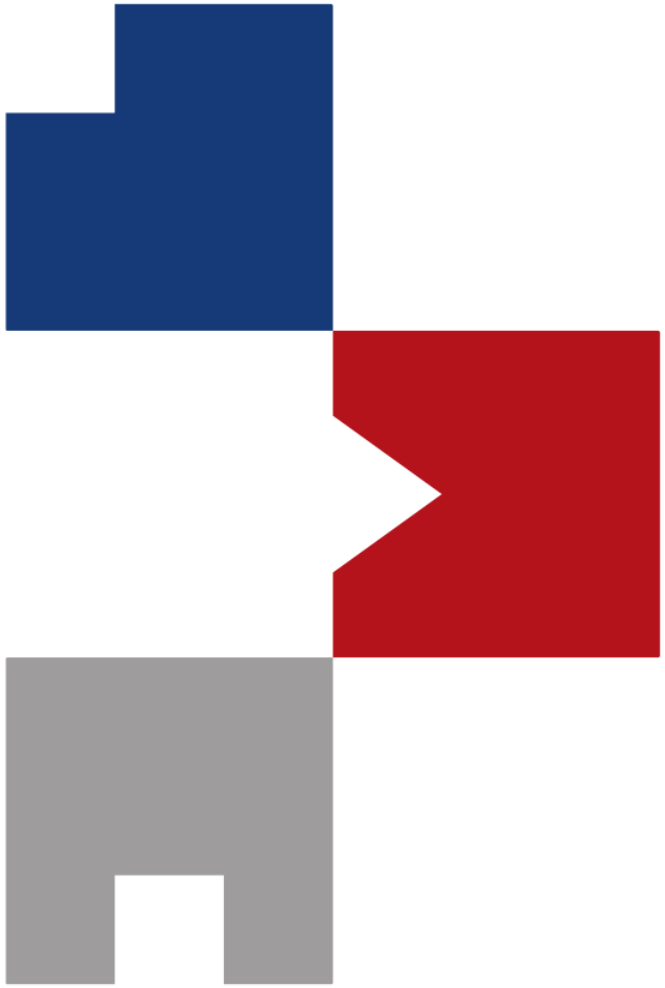
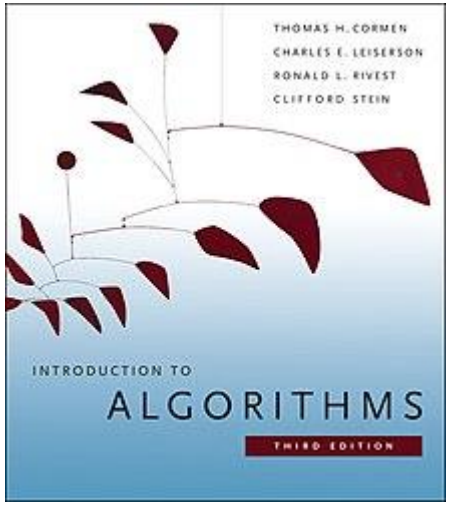
Note) Slides and example codes are available:
https://github.com/mint-lab/3dv_tutorial



Introduction to 3D Vision



1312 pages

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

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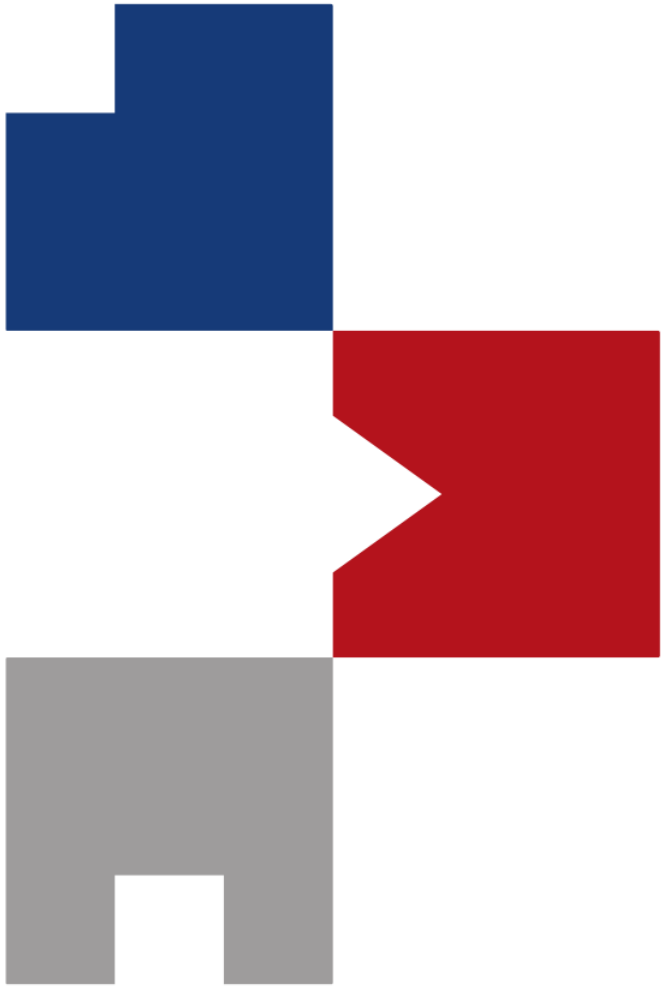
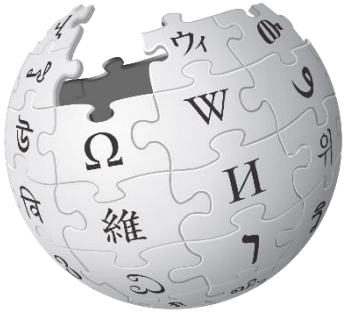


An Invitation ~~Introduction~~ to 3D Vision
: A Tutorial for Everyone

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]



Reference: Wikipedia (Computer Vision)

What is Computer Vision?

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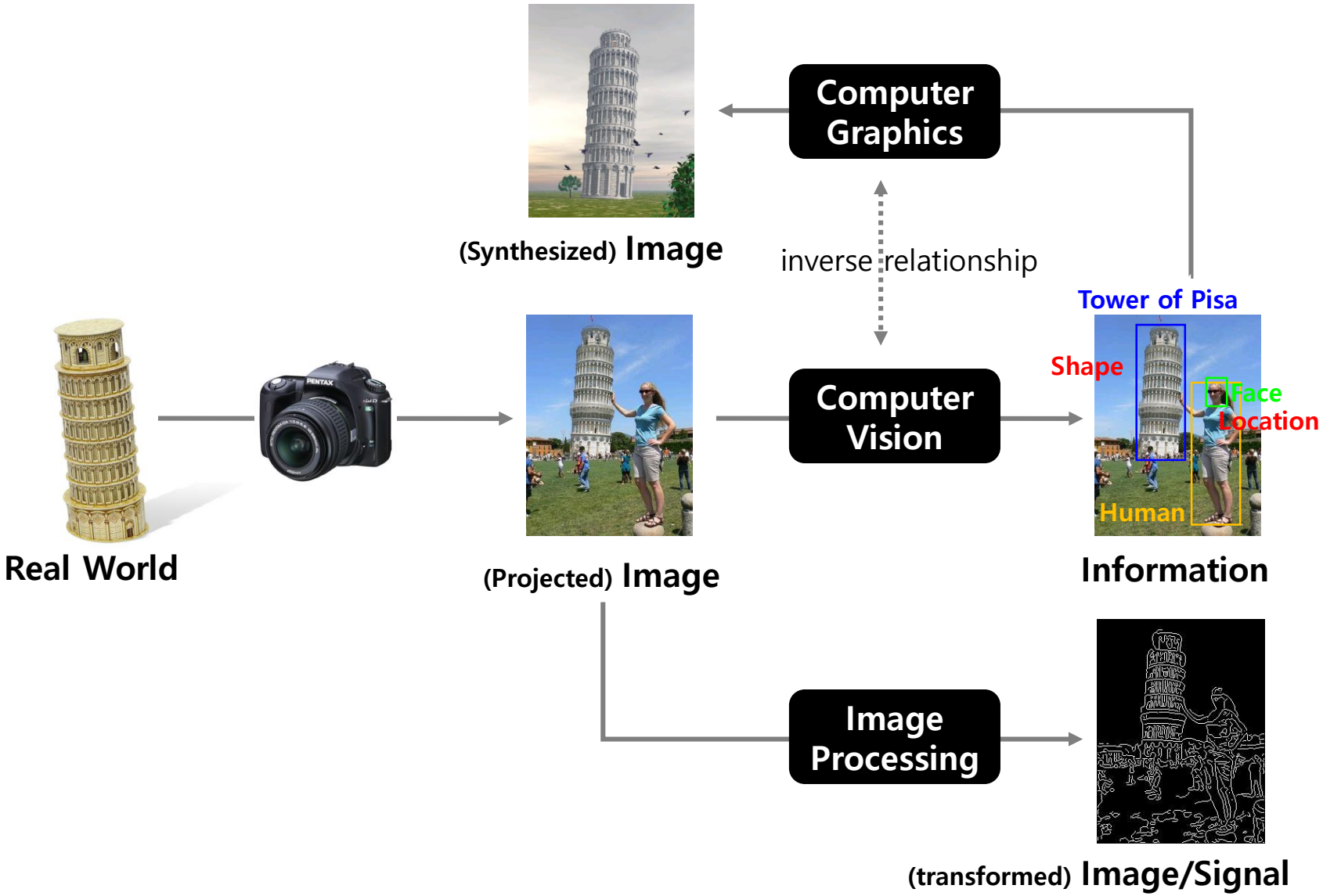
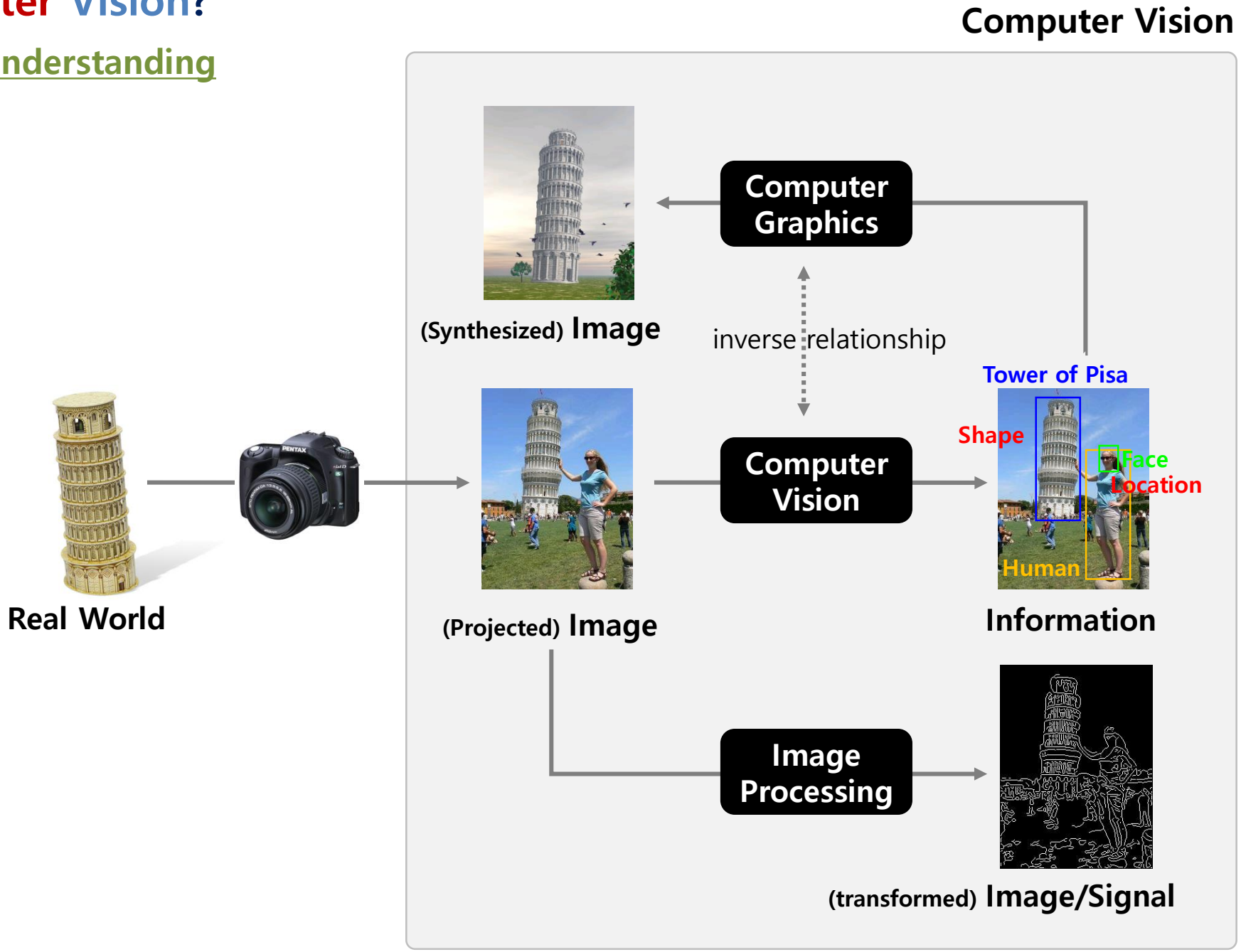
What is Computer Vision?

Image Understanding



What is Computer Vision?

Image Understanding



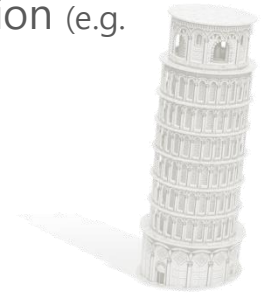
What is Computer Vision?

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?

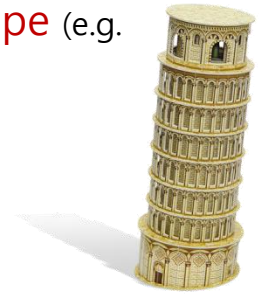
Visual Geometry

Multiple View Geometry

Geometric Vision

Computer Vision

What is it?

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

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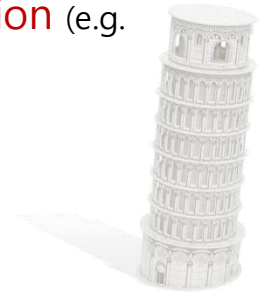
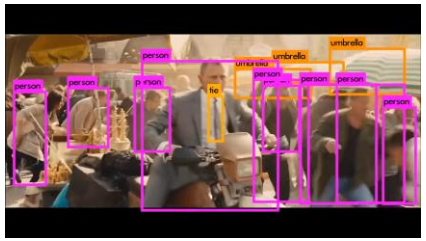
- Location (e.g. )

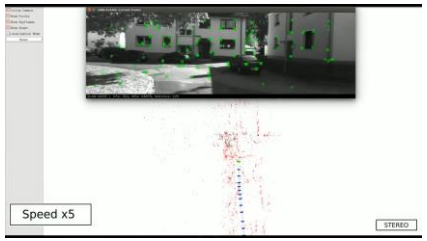
(84, 10, 18) [m]

Recognition Problems **v.s.** **Reconstruction Problems**

Stanford CS231n:
[CNN for Visual Recognition]



YOLO v2 (2016)



ORB-SLAM2 (2016)

Stanford CS231A:
[Computer Vision,
From 3D Reconstruction to Recognition]

What is 3D Vision?

image

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

Perspective Camera

3D Vision v.s. **3D Data Processing**

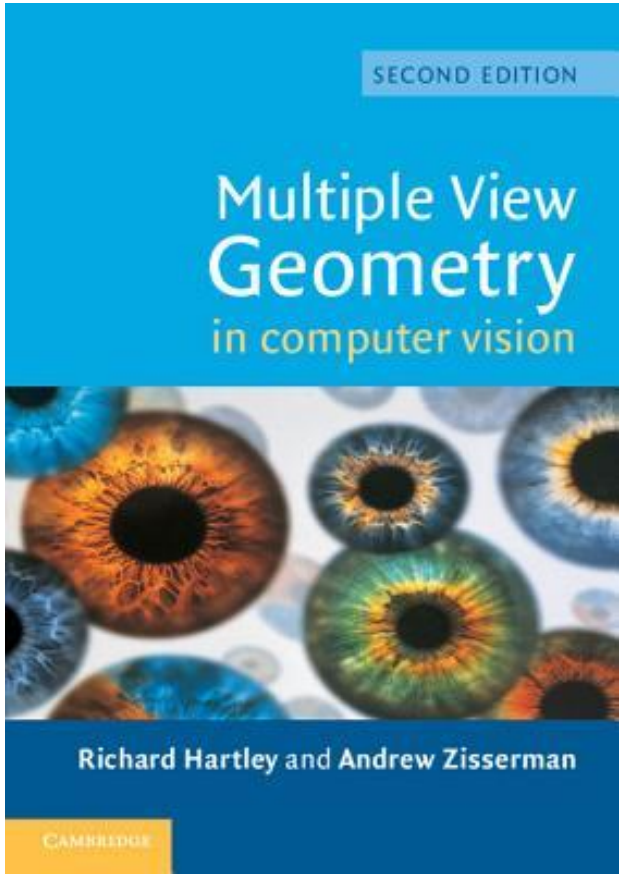
RGB-D Camera
(Stereo, Structured Light, ToF, Light Field)

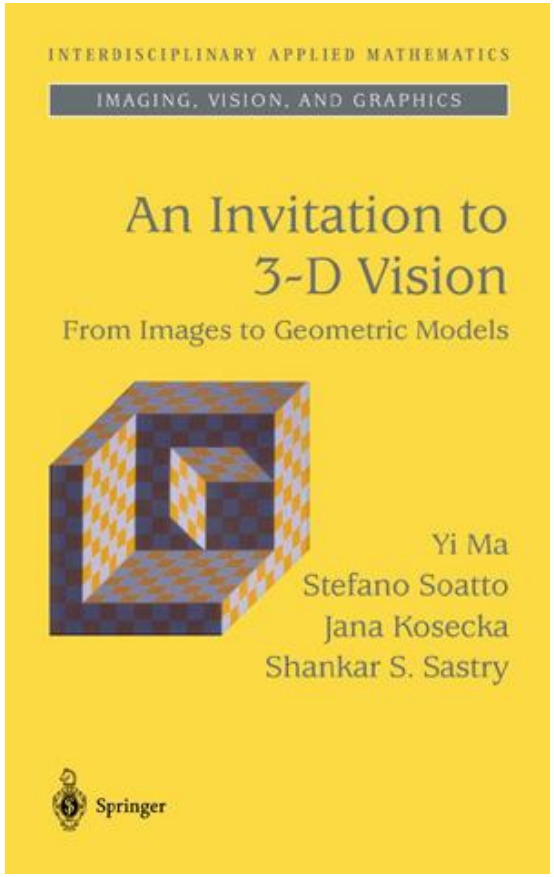
Omni-directional Camera

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.
  - 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:

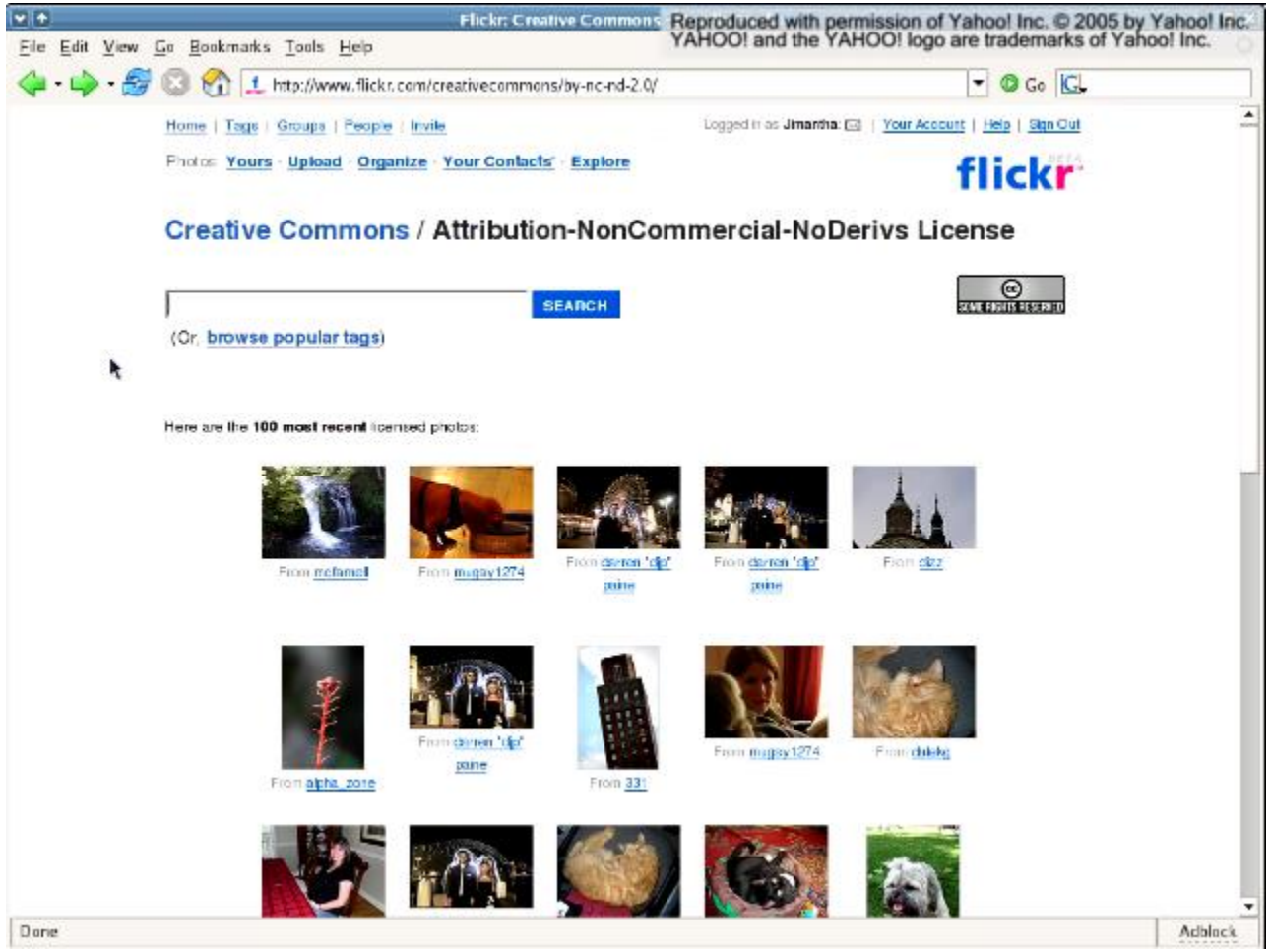
- core. Core functionality
- imgproc. Image Processing
- imgcodecs. Image file reading and writing
- videoio. Video I/O
- highgui. High-level GUI
- video. Video Analysis
- calib3d. Camera Calibration and 3D Reconstruction
- features2d. 2D Features Framework
- objdetect. Object Detection
- dnn. Deep Neural 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)

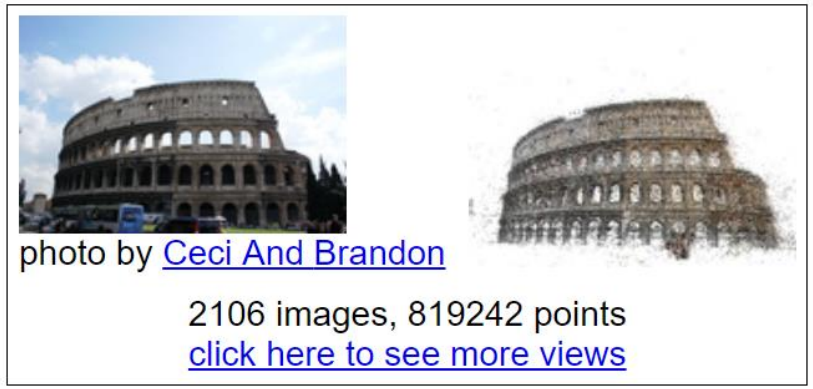


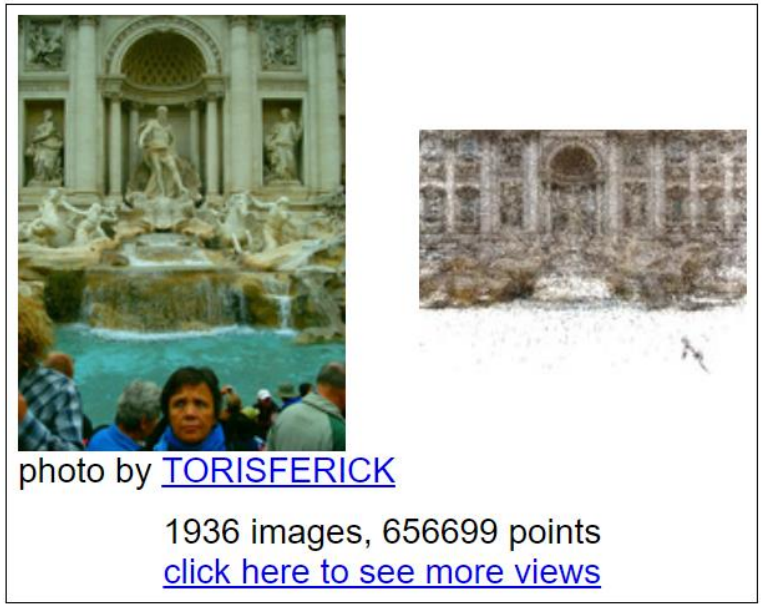
YouTube

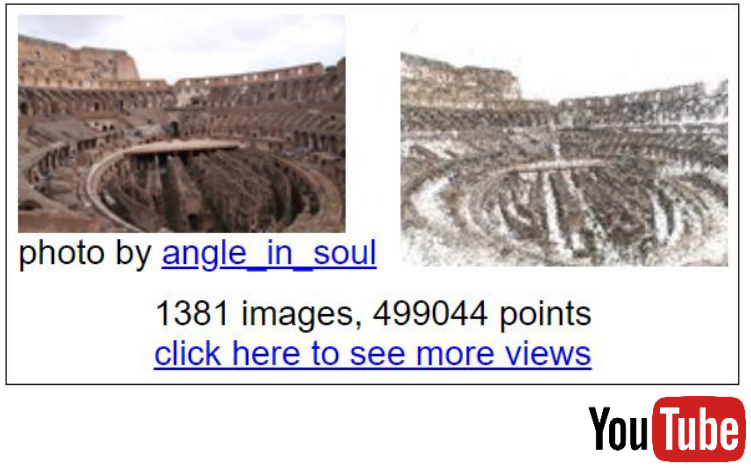
Reference: Snavely et al., **Photo Tourism: Exploring Photo Collections in 3D**, SIGGRAPH, 2006

Applications) 3D Reconstruction

- Building Rome in a Day (2009)





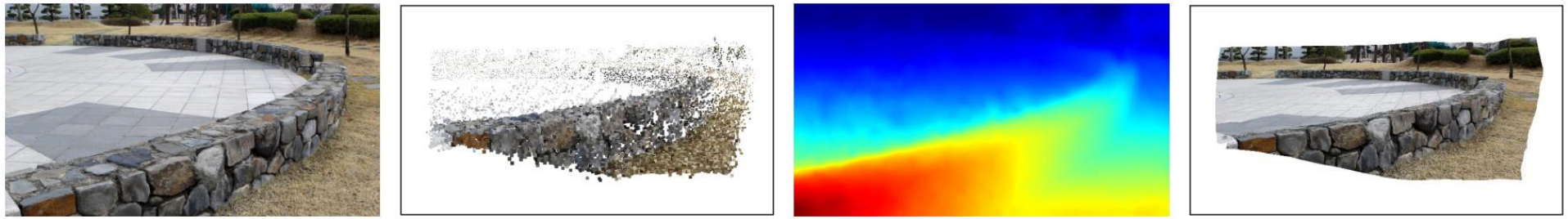


YouTube

Reference: Agarwal et al., **Building Rome in a Day**, ICCV, 2009

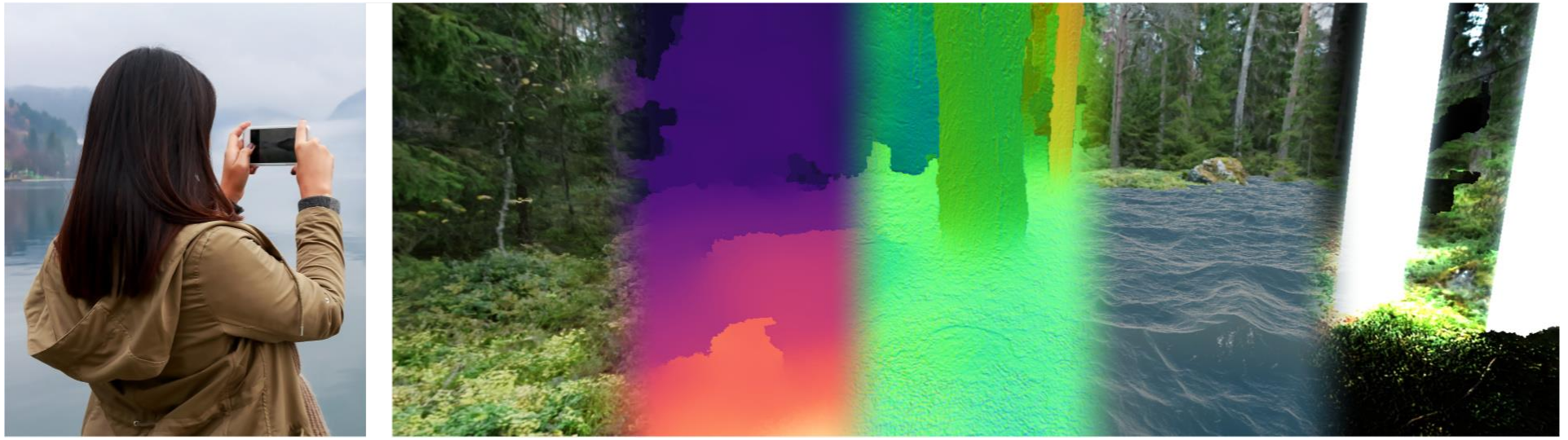
Applications) Depth Estimation from Cellular Phones

- Structure from Small Motion (SfSM; 2015)



(a) Reference images (b) SfSM results (c) Depth maps (d) Our 3D meshes

- Casual 3D Photography (2017)

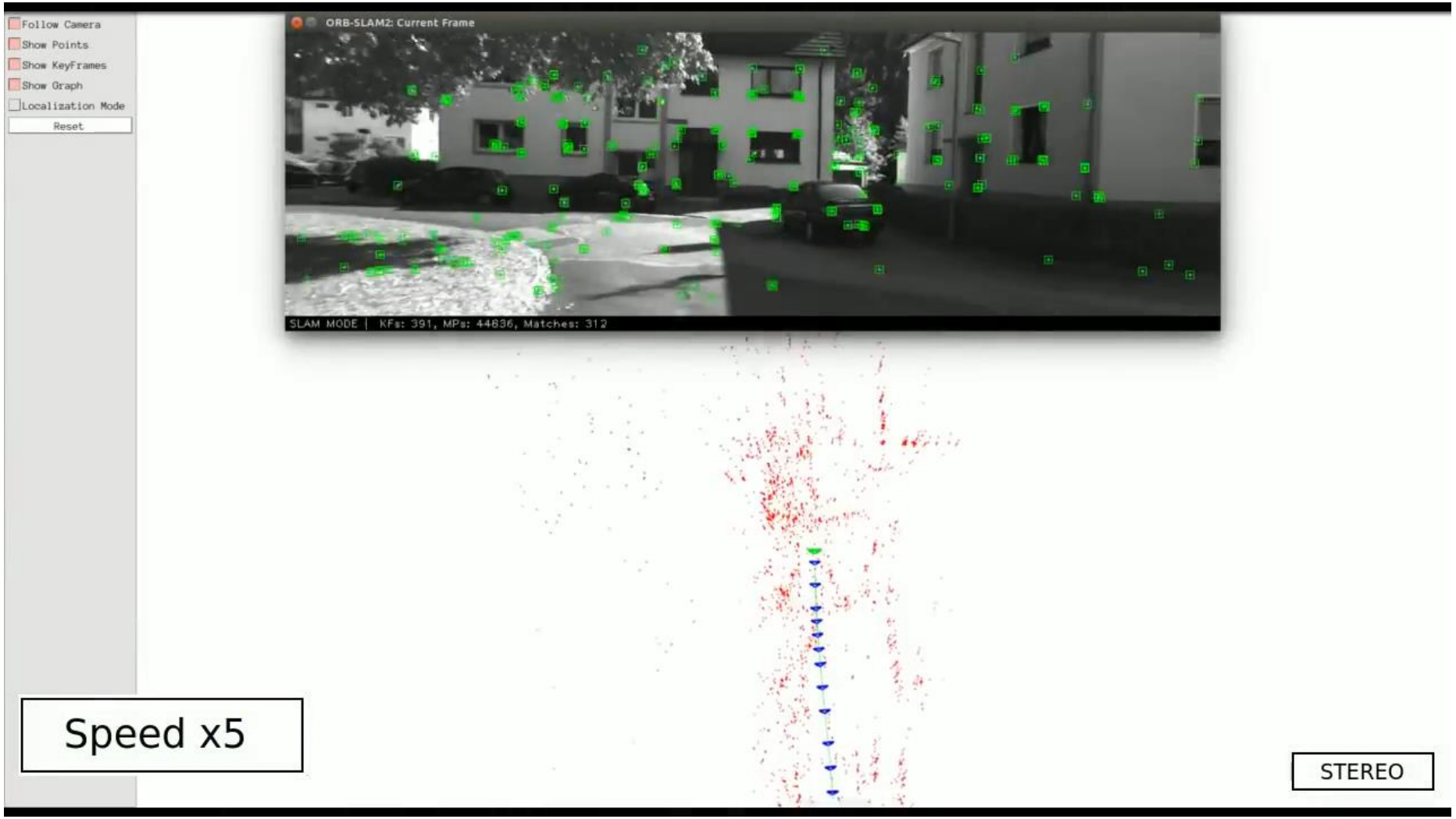


Casual 3D photo capture

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

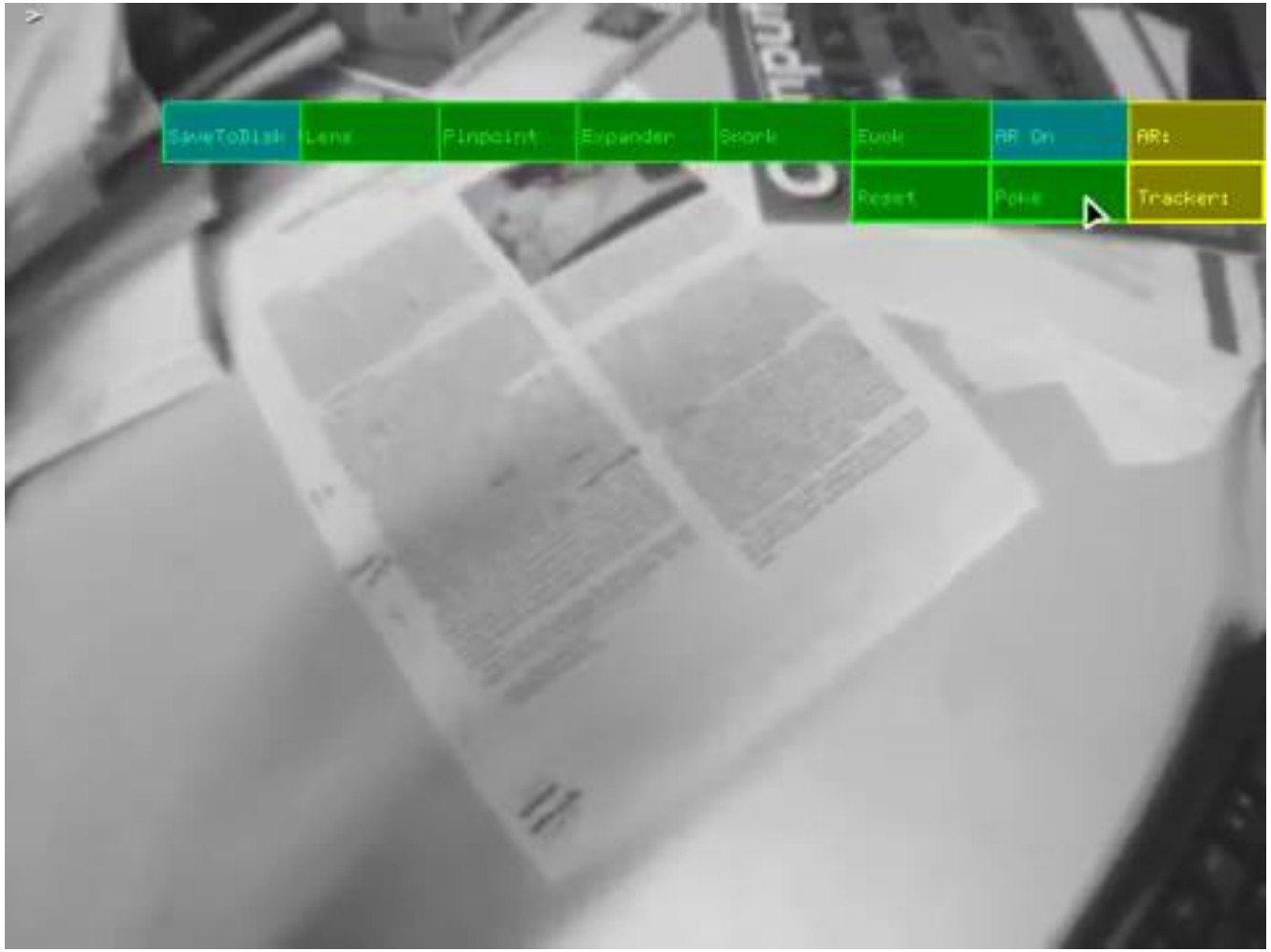
- ORB-SLAM (2014)



Reference: Mur-Artal et al., **ORB-SLAM: A Versatile and Accurate Monocular SLAM System**, T-RO, 2015

Applications) Augmented Reality

- PTAM: Parallel Tracking and Mapping (2007)



Reference: Klein and Murray, **Parallel Tracking and Mapping for Small AR Workspaces**, ISMAR, 2007

Applications) Virtual Reality

- Oculus Quest (2019)

Image: TechSpot

Applications) Mixed Reality

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

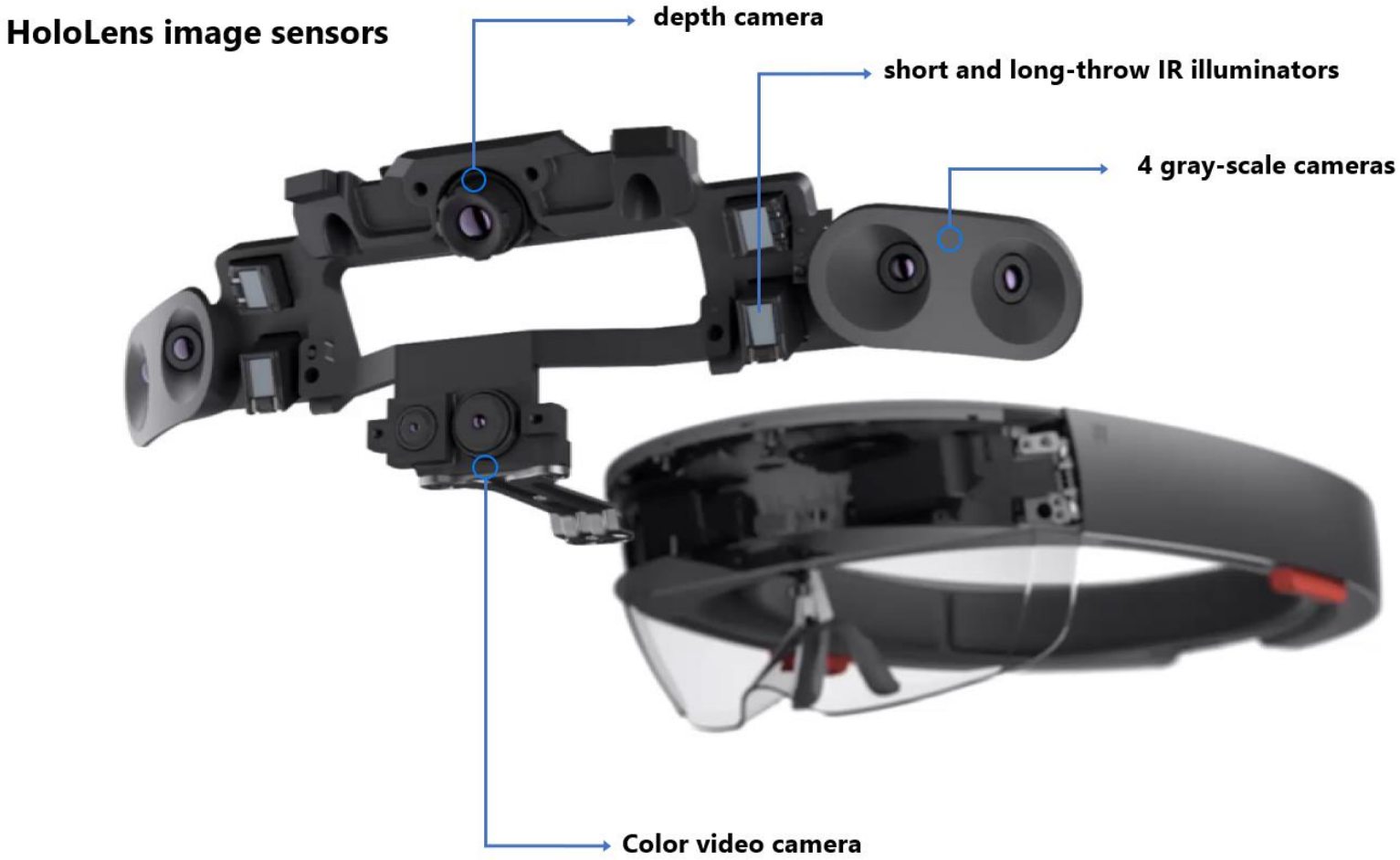


Image: SlashGear

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Summary

- **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 Correspondence**
- **Multiple-view Geometry**
- **Bayesian Filtering**
- **Visual SLAM and Odometry**