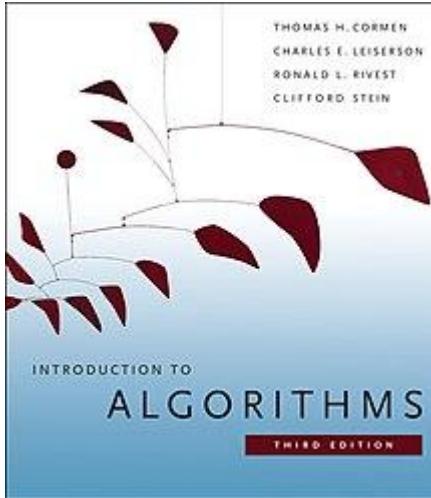
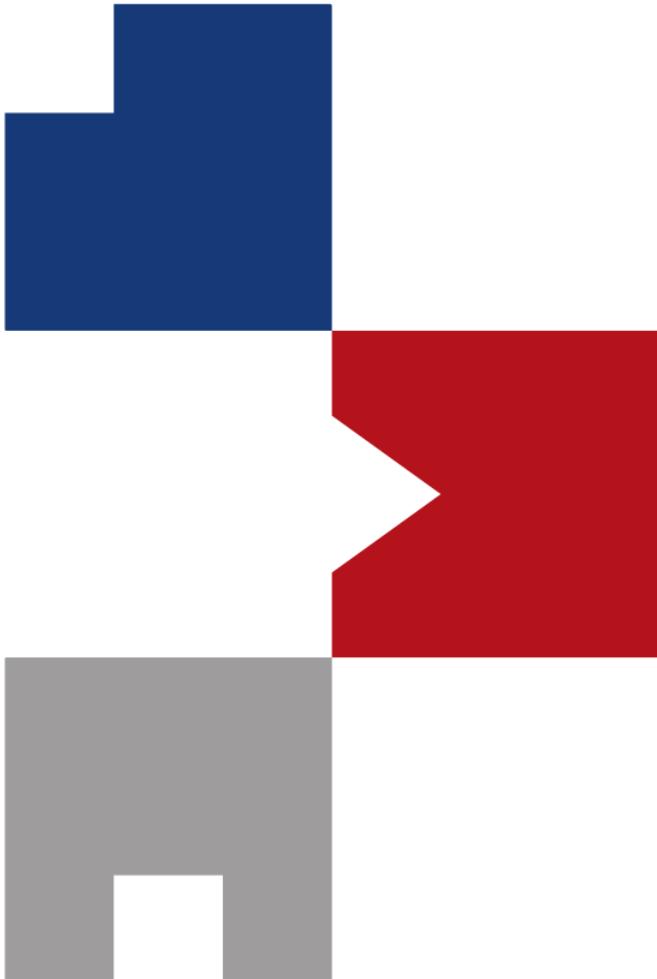


Introduction to 3D Vision



1312 pages

Sunglok Choi, Assistant Professor, Ph.D.
Dept. of Computer Science and Engineering, SEOULTECH
sunglok@seoultech.ac.kr | <https://mint-lab.github.io/>



An Invitation ~~Introduction~~ to 3D Vision : A Tutorial for Everyone

Sunglok Choi, Assistant Professor, Ph.D.
Computer Science and Engineering Department, SEOULTECH
sunglok@seoultech.ac.kr | <https://mint-lab.github.io/>

What is Computer Vision?

- **Computer vision is an interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos.**
- From the perspective of engineering, it seeks to automate tasks that the human visual system can do.[1][2][3]
- "Computer vision is concerned with the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images.
- It involves the development of a theoretical and algorithmic basis to achieve automatic visual understanding."[9]



What is Computer Vision?

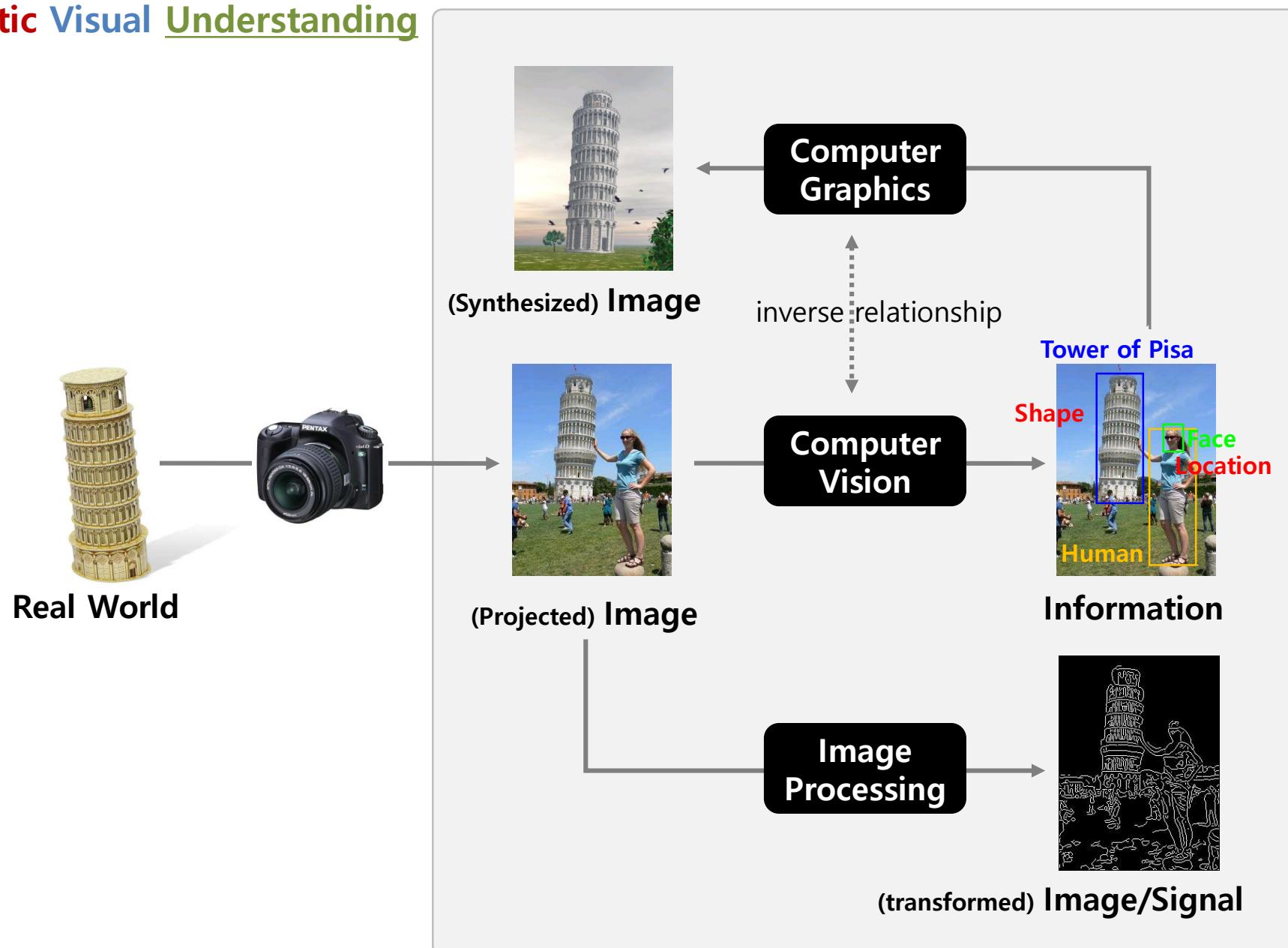
- Computer vision is an interdisciplinary field that deals with how **computers** can be made to gain **high-level understanding** from digital images or videos.
- From the perspective of engineering, it seeks to **automate tasks that the human visual system can do**.[1][2][3]
- "Computer vision is concerned with the **automatic extraction, analysis and understanding of useful information** from a single image or a sequence of images.
- It involves the development of a theoretical and algorithmic basis to achieve **automatic visual understanding**."[9]



What is Computer Vision?

Automatic Visual Understanding

Computer Vision



What is Computer Vision?

Computer Vision

What is it?

- Label (e.g. Tower of Pisa)
- Shape (e.g.)



Where am I?

- Place (e.g. Piazza del Duomo, Pisa, Italy)
- Location (e.g.)



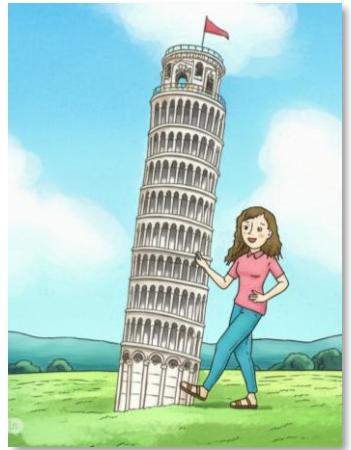
(84, 10, 18) [m]



What is 3D Vision?

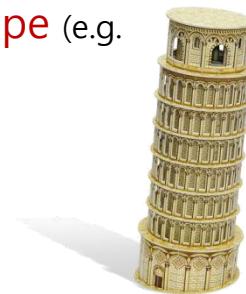
Automatic 3D Visual Perception

Computer Vision



What is it?

- **Label** (e.g. Tower of Pisa)
- **Shape** (e.g.)



Where am I?

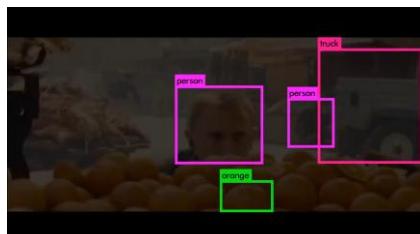
- **Place** (e.g. Piazza del Duomo, Pisa, Italy)
- **Location** (e.g.)



(84, 10, 18) [m]

Generation Problems

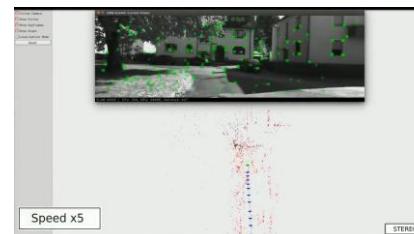
Recognition Problems vs. Reconstruction Problems



YOLO v2 (2016)

Stanford CS231n:

Deep Learning for Computer Vision



ORB-SLAM2 (2016)

Stanford CS231A:

Computer Vision,

From 3D Perception to 3D Reconstruction and beyond



What is 3D Vision?

Visual Geometry

Multiple View Geometry

Geometric Vision

Photogrammetry

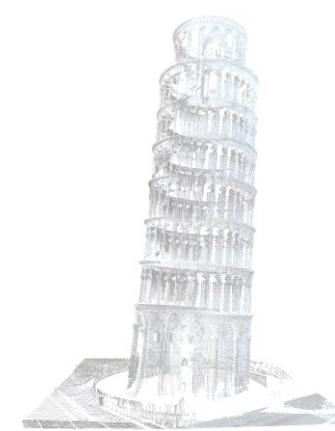


image



3D Vision

vs.



depth image, range data, point cloud, polygon mesh, ...

3D Data Processing



RGB-D Camera

(Stereo, Structured Light, ToF, Light Field)



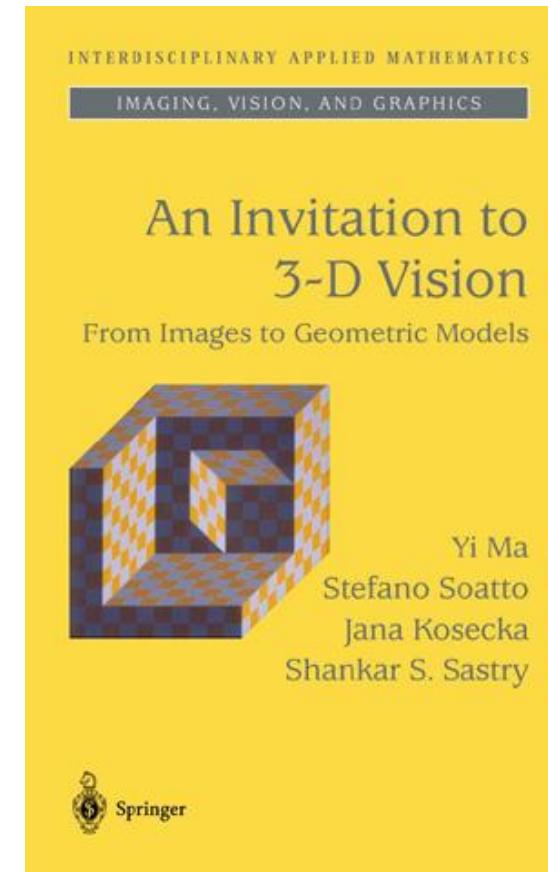
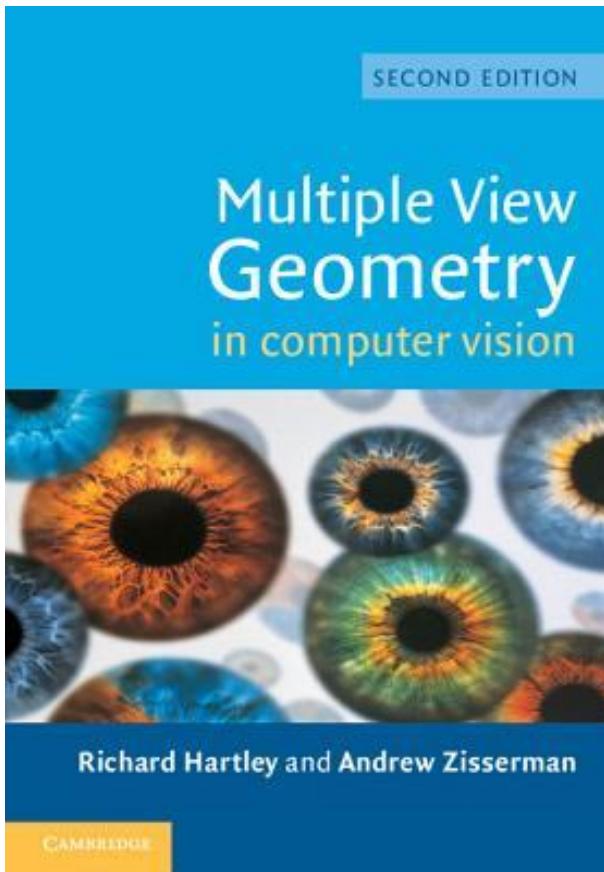
Omni-directional Camera



Range Sensor
(LiDAR, RADAR)

What is 3D Vision?

- Reference books



What is 3D Vision?

- All example codes are available at [https://github.com/mint-lab/3dv tutorial](https://github.com/mint-lab/3dv_tutorial).
 - All example codes are mostly **less than 100 lines** and based on **recent OpenCV (> 3.0.0)**.
 - Note) OpenCV (Open Source Computer Vision)

OpenCV v4.8.0 main modules:

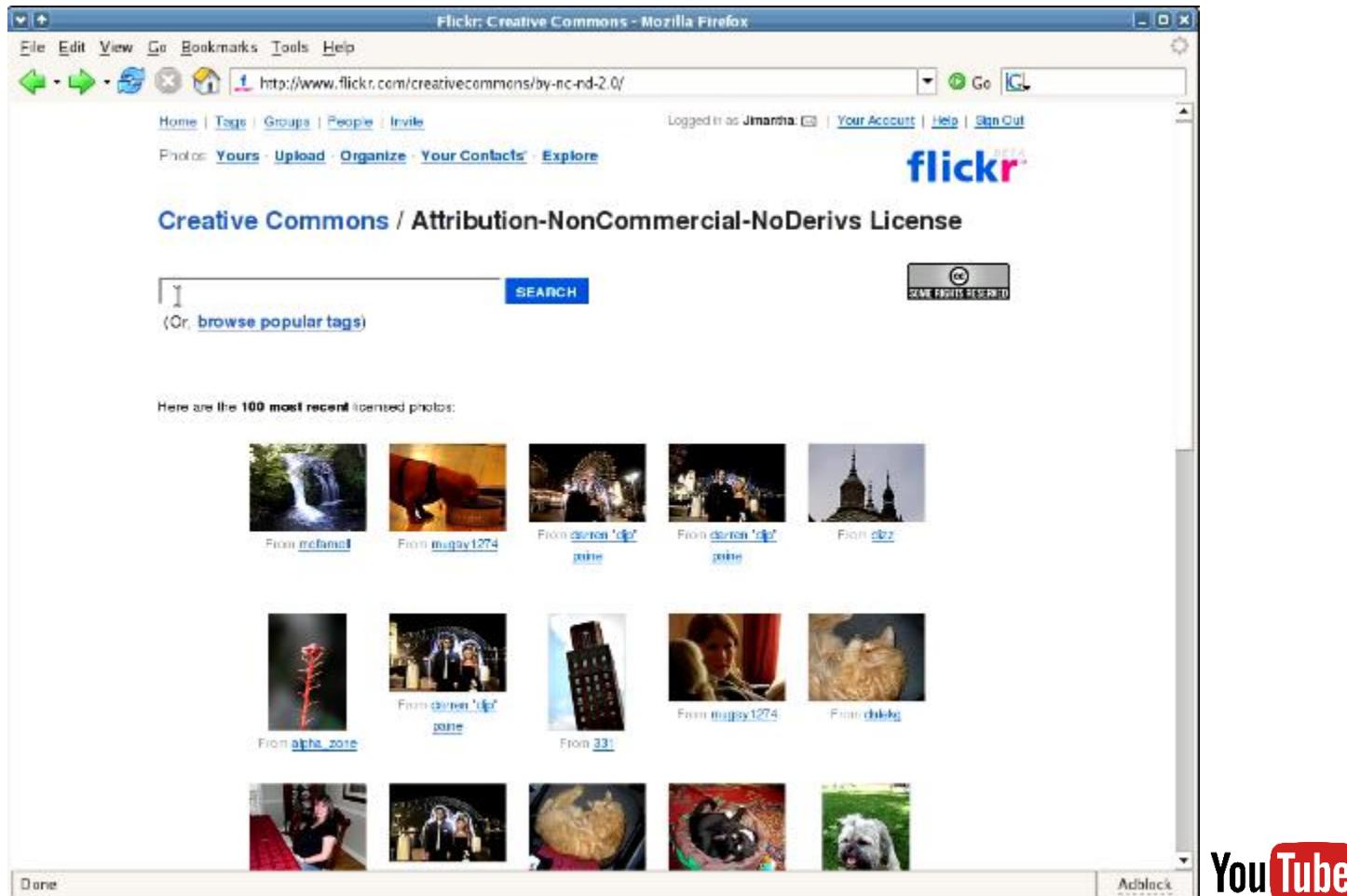
- core. [Core functionality](#)
- imgproc. [Image Processing](#)
- imgcodecs. [Image file reading and writing](#)
- videoio. [Video I/O](#)
- highgui. [High-level GUI](#)
- video. [Video Analysis](#)
- calib3d. [Camera Calibration and 3D Reconstruction](#)
- features2d. [2D Features Framework](#)
- objdetect. [Object Detection](#)
- dnn. [Deep Neural Network module](#)
- ml. [Machine Learning](#)
- flann. [Clustering and Search in Multi-Dimensional Spaces](#)
- photo. [Computational Photography](#)
- stitching. [Images stitching](#)
- gapi. [Graph API](#)

OpenCV v5.0.0-pre main modules:

- core. [Core functionality](#)
- imgproc. [Image Processing](#)
- imgcodecs. [Image file reading and writing](#)
- videoio. [Video I/O](#)
- highgui. [High-level GUI](#)
- video. [Video Analysis](#)
- 3d. [3d](#)
- stereo. [Stereo Correspondence](#)
- features2d. [2D Features Framework](#)
- calib. [Camera Calibration](#)
- objdetect. [Object Detection](#)
- dnn. [Deep Neural Network module](#)
- ml. [Machine Learning](#)
- flann. [Clustering and Search in Multi-Dimensional Spaces](#)
- photo. [Computational Photography](#)
- stitching. [Images stitching](#)
- gapi. [Graph API](#)

Applications) Photo Browsing

- Photo Tourism (2006)



Applications) 3D Reconstruction

- Building Rome in a Day (2009)

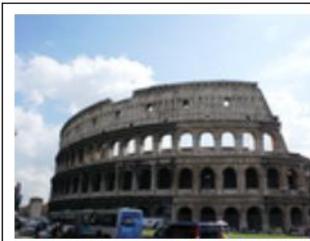


photo by [Ceci And Brandon](#)



2106 images, 819242 points
[click here to see more views](#)



photo by [TORISFERICK](#)



1936 images, 656699 points
[click here to see more views](#)



photo by [act2win](#)



1815 images, 422593 points
[click here to see more views](#)



photo by [angle_in_soul](#)



1381 images, 499044 points
[click here to see more views](#)



Applications) 3D Reconstruction

- [Building Rome in a Day](#) (2009)



The Old City of Dubrovnik



Applications) Depth Estimation from Cellular Phones

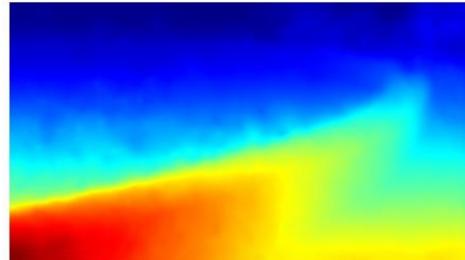
- Structure from Small Motion (SfSM; 2015)



(a) Reference images



(b) SfSM results



(c) Depth maps

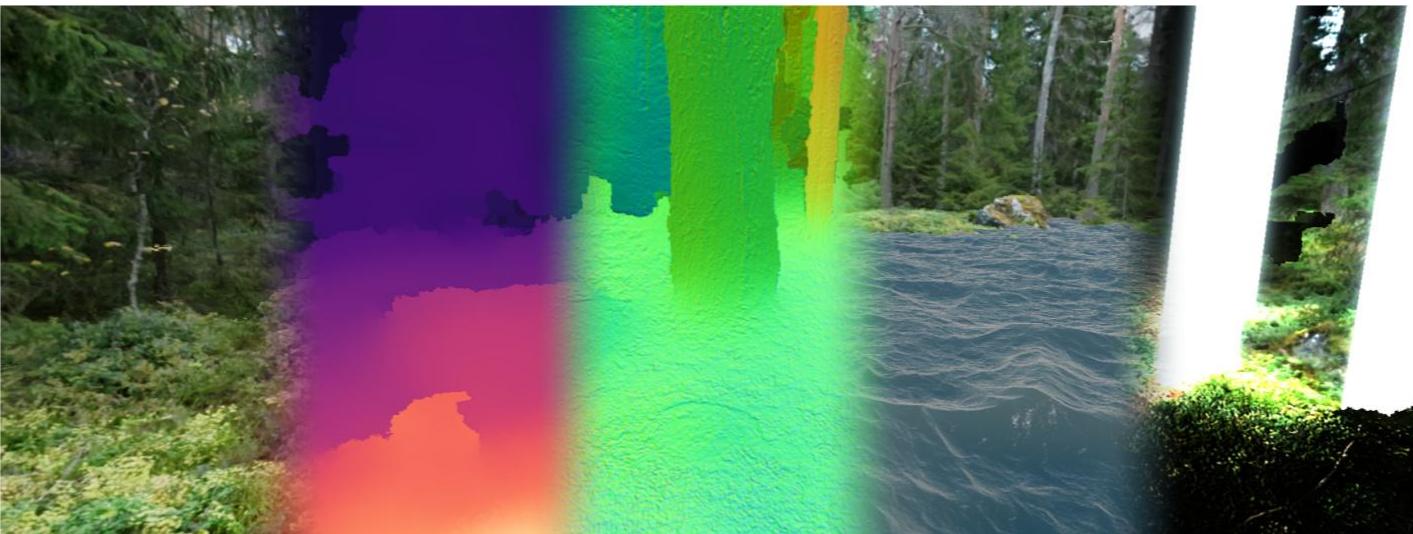


(d) Our 3D meshes

- Casual 3D Photography (2017)



Casual 3D photo capture



Color

Depth
Reconstruction

Normal map

Geometry-aware

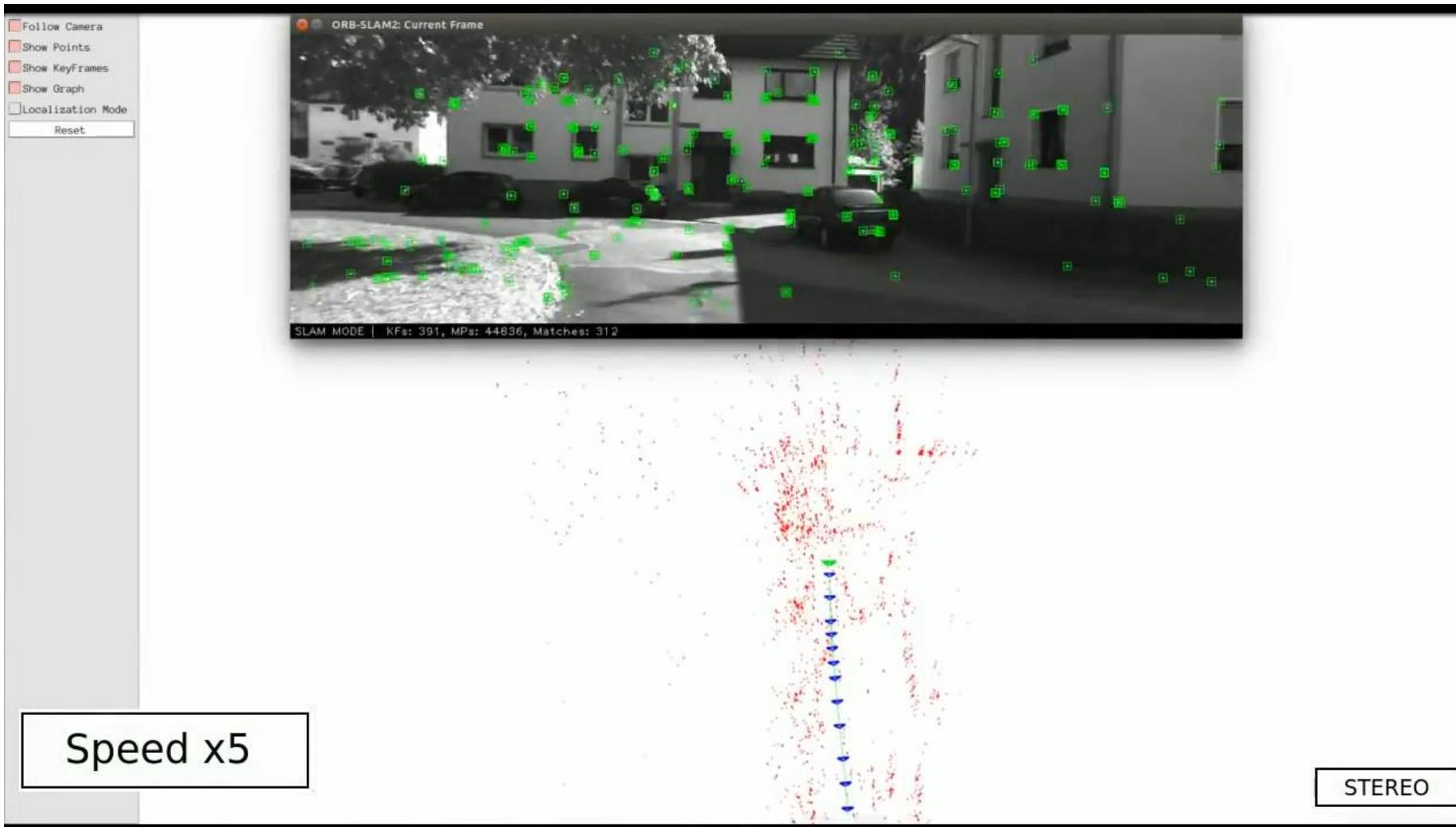
Lighting
Example Effects

Reference: Im et al., "High Quality Structure from Small Motion for Rolling Shutter Cameras", ICCV, 2015

Reference: Hedman et al., "Casual 3D Photography", SIGGRAPH Asia, 2017

Applications) Real-time Visual SLAM

- [ORB-SLAM](#) (2014)



Applications) Augmented Reality

- PTAM: Parallel Tracking and Mapping (2007)

4. Ewok rampage

Here the camera is used to aim Darth Vader's laser pistol. Movement is controlled with the keyboard.



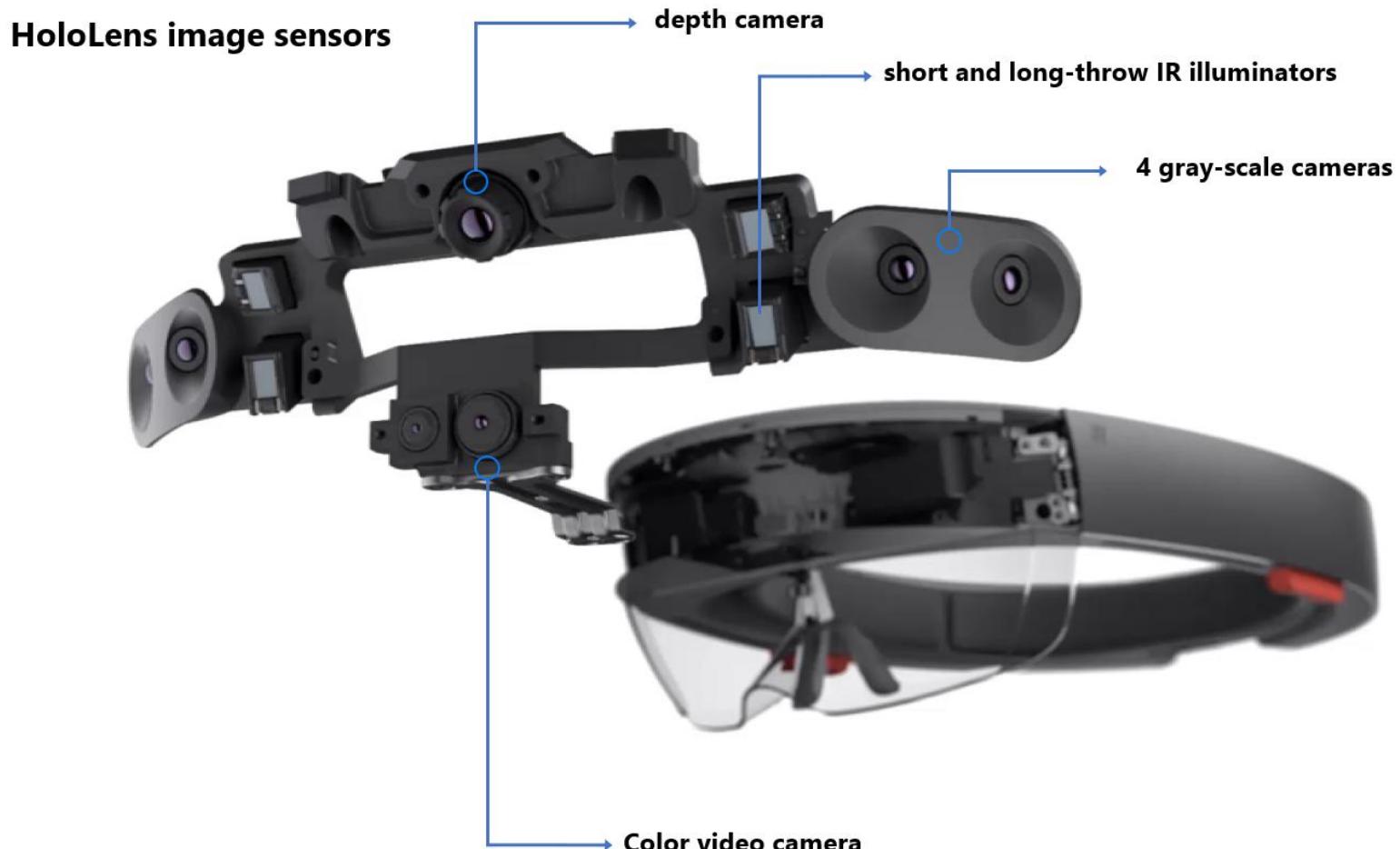
Applications) Virtual Reality

- Oculus Quest (2019)



Applications) Mixed Reality

- Microsoft HoloLens 2 (2019)
 - Head tracking: 4 x visible light cameras



Summary) Introduction

- **What is Computer Vision?**
- **What is 3D Vision?**
 - What? Recognition problem vs. Reconstruction problem
 - Note) Generation problem vs. Reconstruction problem
 - Why? Applications

Next Topics

- **Single-view Geometry**
- **Two-view Geometry**
- **Solving Equations**
- **Finding Correspondences**
- **Multi-view Geometry**
- **Special Topic) Bayesian Filtering**
- **Visual SLAM and Odometry**
- **3D Representations**