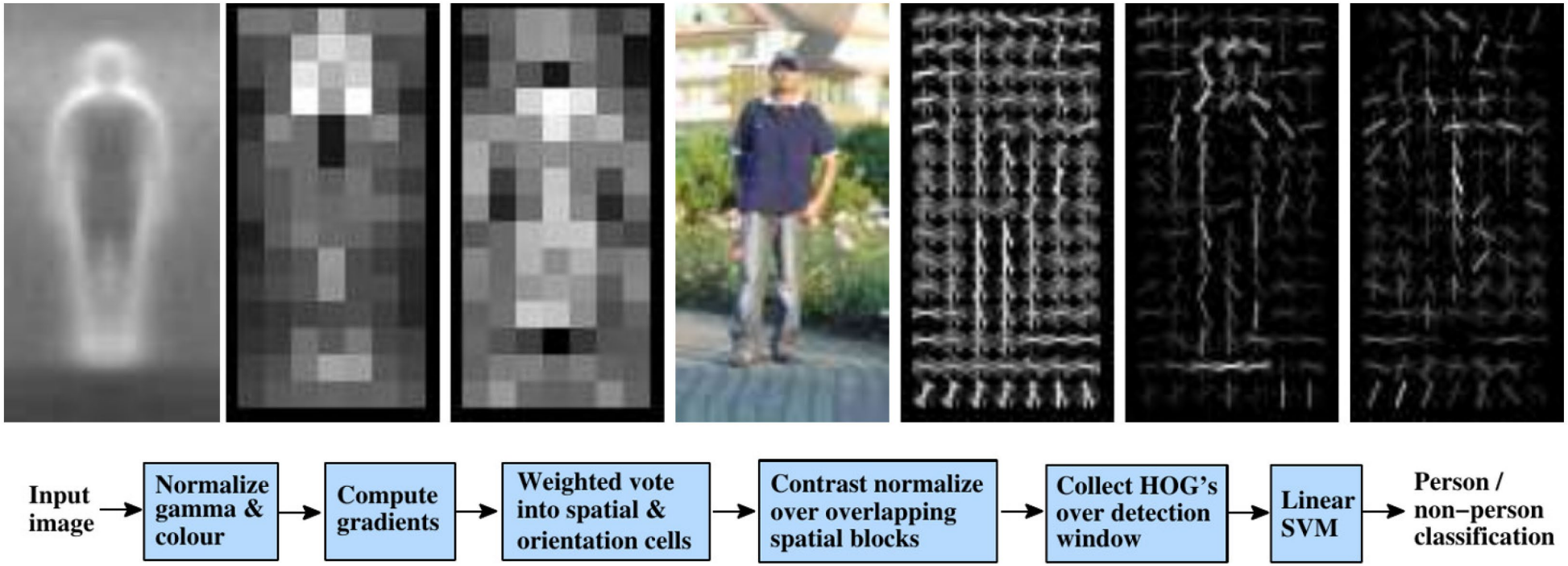




Viola and Jones: Robust Real-time Object Detection. IJCV, 2001.

A Brief CV History and My Chosen Milestones

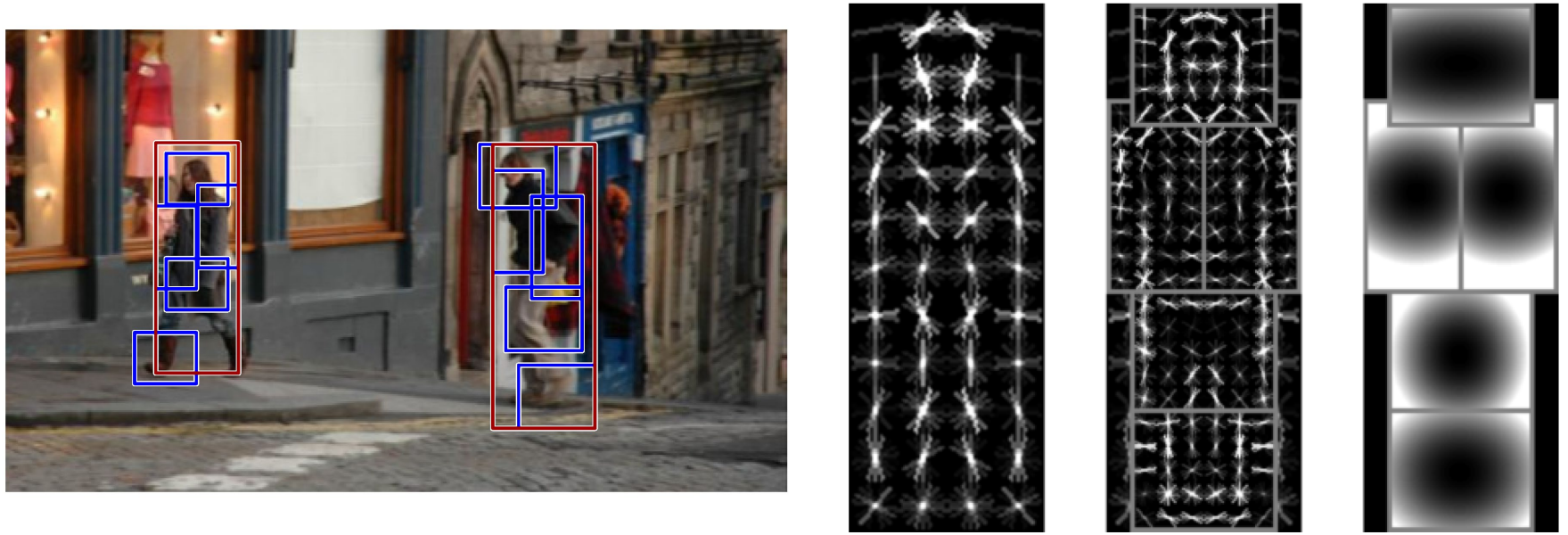
- 2000s
  - Histogram of Oriented Gradients for object detection



Dalal and Triggs: Histograms of Oriented Gradients for Human Detection. CVPR, 2005.

A Brief CV History and My Chosen Milestones

- 2000s
  - Deformable parts models for object detection



Felzenszwalb et al. Object detection with discriminatively trained part-based models . TPAMI, 2009.

A Brief CV History and My Chosen Milestones

- 2000s
  - Datasets

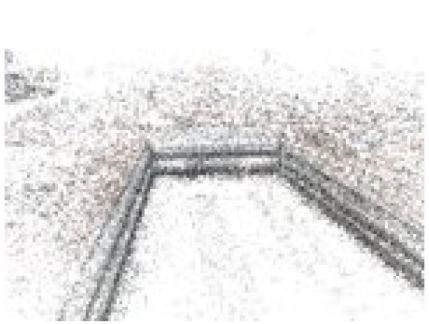
PASCAL VOC, Everingham et al., 2005 - 2012

ImageNet, Deng et al., 2009

A Brief CV History and My Chosen Milestones

- 2000s
  - Large-scale structure from motion



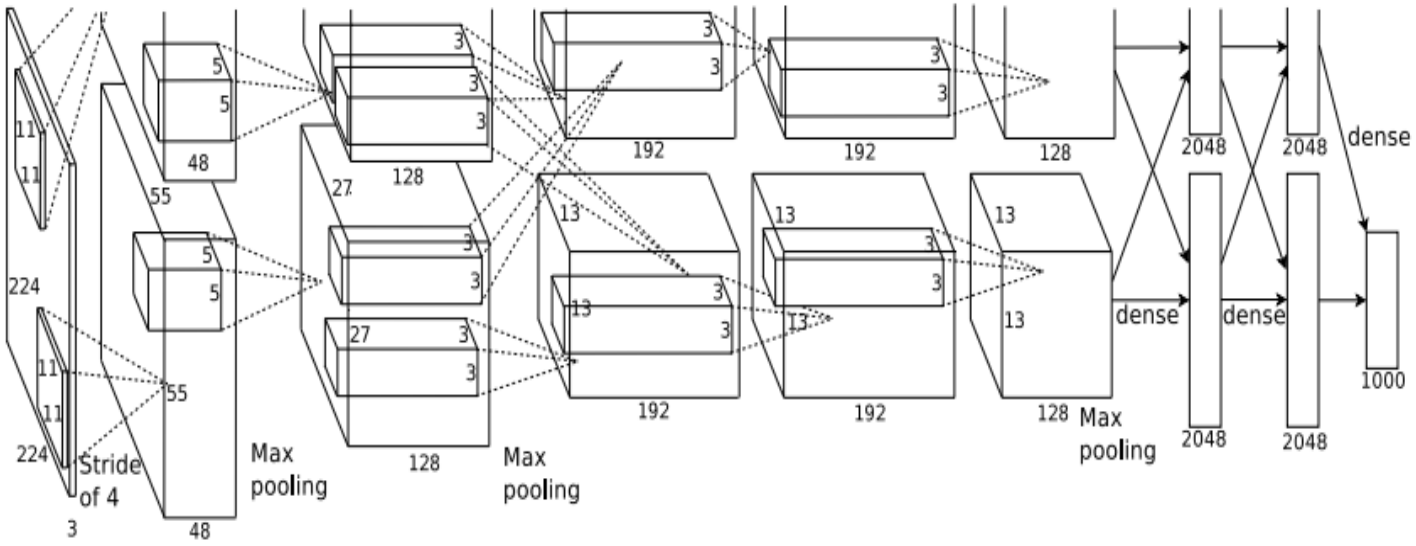



San Marco Square: 13,699 images, 4,515,157 points

Agarwal et al. Building Rome in day. ICCV, 2009.

A Brief CV History and My Chosen Milestones

- 2010s
  - Deep Learning in CV

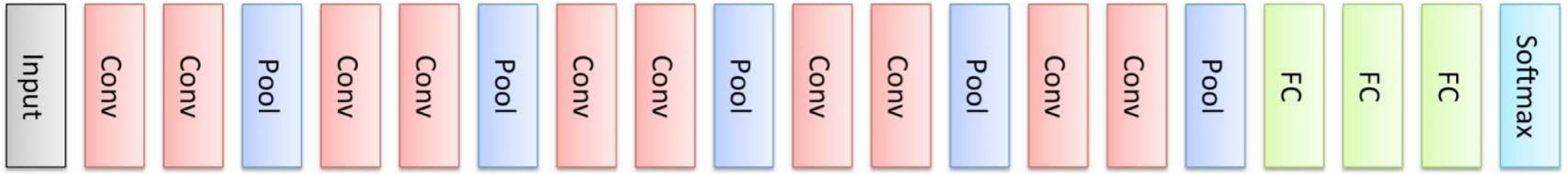


AlexNet. Krizhevsky et al., 2012, designed for ImageNet classification

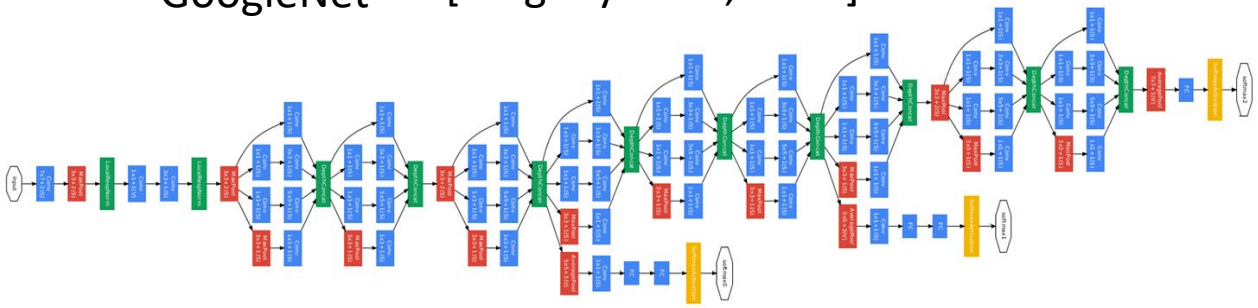
A Brief CV History and My Chosen Milestones

- 2010s
  - Deeper and wider networks

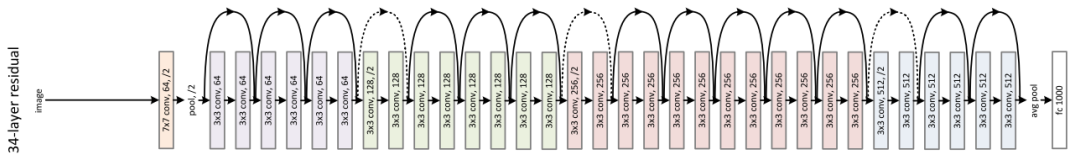
VGGNet [Simonyan and Zisserman, 2014]



GoogleNet [Szegedy et al., 2014]

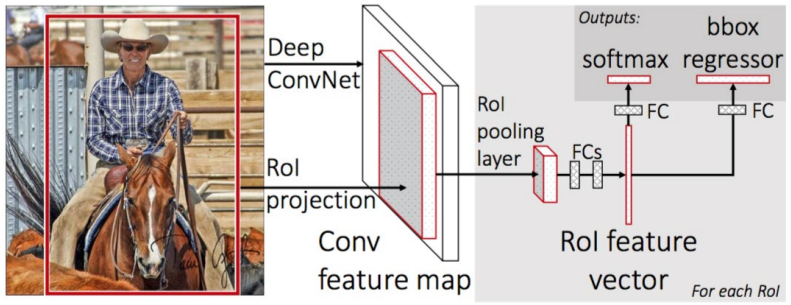


ResNet [He et al., 2015]

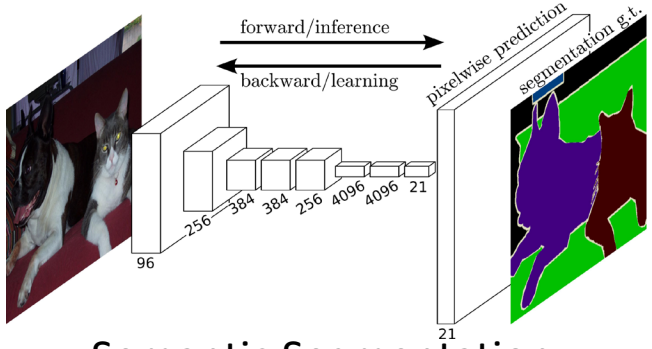


A Brief CV History and My Chosen Milestones

- 2010s
  - Neural networks for recognition



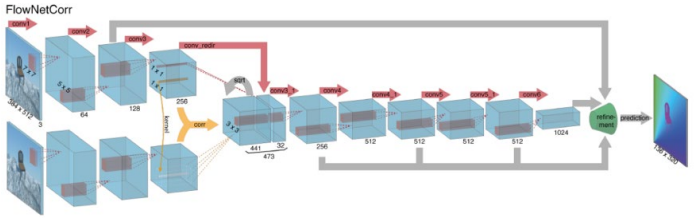
Object Detection (Fast RCNN, Girshick, 2015)



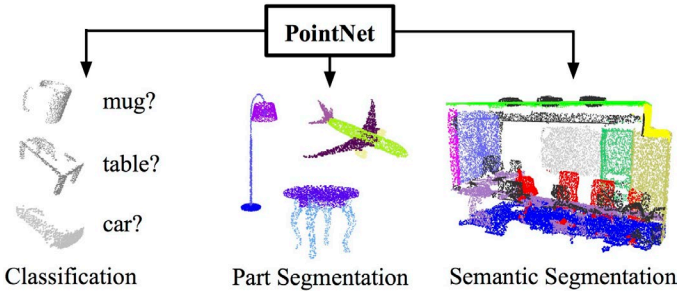
Semantic Segmentation
(FCN, Long et al., 2014)

Human Pose Estimation
(OpenPose, Cao et al., 2017)

Depth Estimation (Eigen et al. 2014)



Optical Flow
(FlowNet Fischer et al. 2015)

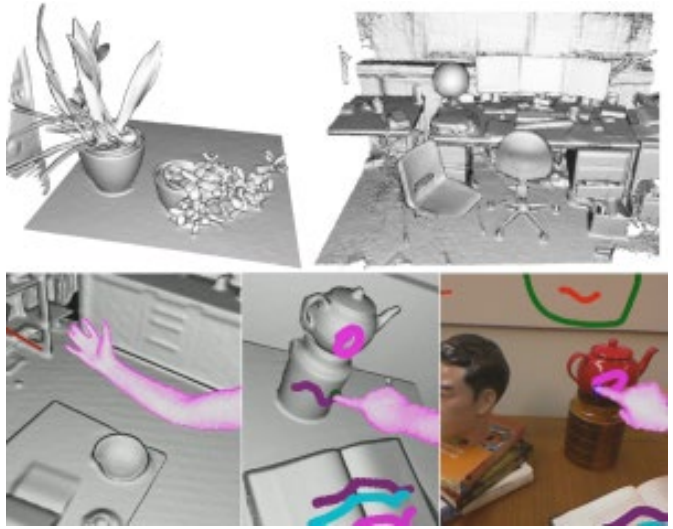


Point Cloud Recognition
(PoinetNet, Qi et al., 2016)

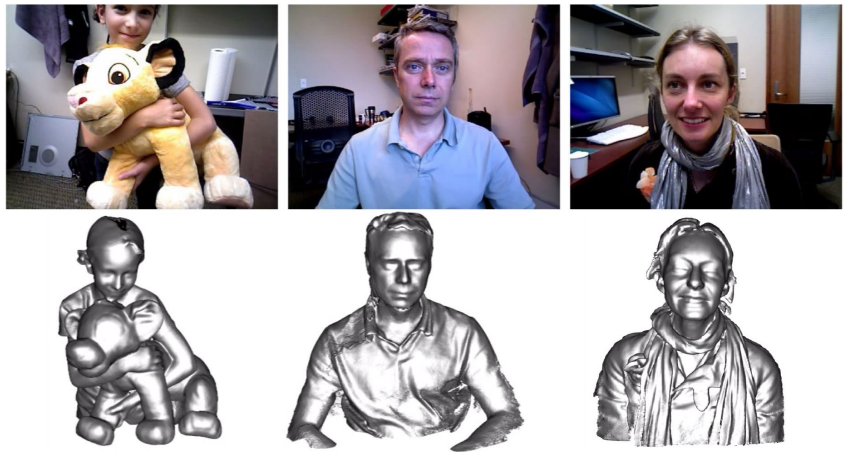
A Brief CV History and My Chosen Milestones

- 2010s
  - Depth sensing and 3D vision

Microsoft Kinect, 2010



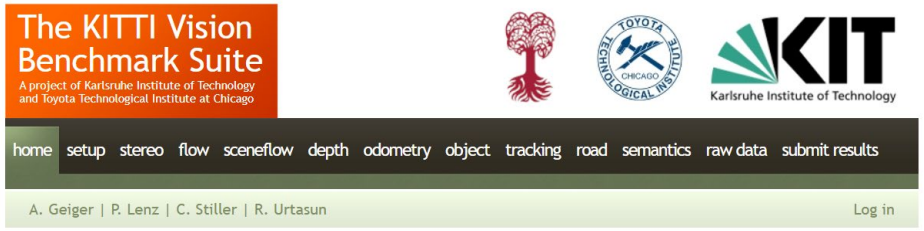
KinectFusion, Newcombe et al., 2011

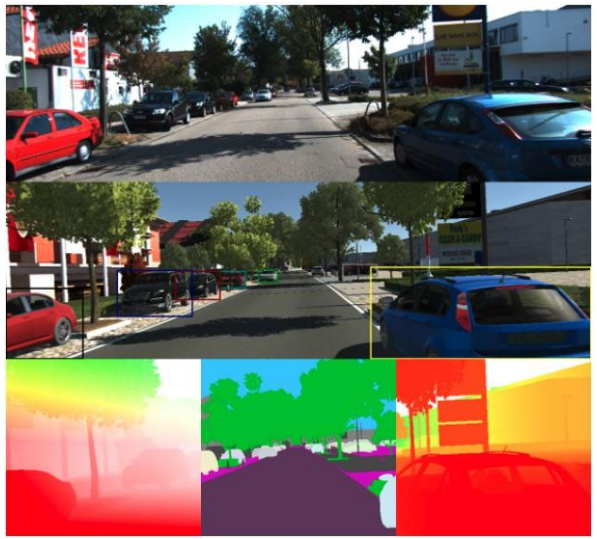


DynamicFusion, Newcombe et al., 2015

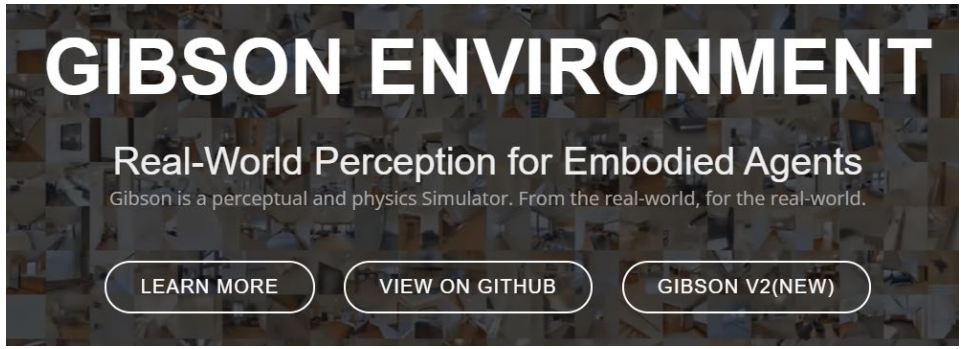
A Brief CV History and My Chosen Milestones

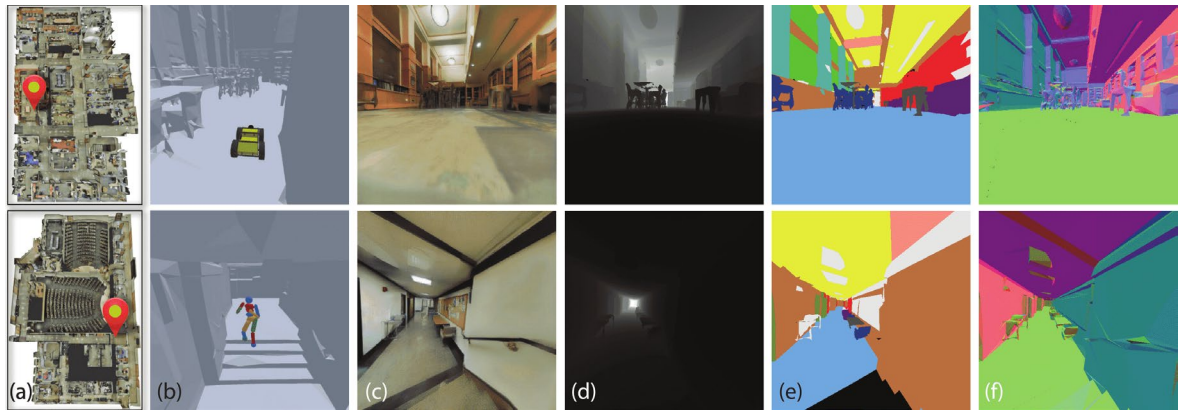
- 2010s
  - Autonomous driving and embodied AI





The KITTI dataset, Geiger et al., 2012

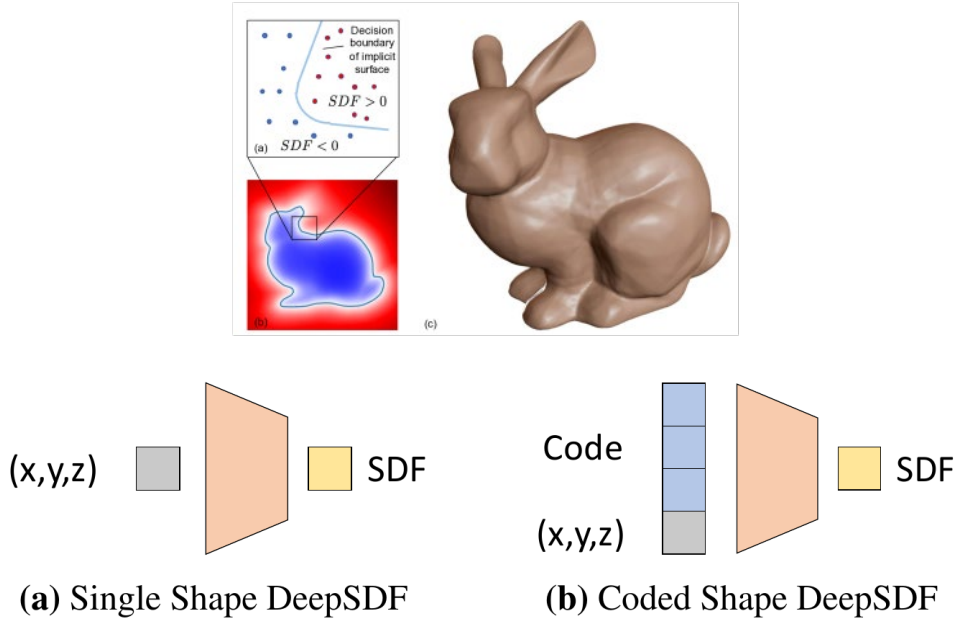




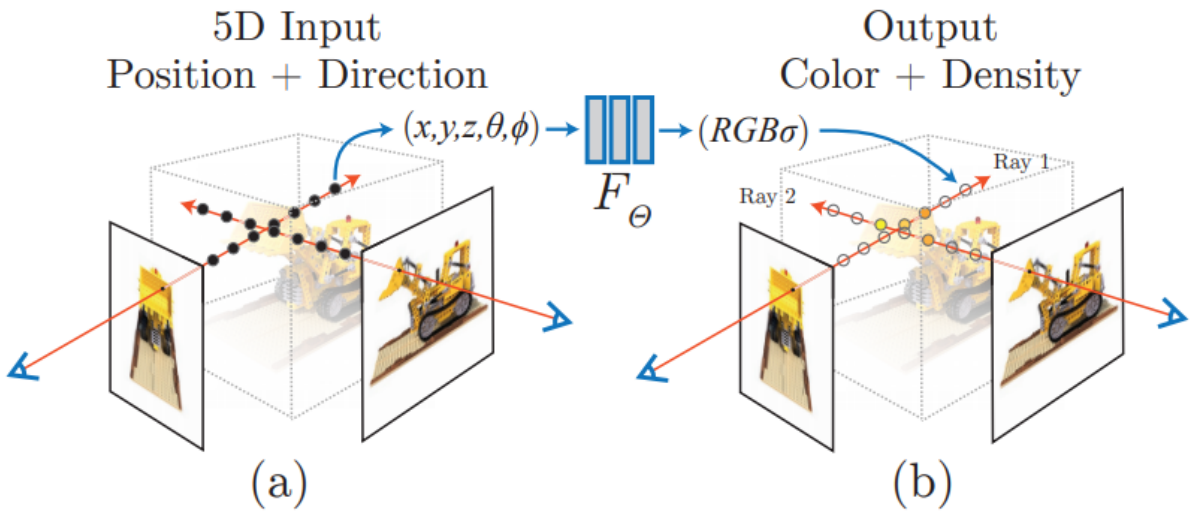
The Gibson environment, Xia et al., 2018

A Brief CV History and My Chosen Milestones

- 2010s
  - Neural implicit representations



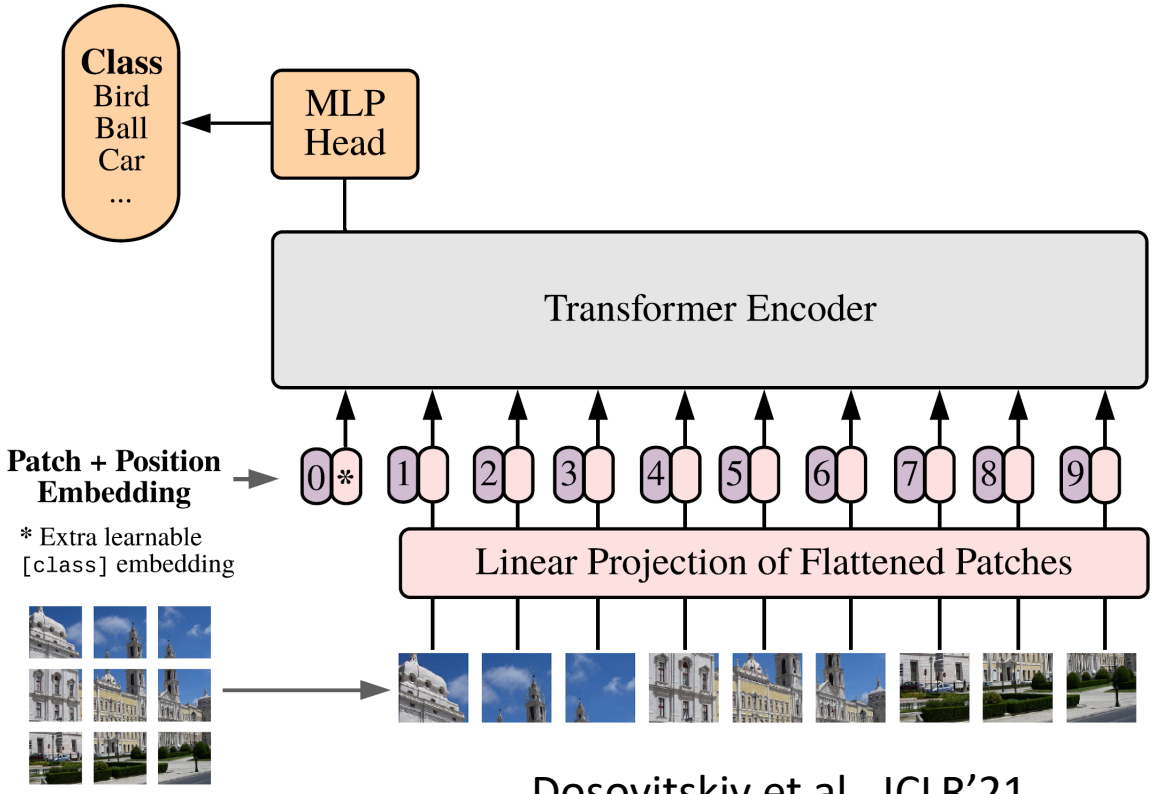
DeepSDF, Park et al., 2019



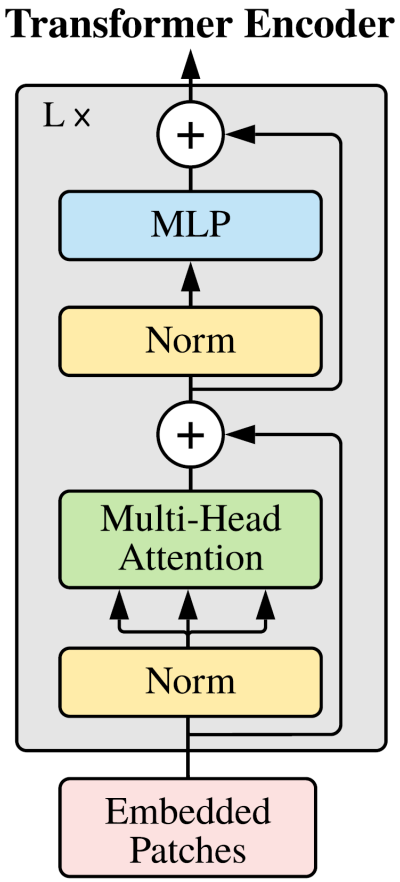
NeRF: Neural Radiance Fields. Midenhall et al. 2020

A Brief CV History and My Chosen Milestones

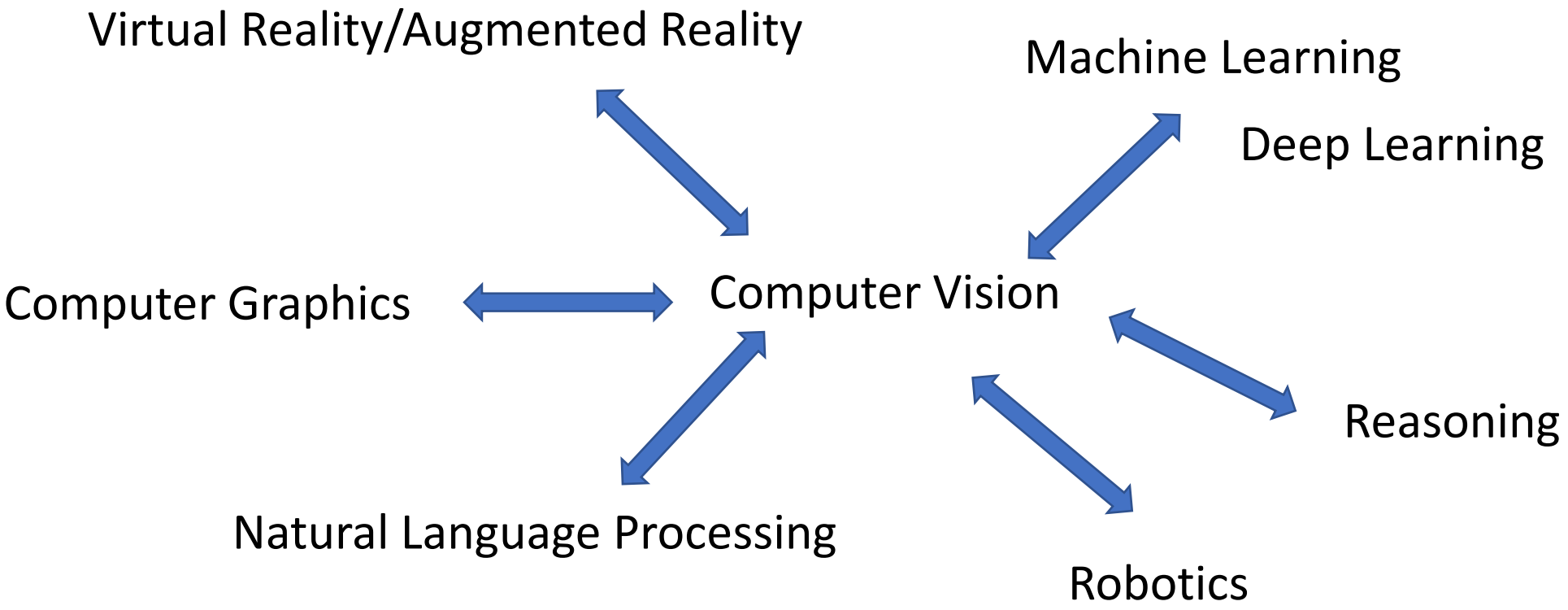
- 2020s
  - Vision transformers



Dosovitskiy et al., ICLR'21



Computer Vision in AI



Computer Vision in AI

Datasets $\neq$ Real World

Test your algorithms in the real world, e.g., with a camera

What will you learn in this course?

- Geometry in computer vision
  - Camera model, stereo geometry, multi-view geometry, etc.
- Image Features
  - Point features, edges, contours, etc.
- Deep learning in computer vision
  - Convolutional neural networks, recurrent neural networks, generative networks, etc.
- Visual recognition
  - Object detection, semantic segmentation, human pose estimation, images and languages, etc.

Grading Policy

- Homework (50%)
  - 5 homework in total
  - Individual submission
- Team Project (45%)
  - 2 to 4 students for a project
  - Project proposal (5%)
  - Project mid-term report (10%)
  - Project presentation (15%)
  - Project final report (15%)
- In-class Activity (5%)
- No final exam

Start thinking about the course project

Examples of Previous Course Projects

- Group 1: Visual Navigation Using ORB-SLAM3 (slides, demo)
  Group 2: Teaching Robots to Explore Unseen Environments (slides)
  Group 3: Interacting with Virtual Environment through Hand Pose Estimation (slides, demo)
  Group 4: Image Segmentation (slides)
  Group 6: Pose Based Form Correction Trainer (slides, demo)
  Group 8: Parking Spot Detection OpenCV (slides)
  Group 9: Identity Verification using Siamese Neural Networks (slides)
  Group 11: Few-shot Object Classification in Clutter Scenes (slides)
  Group 16: Solving Sudoku using Object Character Recognition (slides)

Examples of Previous Course Projects

- Group 10: Visual Question Answering (slides)
  Group 12: Scene Description Generation (slides)
  Group 13: A Study on Artist Attestation (slides)
  Group 14: Object Detection with DETR (slides)
  Group 15: Comparative Analysis of Blood Cell Image Classification (slides)
  Group 17: Referring Expression Comprehension with Audio Query (slides)
  Group 18: Image Segmentation for Platypuses in Nature (slides)
  Group 19: Image Grounding using Attention based Transformer (slides)
  Group 20: Cutting-Edge Techniques for Depth Map Super-Resolution (slides)

Course Details

- Textbook
  - Richard Szeliski. **Computer Vision: Algorithms and Applications**. 2011th Edition. Springer. Second Edition draft available online https://szeliski.org/Book/
  - David Forsyth, Jean Ponce. **Computer Vision: A Modern Approach**, 2nd Edition. Pearson, 2011. (Optional)
  - Richard Hartley. **Multiple View Geometry in Computer Vision**, 2nd Edition. Cambridge University Press, 2004. (Optional)
- My office hour

  Monday & Wednesday 3:30PM – 4:30 PM
  ECSS 4.702
- TA office hour: TBD
- Course access and navigation: eLearning

Questions?