if a stranger on the train asked you about

Computer Vision

Simen Haugo

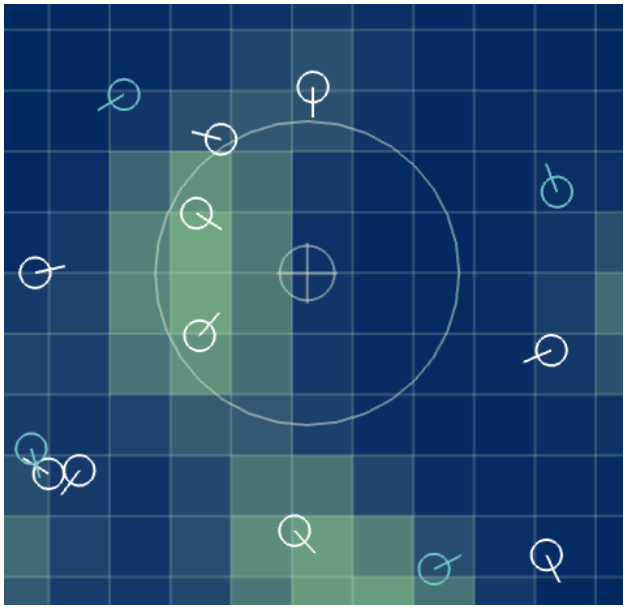
Mentor at Ascend NTNU and PhD student

@uint9

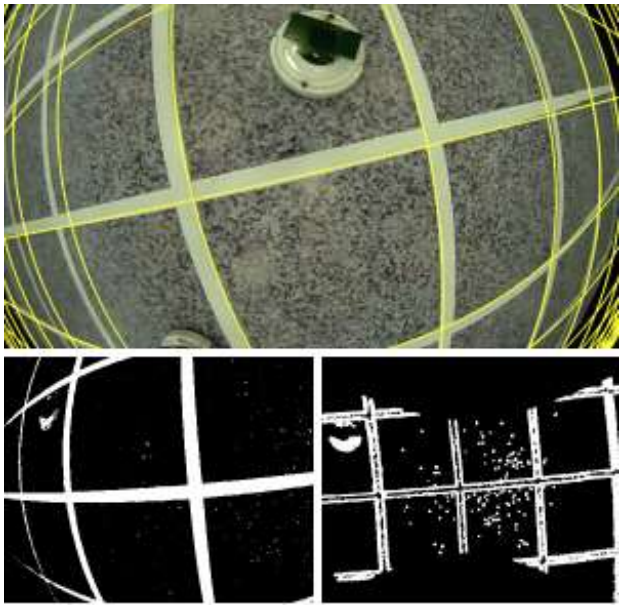
IARC Mission 7



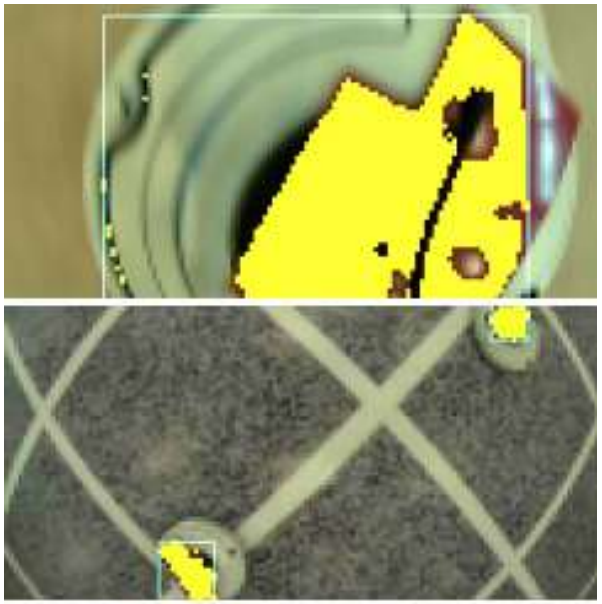

How I got into computer vision



2015
AI

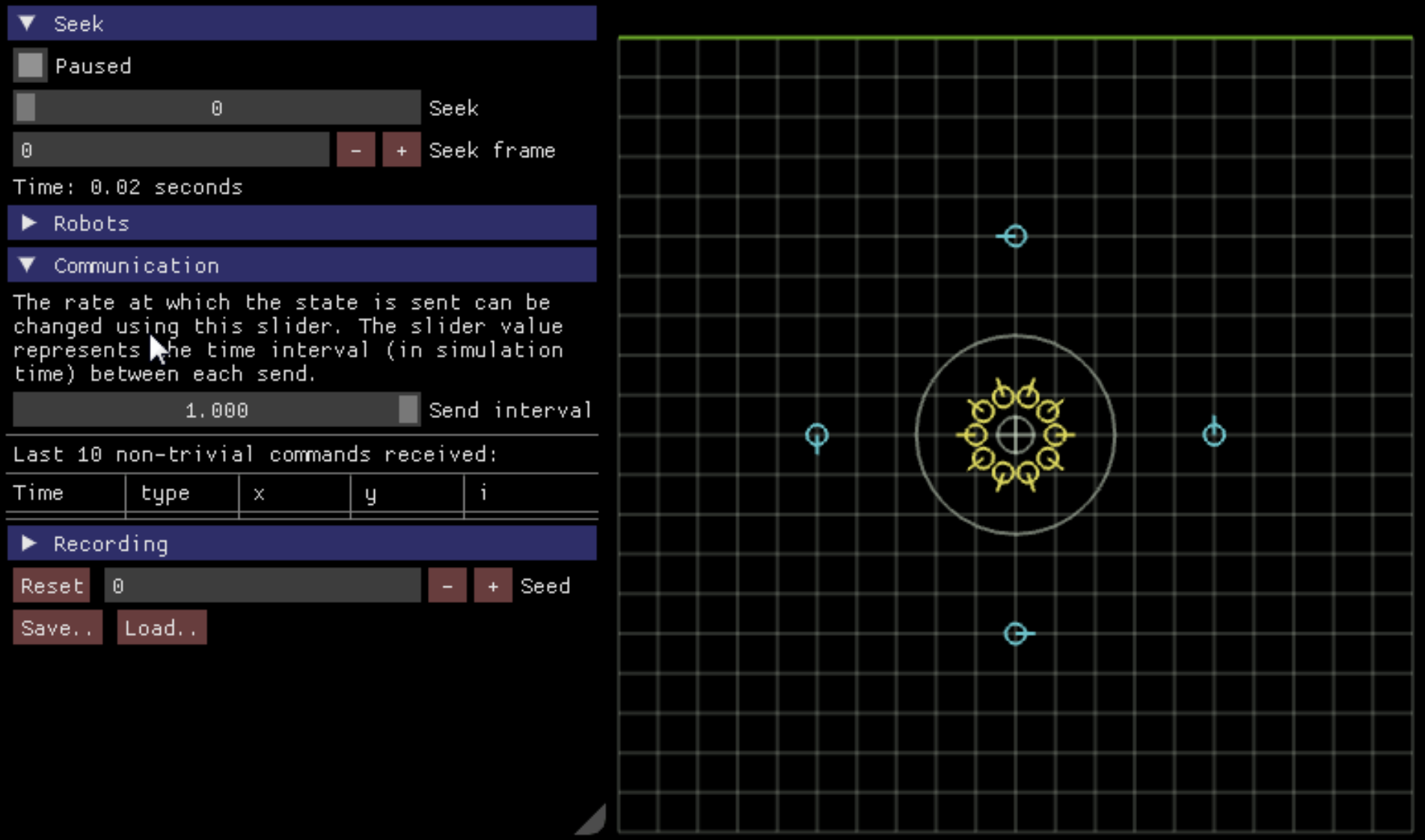


2016
Localization



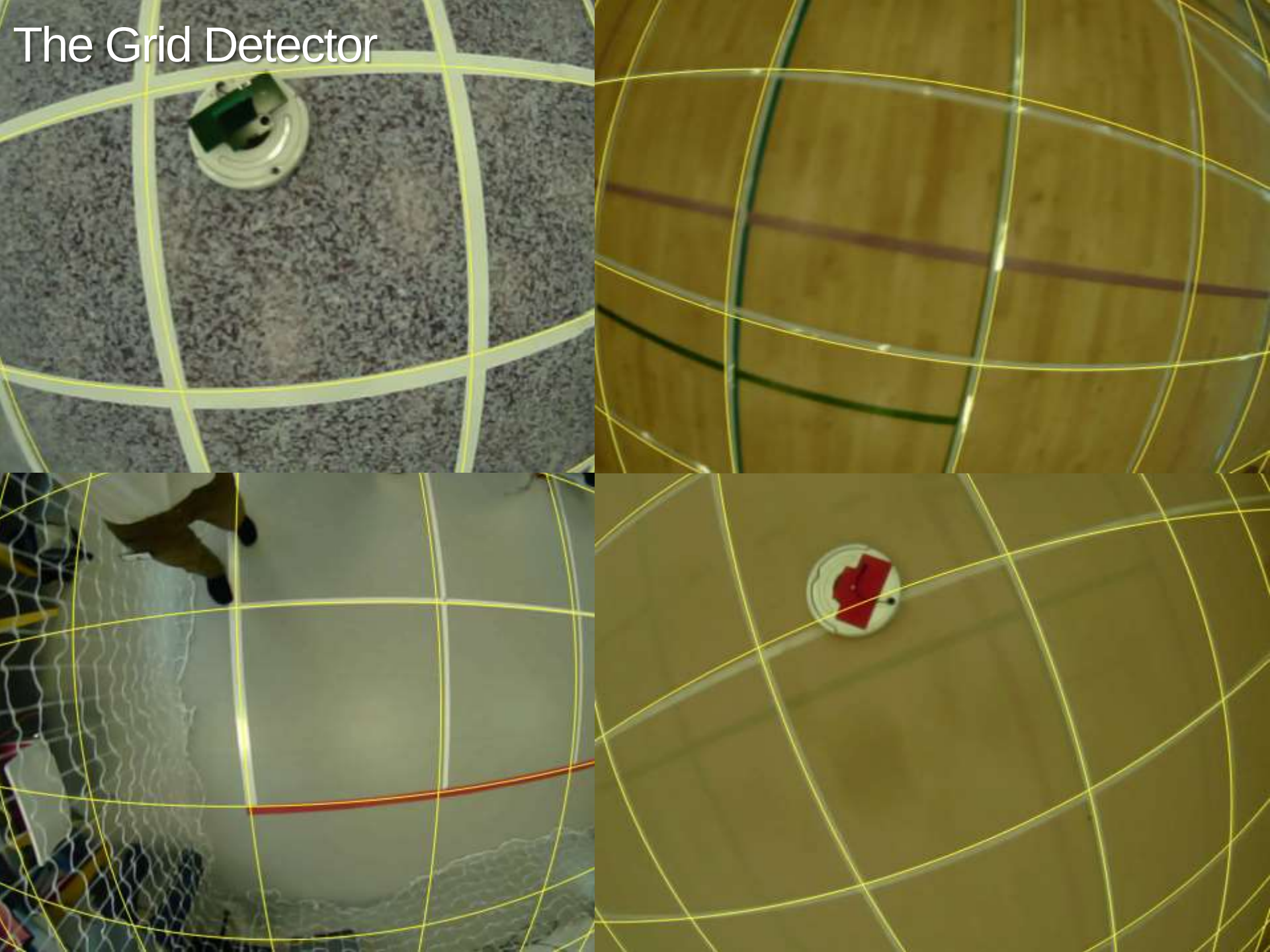
2017
Tracking

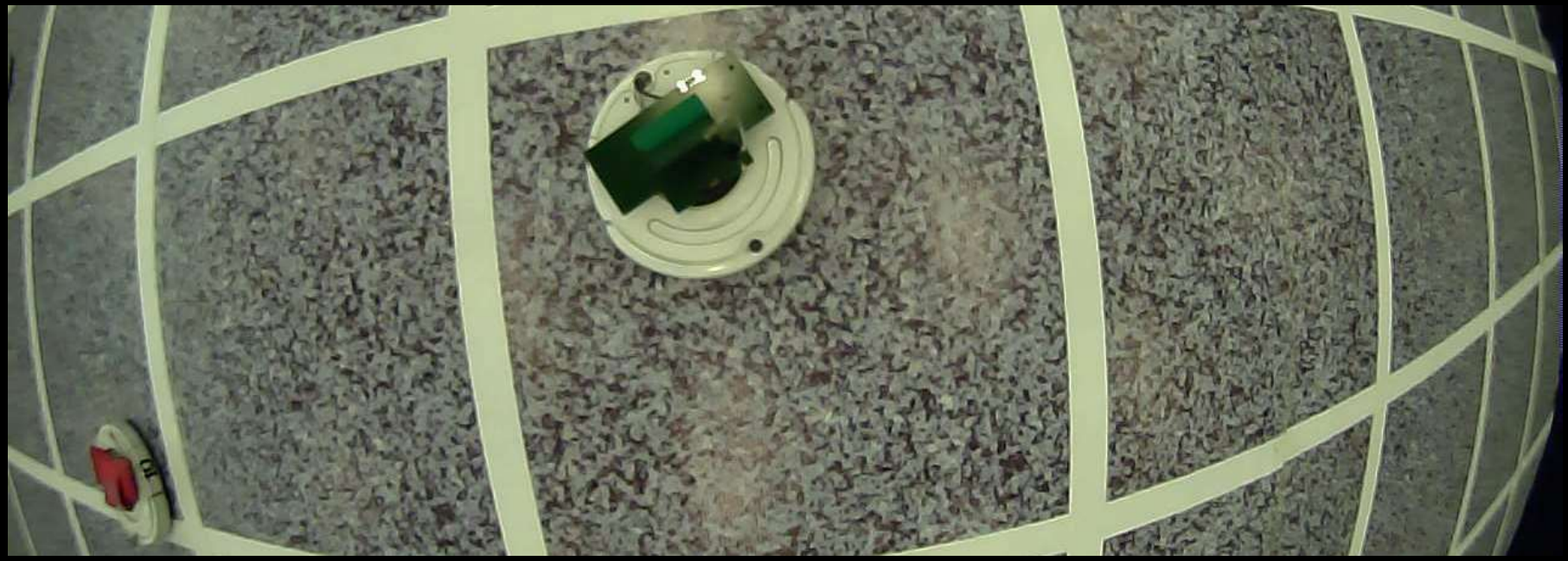
Mission simulator

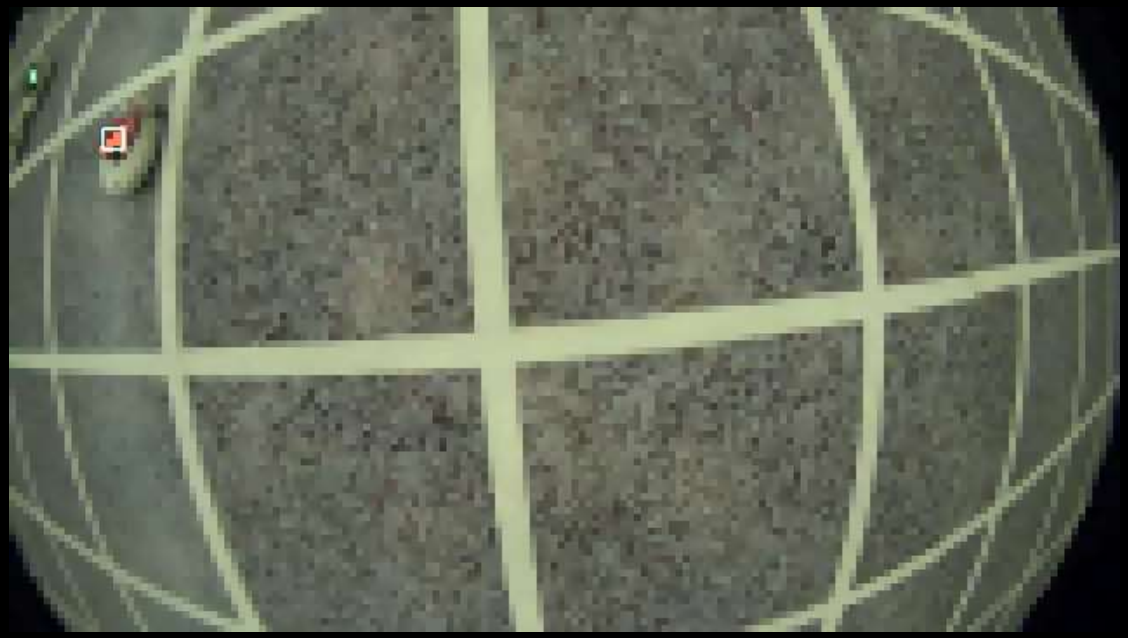



The Grid Detector

The Grid Detector





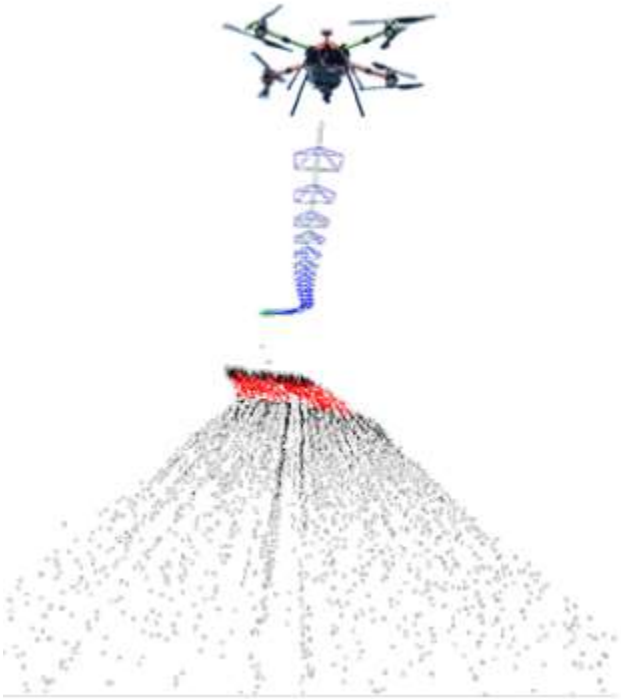


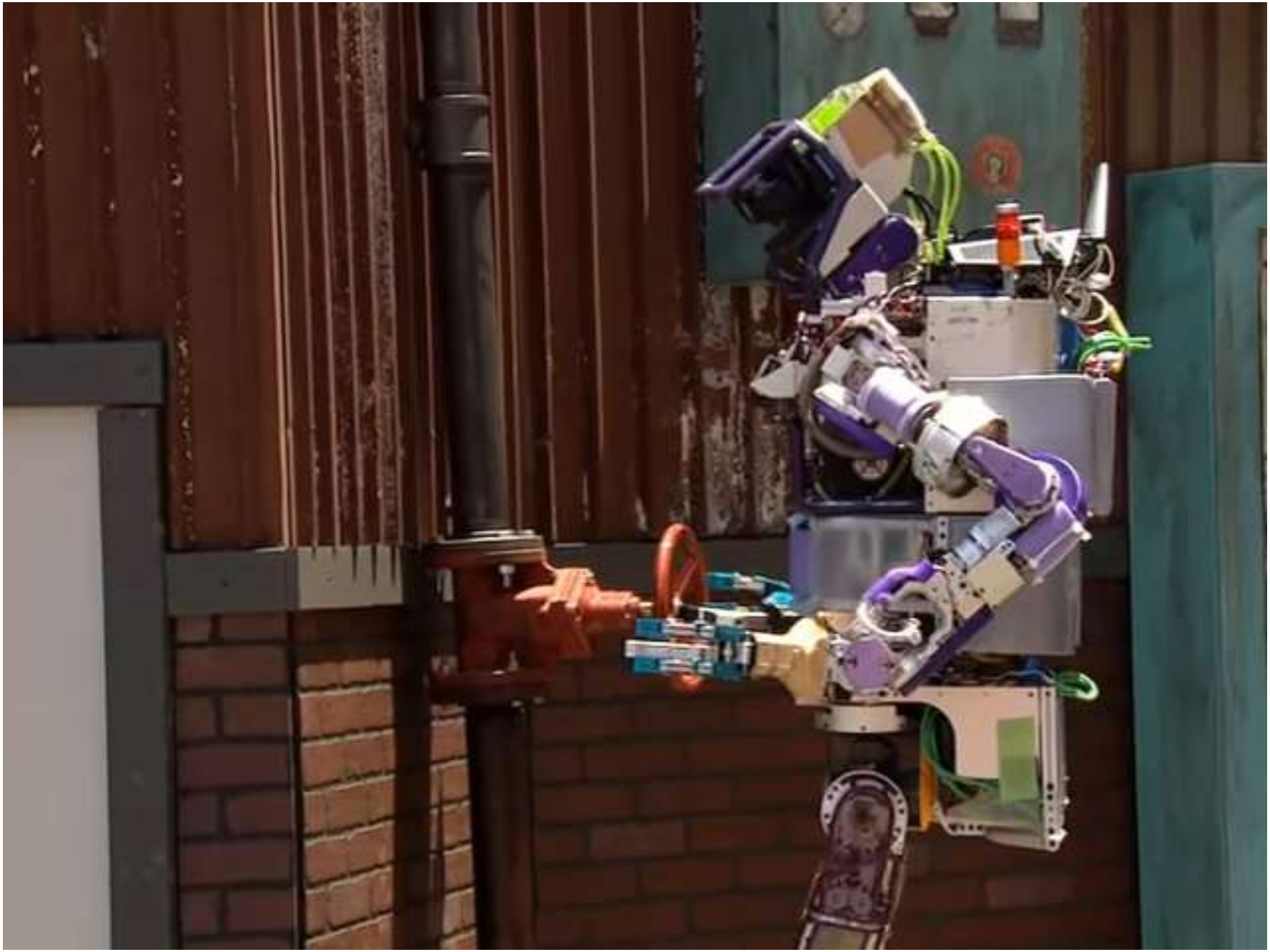
What I’m doing now

1. Ph.D at NTNU Robot Vision Group

2. Mentor for Ascend

NTNU Robot Vision Group

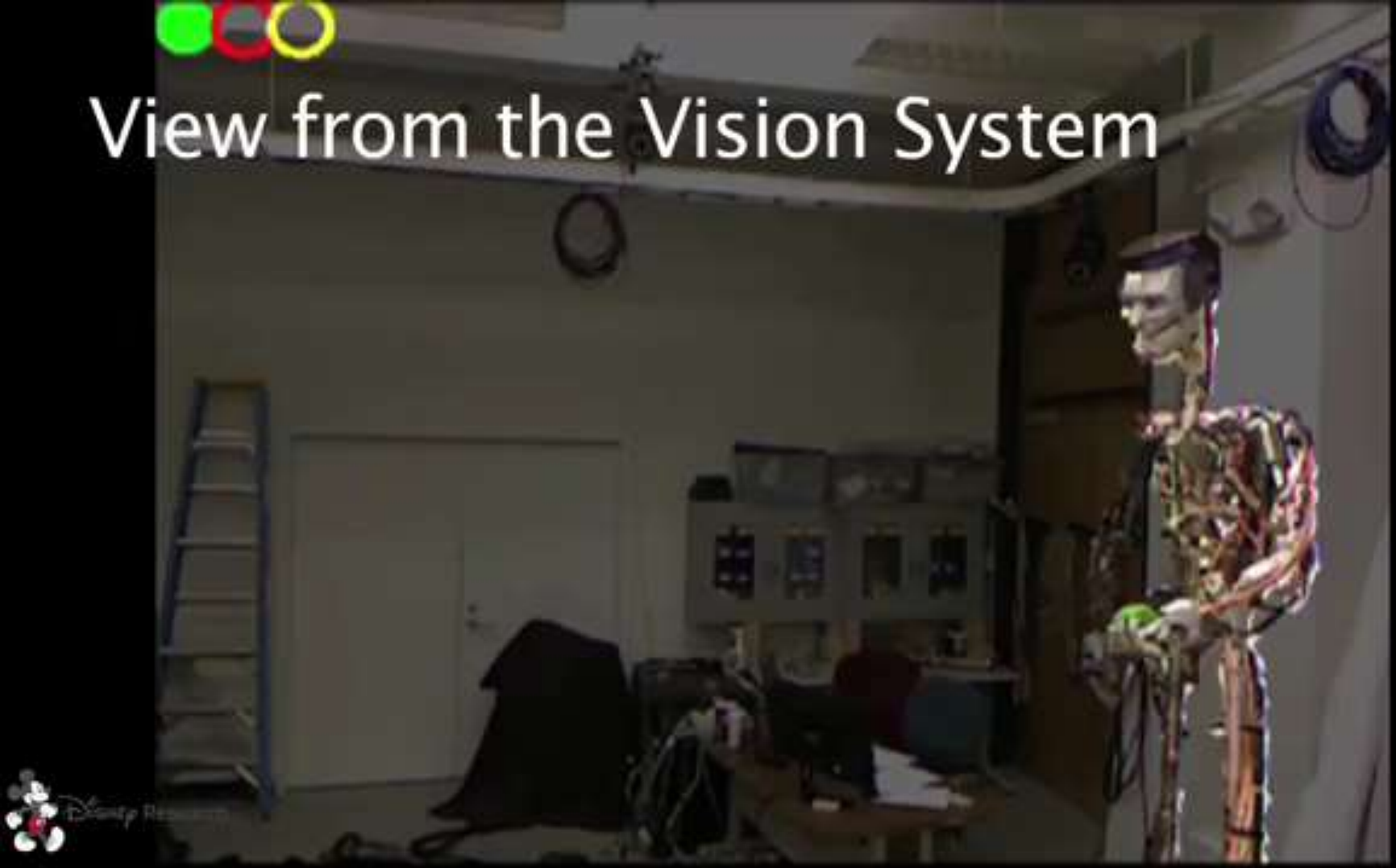




DARPA Robotics Challenge 2015


Untrained Participants

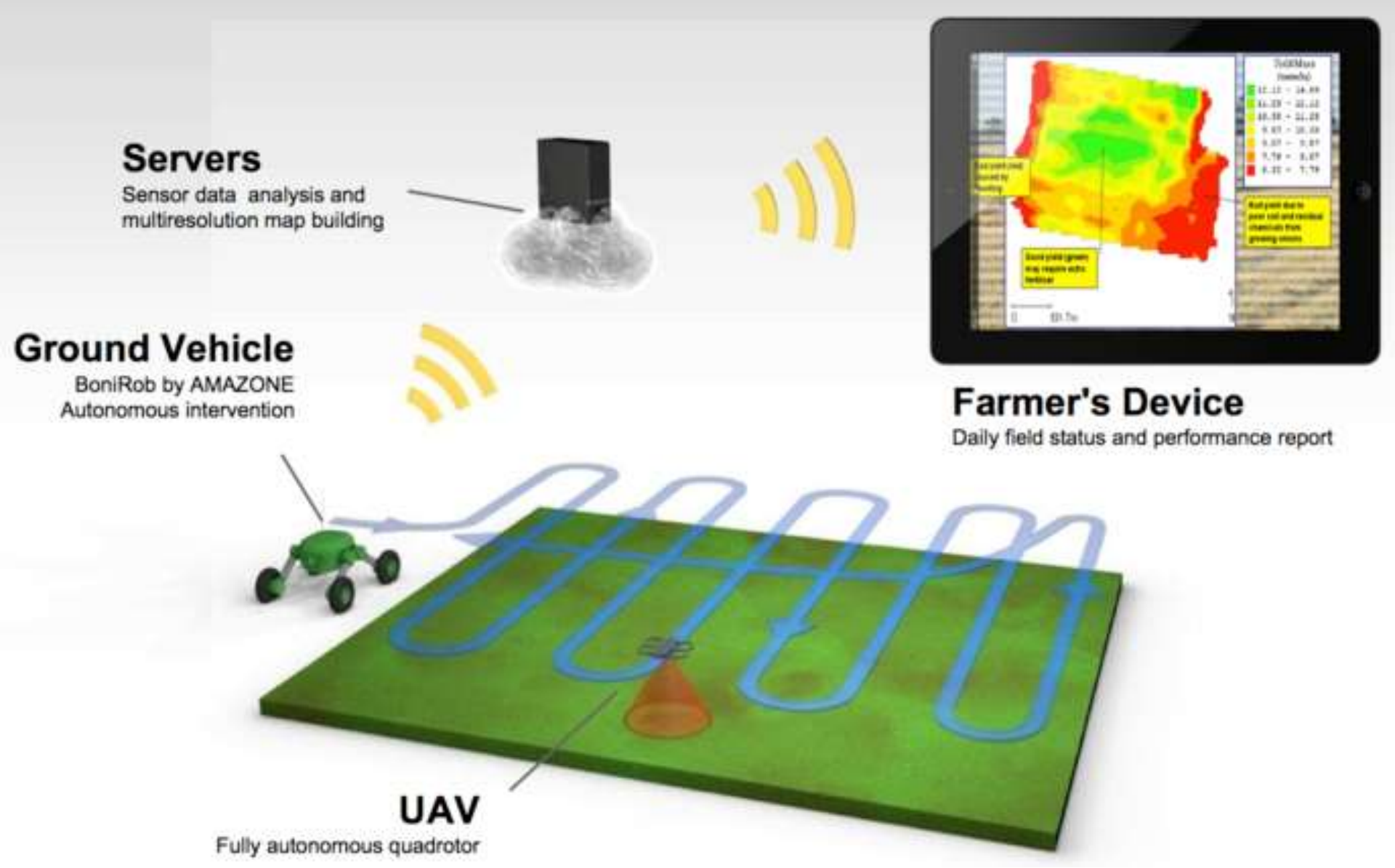

Untrained Participants


View from the Vision System

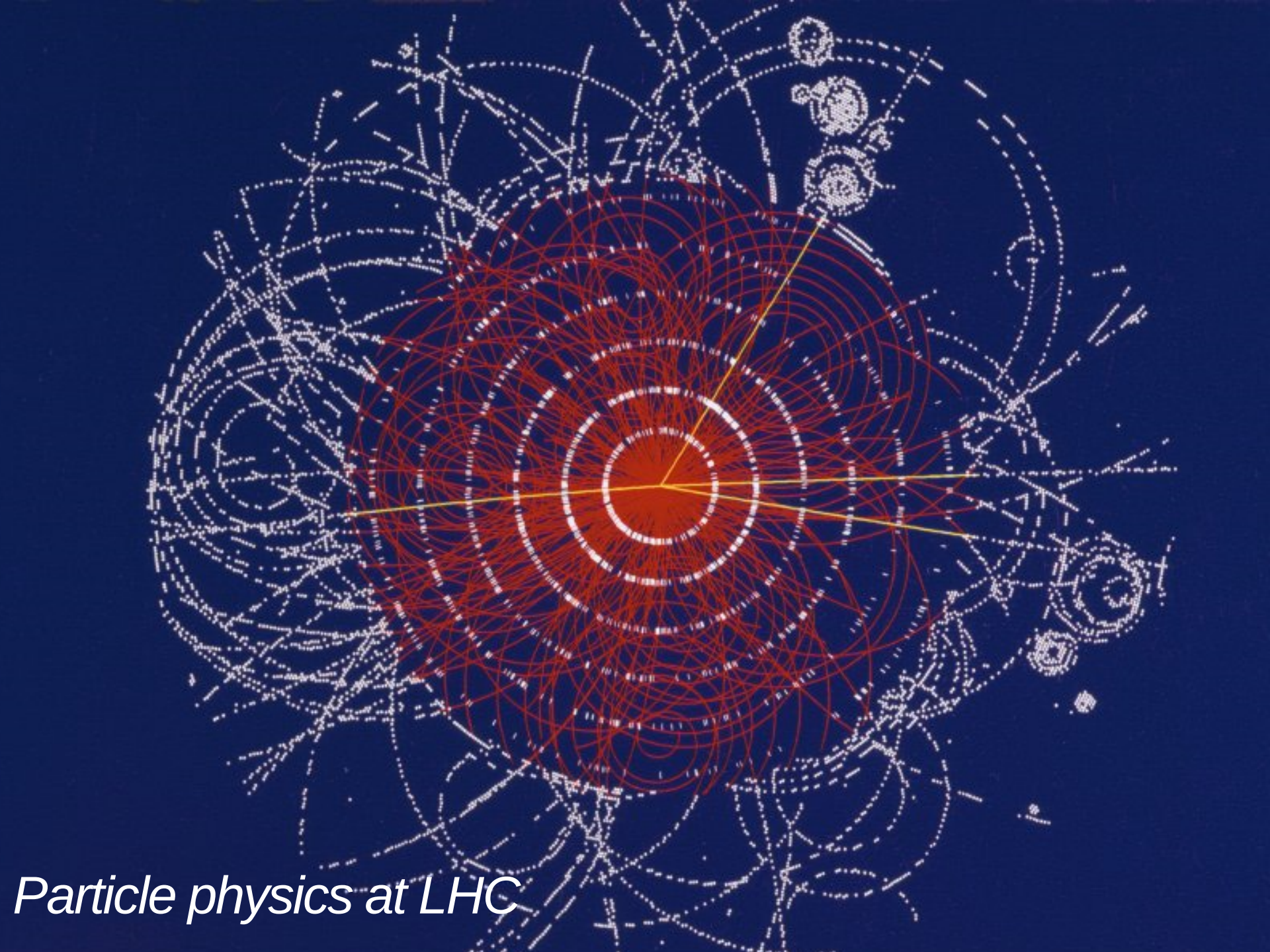

Untrained Participants


Adigo: Asterix

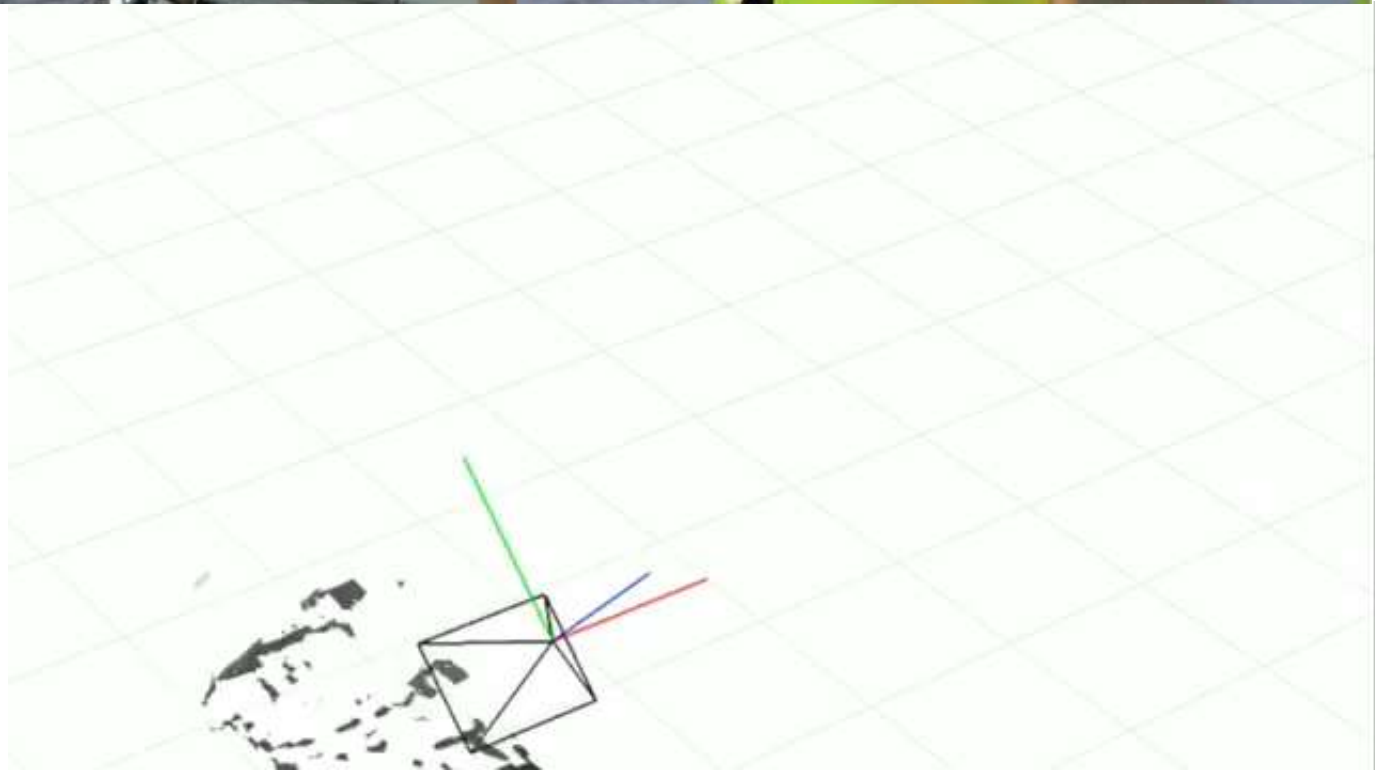

Adigo: Asterix



Flourish project



Particle physics at LHC

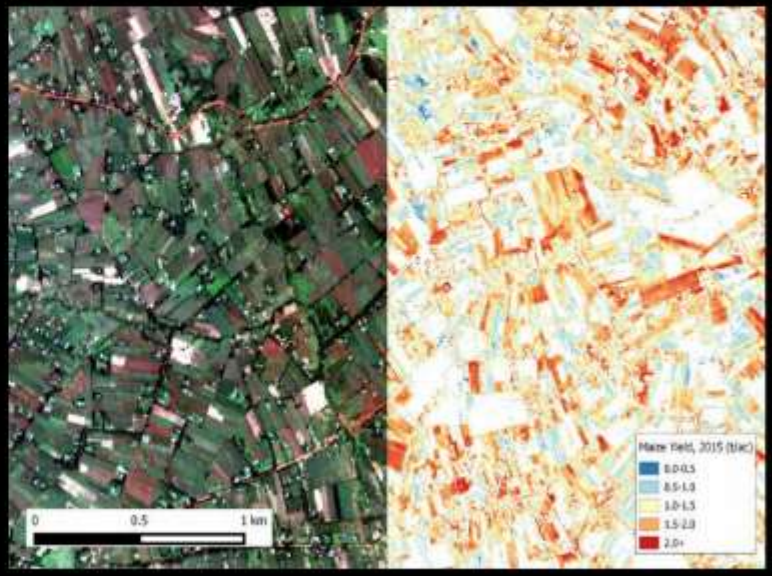


Imerso AS

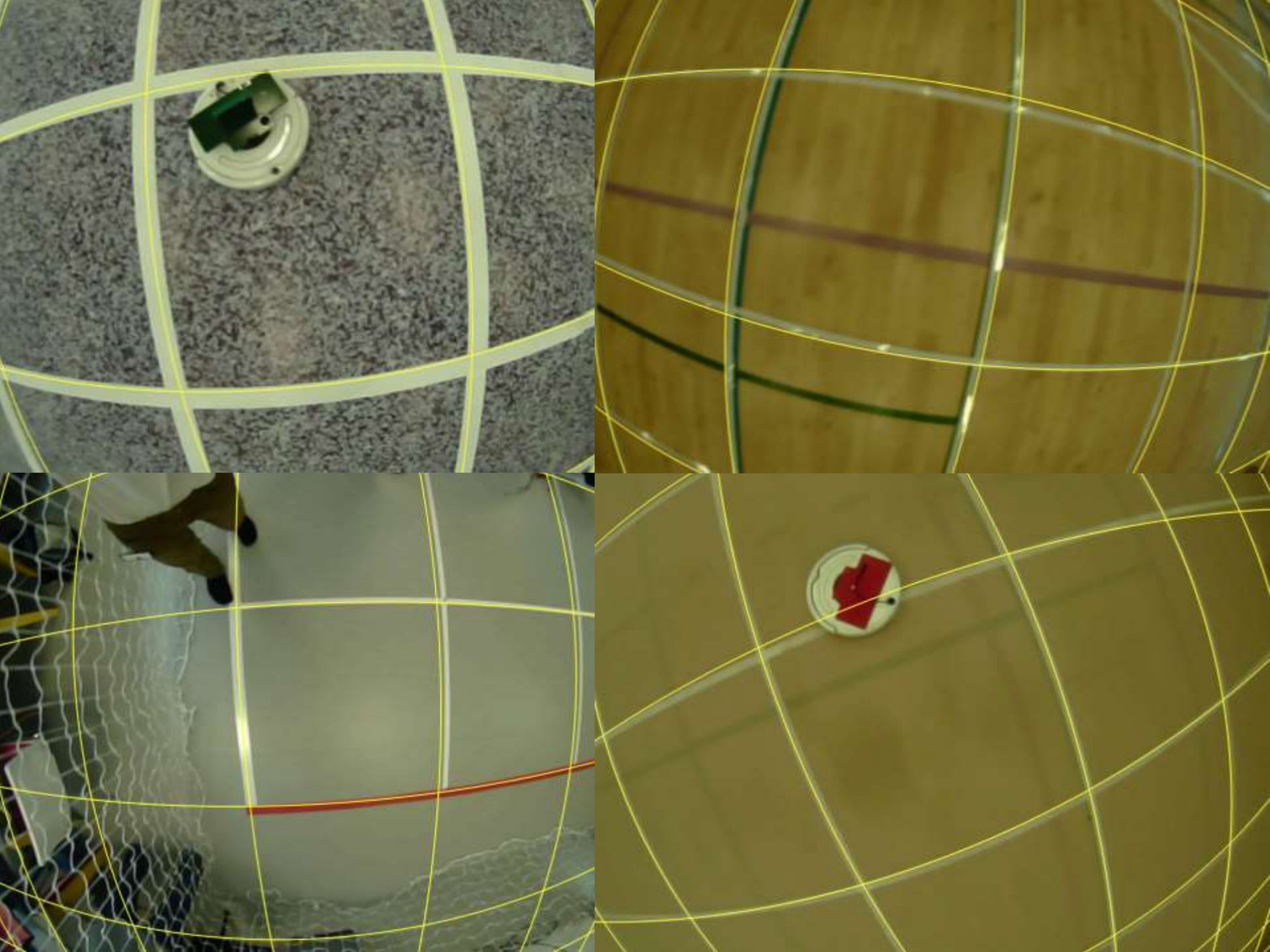
Planet Labs

Planet Labs: Disaster Data

Predicting Smallholder Productivity in Kenya and Nigeria



Planet Labs



The Pattern Hough Transform for Crop Row Detection

Wera Winterhalter, Freya Fleckenstein, Christian Dornhege and Wolfram Burgard

AiS

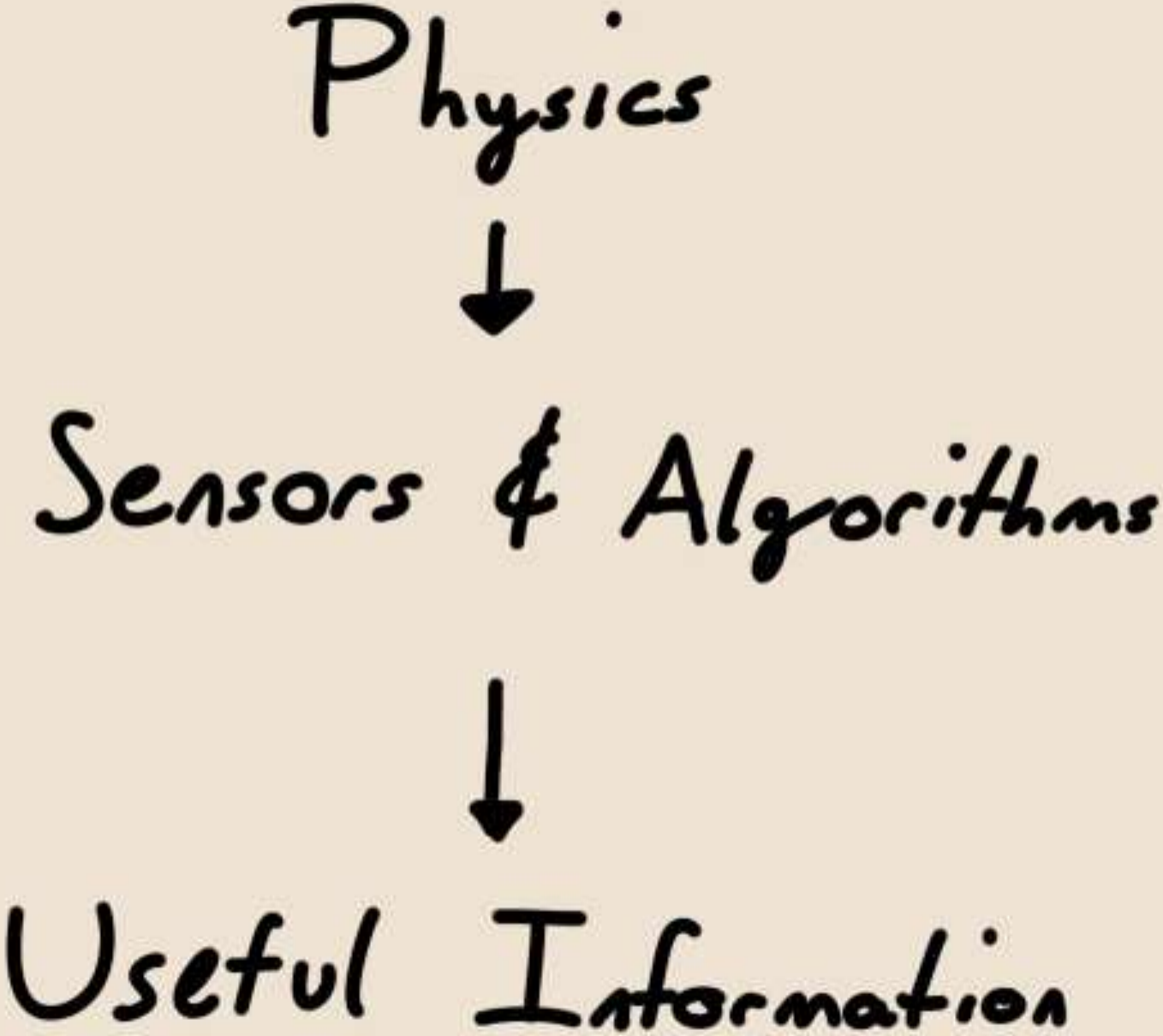
Flourish project

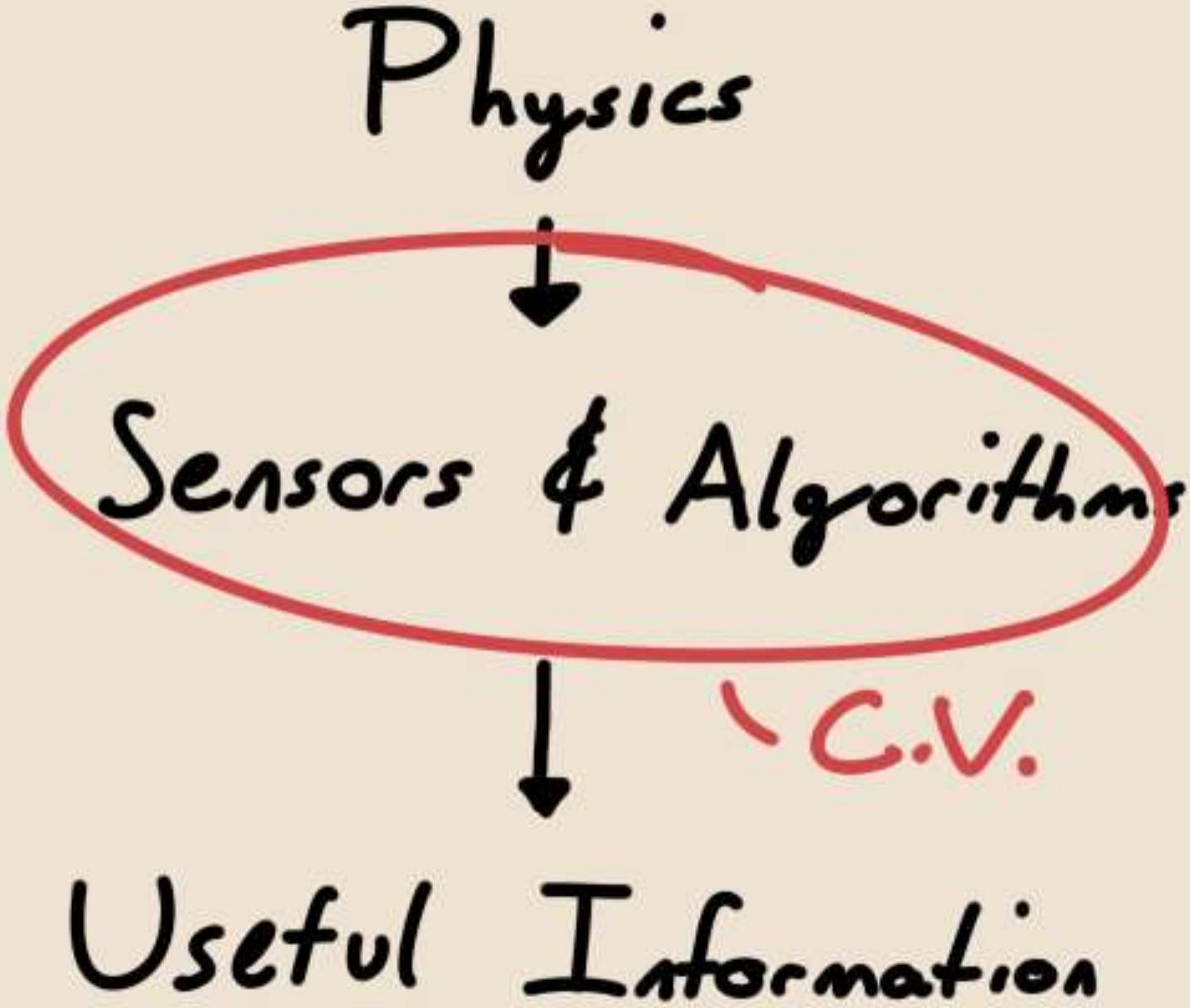
← Part 1 - What is computer vision?

Part 2 - How do I solve problems? →

← Part 1 - What is computer vision?

Part 2 - How do I solve problems? →

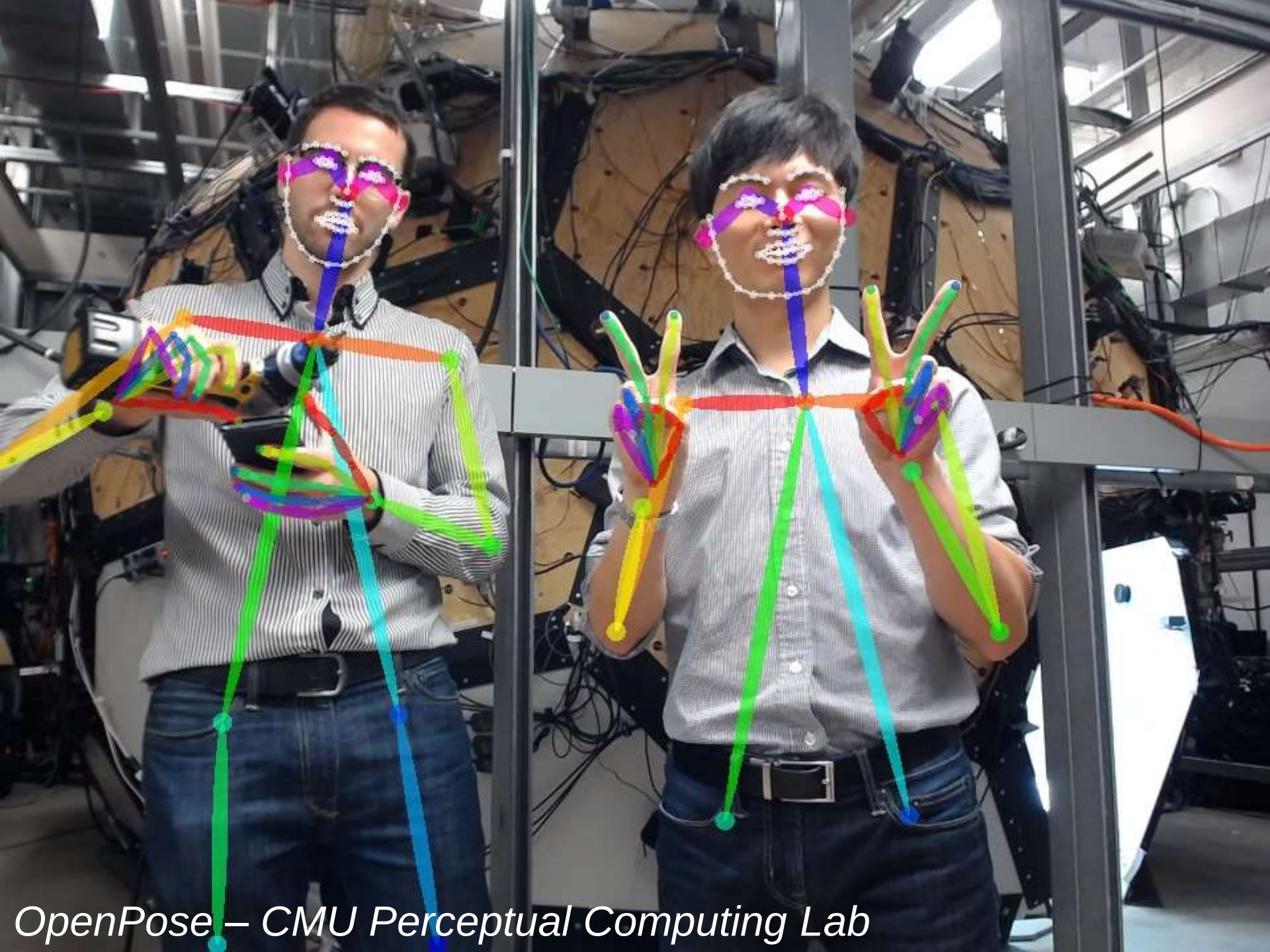

Physics
Sensors & Algorithms
Useful Information


Physics
Sensors & Algorithms
C.V.
Useful Information


The
Hardware & Software
Tradeoff


CMU Panoptic Dataset


CMU Panoptic Dataset

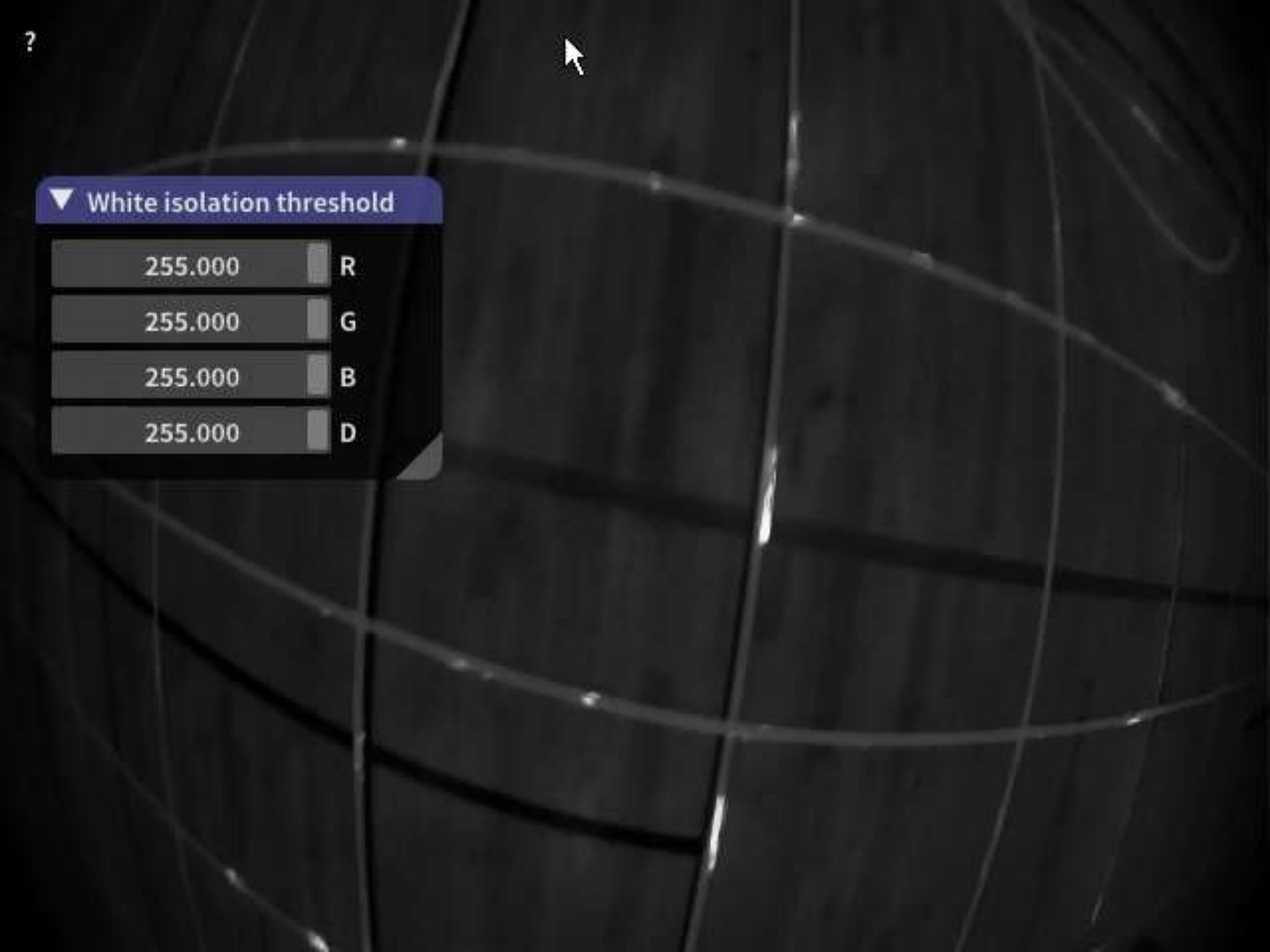

OpenPose – CMU Perceptual Computing Lab

Hand-Clapping Games with a Baxter Robot

Choose your hardware

Step 1: Get a visualizer


line detection done...
angle distance votes
1.75 50.38 193
1.56 127.83 31
0.18 162.11 31
1.73 167.68 195
0.17 274.04 186
0.13 374.56 238
0.00 463.02 42
0.10 483.13 54
8 lines found


?
White isolation threshold
255.000
R
255.000
G
255.000
B
255.000
D

1

Input

2

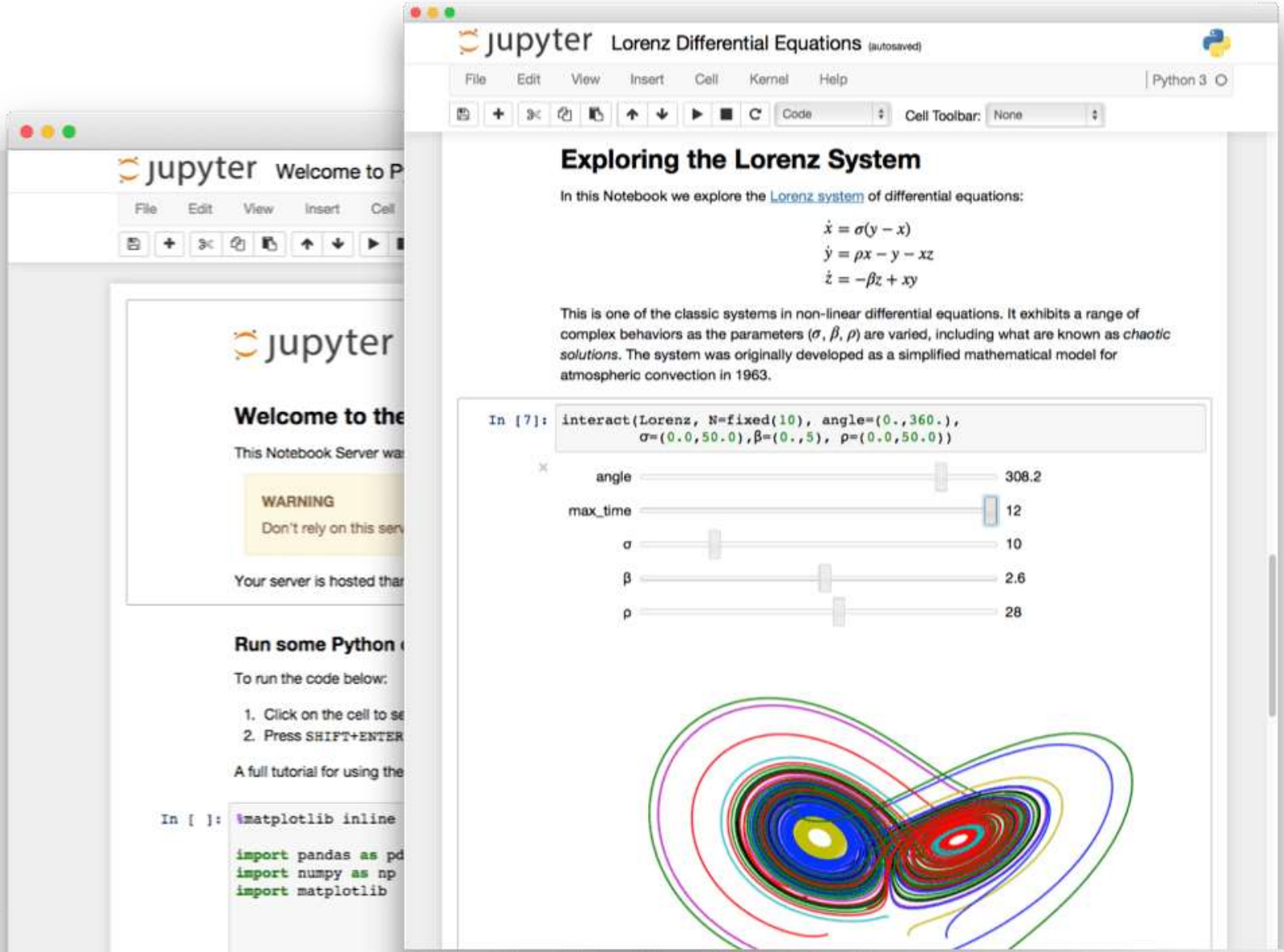
White color filter

3

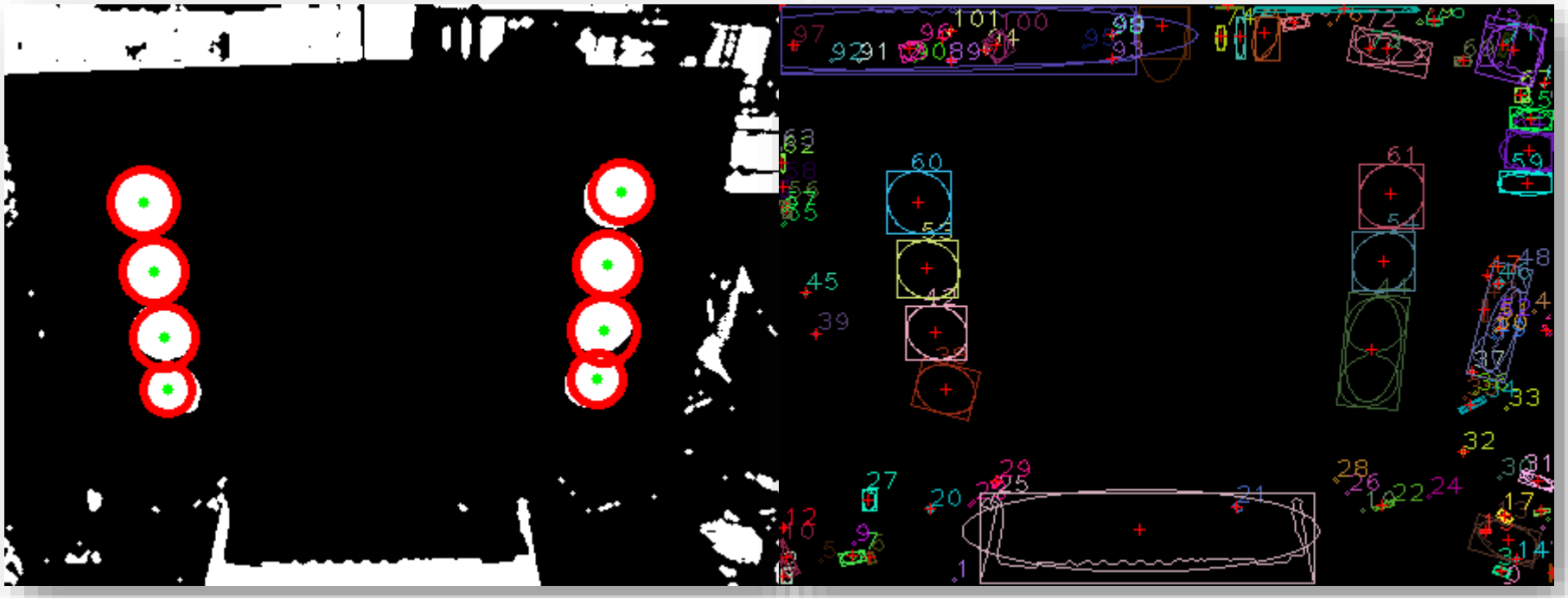
Dewarp fisheye

Visualization tools

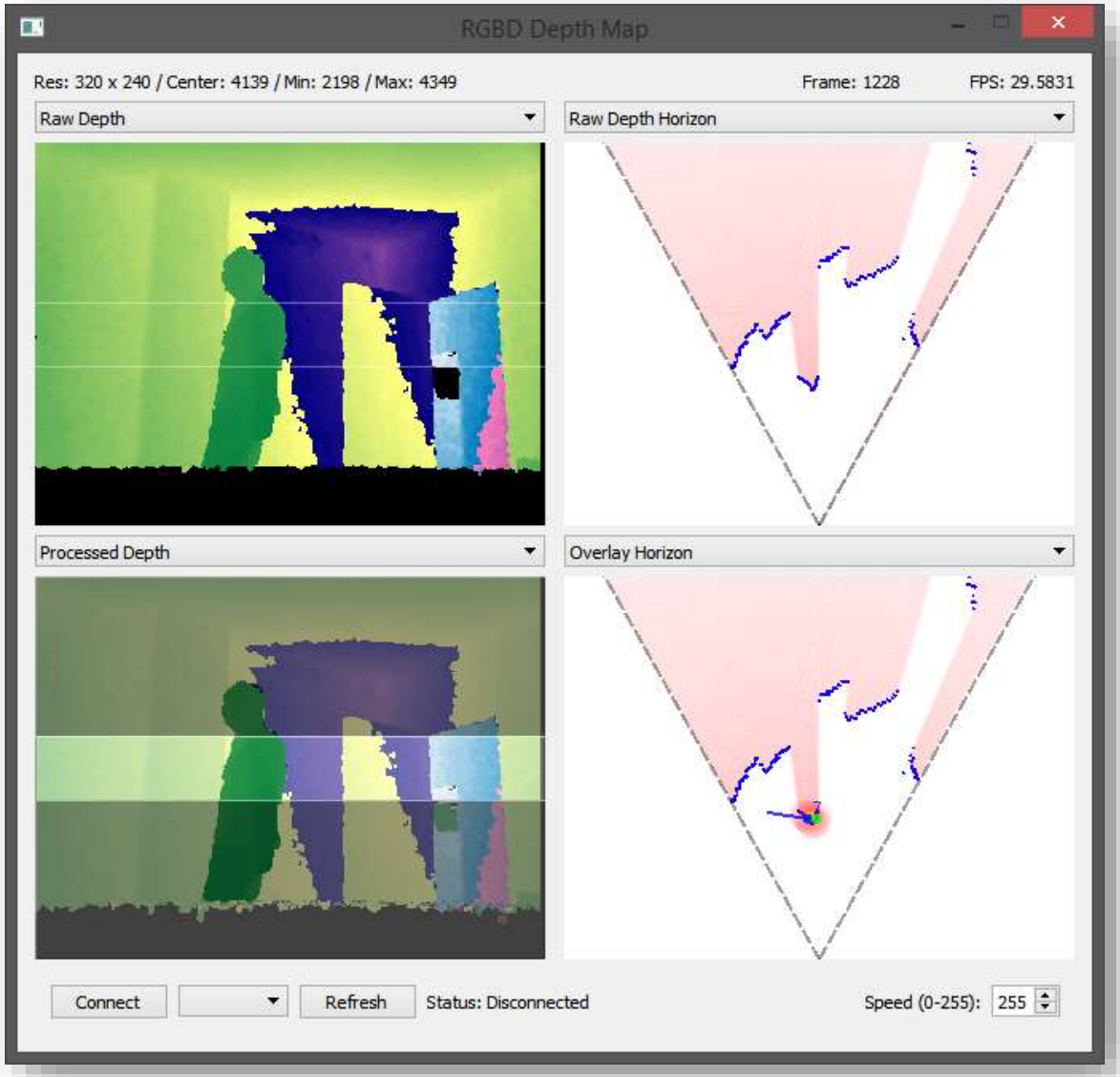
Jupyter Notebooks



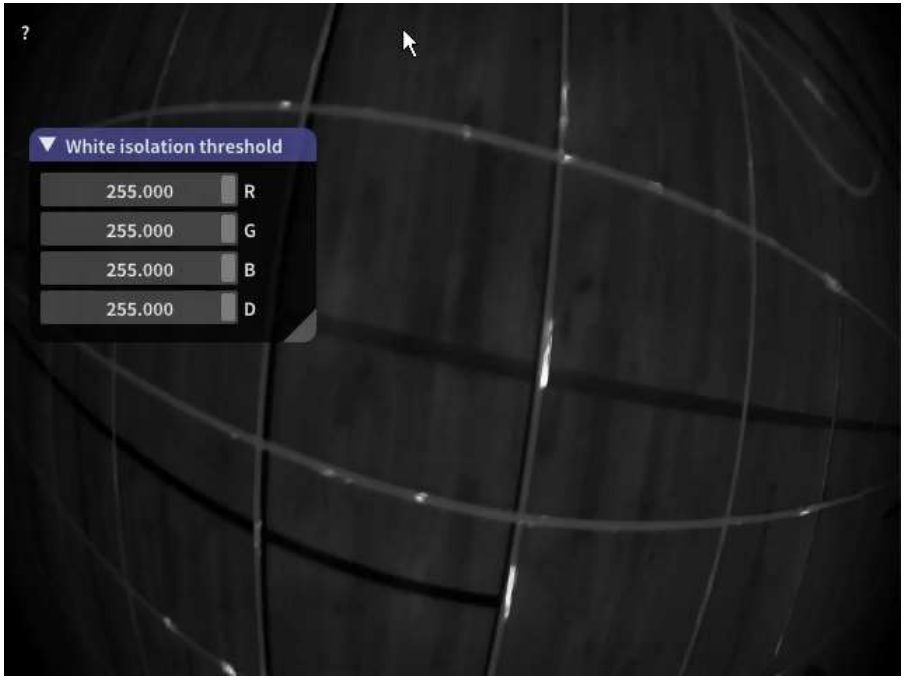
OpenCV

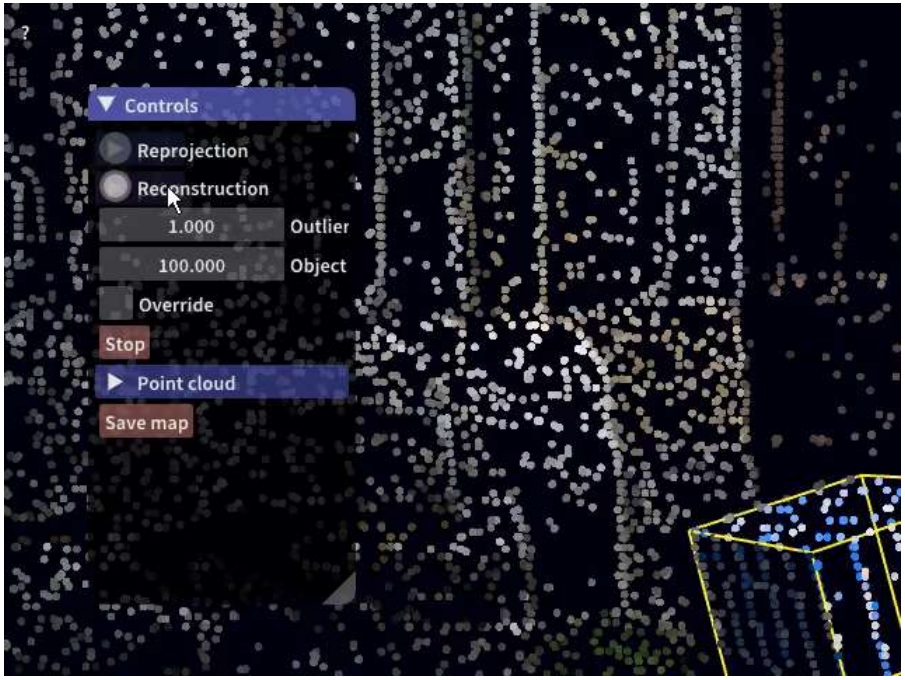


Qt

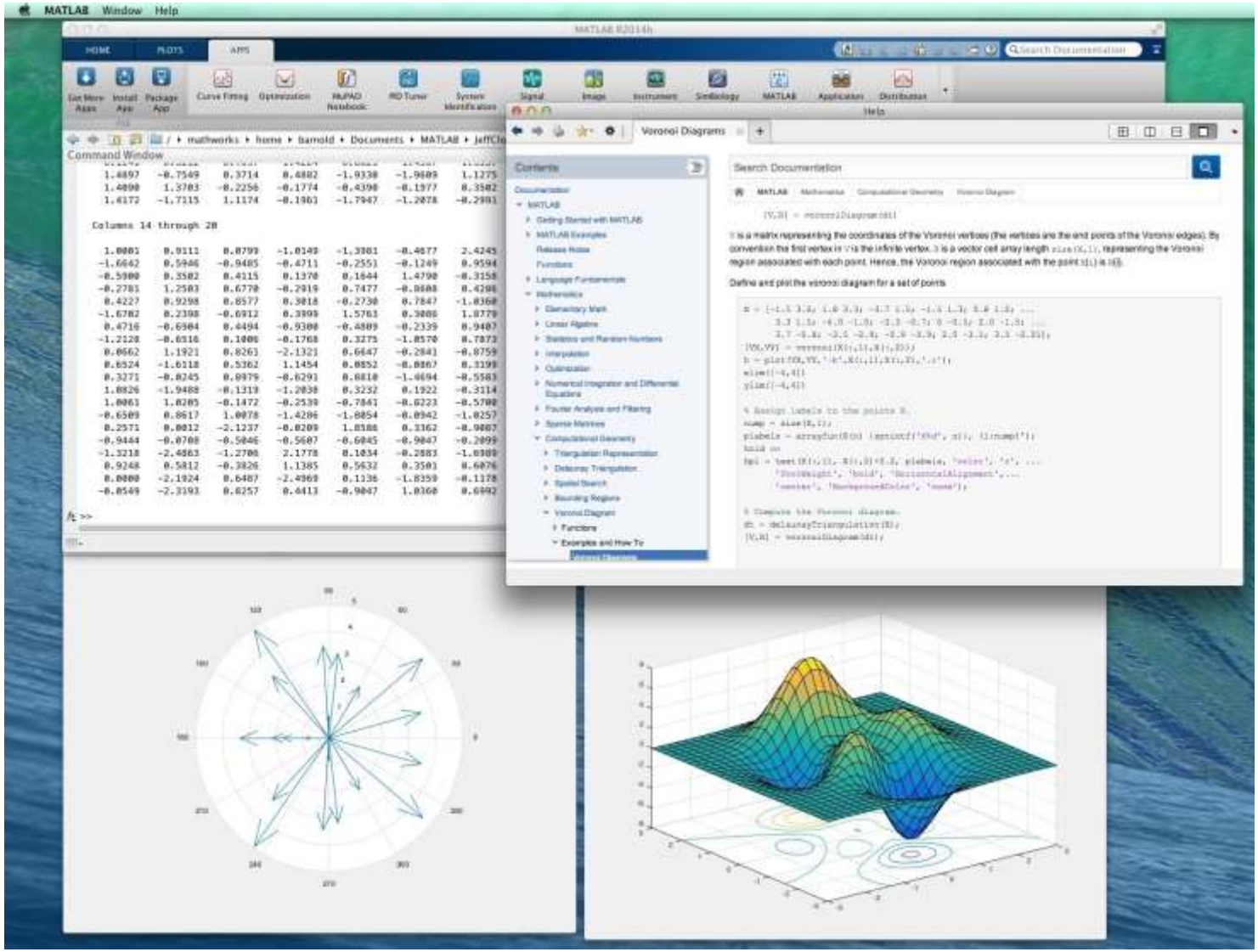

RGBD Depth Map
Res: 320 x 240 / Center: 4139 / Min: 2198 / Max: 4349
Frame: 1228
FPS: 29.5831
Raw Depth
Raw Depth Horizon
Processed Depth
Overlay Horizon
Connect
Refresh
Status: Disconnected
Speed (0-255):
255

VDB

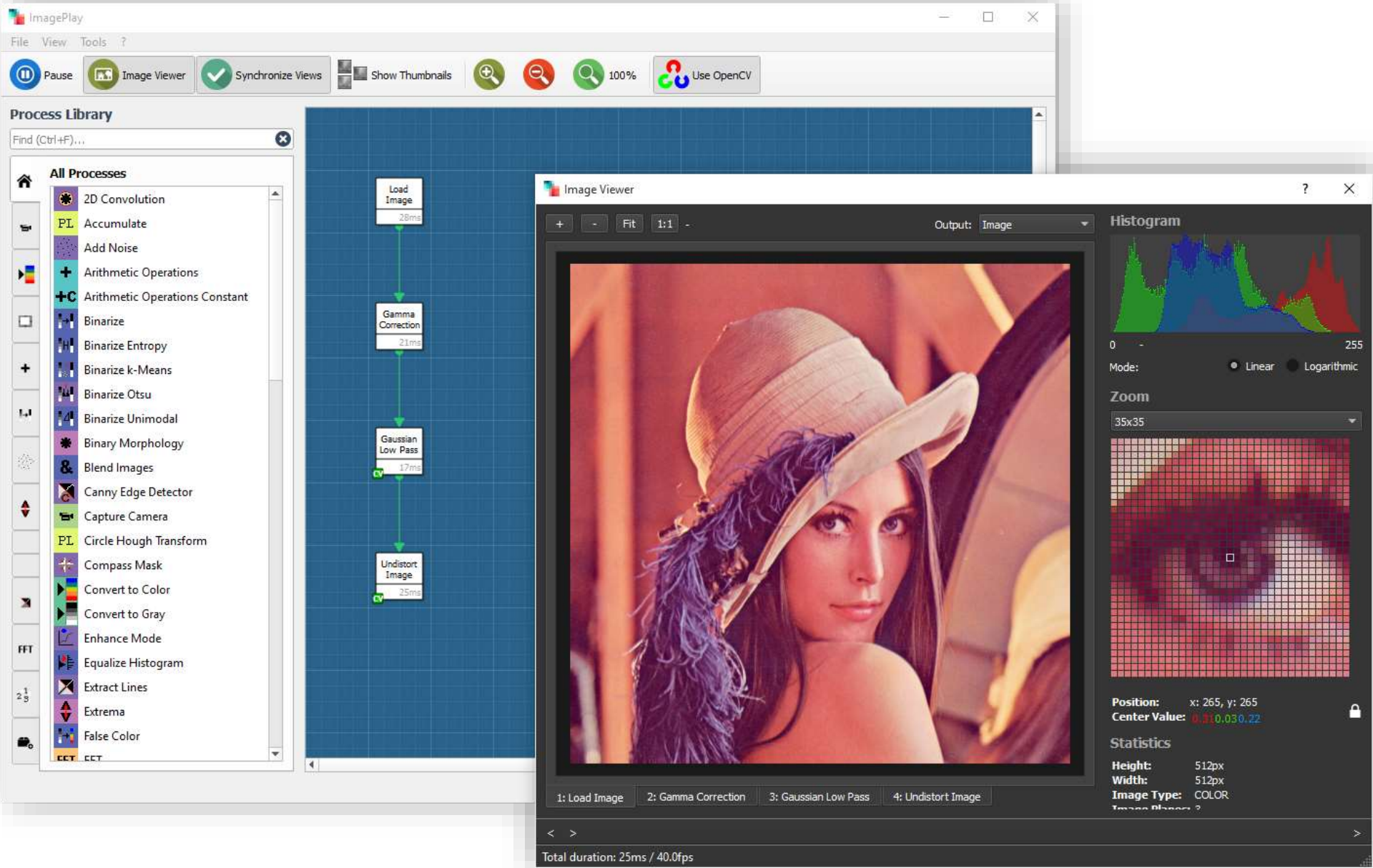

?
White isolation threshold
255.000
R
255.000
G
255.000
B
255.000
D


?
Controls
Reprojection
Reconstruction
1.000
Outlier
100.000
Object
Override
Stop
Point cloud
Save map

MATLAB / Octave / Matplotlib



ImagePlay


ImagePlay
File View Tools ?
Pause
Image Viewer
Synchronize Views
Show Thumbnails
100%
Use OpenCV
Process Library
Find (Ctrl+F)...
All Processes
2D Convolution
Accumulate
Add Noise
Arithmetic Operations
Arithmetic Operations Constant
Binarize
Binarize Entropy
Binarize k-Means
Binarize Otsu
Binarize Unimodal
Binary Morphology
Blend Images
Canny Edge Detector
Capture Camera
Circle Hough Transform
Compass Mask
Convert to Color
Convert to Gray
Enhance Mode
Equalize Histogram
Extract Lines
Extrema
False Color
Load Image
28ms
Gamma Correction
21ms
Gaussian Low Pass
17ms
Undistort Image
25ms
Image Viewer
Fit
1:1
Output: Image
Histogram
0
255
Mode: Linear Logarithmic
Zoom
35x35
Position: x: 265, y: 265
Center Value:
Statistics
Height: 512px
Width: 512px
Image Type: COLOR
1: Load Image
2: Gamma Correction
3: Gaussian Low Pass
4: Undistort Image
Total duration: 25ms / 40.0fps

Links

SimpleCV – Computer Vision using Python
https://www.youtube.com/watch?v=UZSm7Q2bZoc&t=570s

CVUI: GUI library on top of OpenCV
https://www.learnopencv.com/cvui-gui-lib-built-on-top-of-opencv-drawing-primitives/

VDB and ImGui
https://lightbits.github.io/vdb/

ImagePlay
imageplay.io

Step 1: Get a visualizer

Find object in image????

SLAM
SfM
Photogrammetry
MVG
PnP
Recognition
Detection
Localization
Inference
Deep learning
SVM
Classification

Image alignment
Orthorectification
Lucas-Kanade
Optical flow
SIFT, BRISK, ORB
Shi-Thomasi
Harris
Corners
Keypoints
Features
Edges
RANSAC

SVM
HoG
Hough
Canny
Sobel
Otsu
Gabor
Filtering
Convolution
Segmentation
Connected
components

Step 2: Don’t panic

Kinda like pokemon

SLAM
SfM
Photogrammetry
MVG
PnP
Recognition
Detection
Localization
Inference
Deep learning
SVM
Classification

Image alignment
Orthorectification
Lucas-Kanade
Optical flow
SIFT, BRISK, ORB
Shi-Thomasi
Harris
Corners
Keypoints
Features
Edges
RANSAC

SVM
HoG
Hough
Canny
Sobel
Otsu
Gabor
Filtering
Convolution
Segmentation
Connected
components

Enhancing images

De-noising

Stitching, mosaicing

Orthorectification, de-warping

Computational photography

Google Photoscan

Google Photoscan

Gravy

Pour off liquid in pan in which chicken has been roasted. From liquid skim off four tablespoons fat; return fat to pan, and brown with four tablespoons flour; add two cups stock in which giblets, neck, and tips of wings have been cooked. Cook five minutes, season with salt and pepper, then strain. The remaining fat may be used, in place of butter, for frying potatoes, or for basting when roasting another chicken.

For **Giblet Gravy**, add to the above, giblets (heart, liver, and gizzard) finely chopped.

Braised Chicken

Dress, clean, and truss a four-pound fowl. Try out two slices fat salt pork cut one-fourth inch thick; remove scraps, and add to fat five slices carrot cut in small cubes, one-half sliced onion, two sprigs thyme, one sprig parsley, and one bay leaf, then cook ten minutes; add two tablespoons butter, and fry fowl, turning often until surface is well browned. Place on trivet in a deep pan, pour over fat, and add two cups boiling water or Chicken Stock. Cover, and bake in slow oven until tender, basting often, and adding more water if needed. Serve with a sauce made from stock in pan, first straining and removing the fat.

Chicken Fricassee

Dress, clean, and cut up a fowl. Put in a kettle, cover with boiling water, and cook slowly until tender, adding salt to water when chicken is about half done. Remove from water, sprinkle with salt and pepper, dredge with flour, and sauté in butter or pork fat. Arrange chicken on pieces of dry toast placed on a hot platter, having wings and second joints opposite each other, breast in centre of platter, and drumsticks crossed just below second joints. Pour around White or Brown Sauce. Reduce stock to two cups, strain, and remove the fat. Melt three tablespoons butter, add four tablespoons flour, and pour on gradually one and one-half cups stock. Just before serving, add one-half cup cream, and salt and pepper to taste;

Gravy

Pour off liquid in pan in which chicken has been roasted. From liquid skim off four tablespoons fat; return fat to pan, and brown with four tablespoons flour; add two cups stock in which giblets, neck, and tips of wings have been cooked. Cook five minutes, season with salt and pepper, then strain. The remaining fat may be used, in place of butter, for frying potatoes, or for basting when roasting another chicken.

For **Giblet Gravy**, add to the above, giblets (heart, liver, and gizzard) finely chopped.

Braised Chicken

Dress, clean, and truss a four-pound fowl. Try out two slices fat salt pork cut one-fourth inch thick; remove scraps, and add to fat five slices carrot cut in small cubes, one-half sliced onion, two sprigs thyme, one sprig parsley, and one bay leaf, then cook ten minutes; add two tablespoons butter, and fry fowl, turning often until surface is well browned. Place on trivet in a deep pan, pour over fat, and add two cups boiling water or Chicken Stock. Cover, and bake in slow oven until tender, basting often, and adding more water if needed. Serve with a sauce made from stock in pan, first straining and removing the fat.

Chicken Fricassee

Dress, clean, and cut up a fowl. Put in a kettle, cover with boiling water, and cook slowly until tender, adding salt to water when chicken is about half done. Remove from water, sprinkle with salt and pepper, dredge with flour, and sauté in butter or pork fat. Arrange chicken on pieces of dry toast placed on a hot platter, having wings and second joints opposite each other, breast in centre of platter, and drumsticks crossed just below second joints. Pour around White or Brown Sauce. Reduce stock to two cups, strain, and remove the fat. Melt three tablespoons butter, add four tablespoons flour, and pour on gradually one and one-half cups stock. Just before serving, add one-half cup cream, and salt and pepper to taste;

248 BOSTON COOKING-SCHOOL COOK BOOK

Gravy

Pour off liquid in pan in which chicken has been roasted. From liquid skim off four tablespoons fat; return fat to pan, and brown with four tablespoons flour; add two cups stock in which giblets, neck, and tips of wings have been cooked. Cook five minutes, season with salt and pepper, then strain. The remaining fat may be used, in place of butter, for frying potatoes, or for basting when roasting another chicken.

For Giblet Gravy, add to the above, giblets (heart, liver, and gizzard) finely chopped.

Braised Chicken

Dress, clean, and truss a four-pound fowl. Try out two slices fat salt pork cut one-fourth inch thick; remove scraps, and add to fat five slices carrot cut in small cubes, one-half sliced onion, two sprigs thyme, one sprig parsley, and one bay leaf, then cook ten minutes; add two tablespoons butter, and fry fowl, turning often until surface is well browned. Place on trivet in a deep pan, pour over fat, and add two cups boiling water or Chicken Stock. Cover, and bake in slow oven until tender, basting often, and adding more water if needed. Serve with a sauce made from stock in pan, first straining and removing the fat.

Chicken Fricassee

Dress, clean, and cut up a fowl. Put in a kettle, cover with boiling water, and cook slowly until tender, adding salt to water when chicken is about half done. Remove from water, sprinkle with salt and pepper, dredge with flour, and sauté in butter or pork fat. Arrange chicken on pieces of dry toast placed on a hot platter, having wings and second joints opposite each other, breast in centre of platter, and drumsticks crossed just below second joints. Pour around White or Brown Sauce. Reduce stock to two cups, strain, and remove the fat. Melt three tablespoons butter, add four tablespoons flour, and pour on gradually one and one-half cups stock. Just before serving, add one-half cup cream, and salt and pepper to taste;

A Computational Approach for Obstruction-Free Photography

A Computational Approach for Obstruction-Free Photography

Star Stacker - Benedikt Bitterli


Star Stacker - Benedikt Bitterli

PhotoScan: Taking Glare-Free Pictures of Pictures

https://research.googleblog.com/2017/04/photoscan-taking-glare-free-pictures-of.html

Page dewarping

https://mzucker.github.io/2016/08/15/page-dewarping.html

A Computational Approach for Obstruction-Free Photography

https://sites.google.com/site/obstructionfreephotography/

Star Stacker: Astrophotography with C++11

https://benedikt-bitterli.me/astro/

Finding shapes

Segmentation

Blobs, components

Lines, circles, ellipses

Feature detection and extraction

4.1.1.2. Syllabification

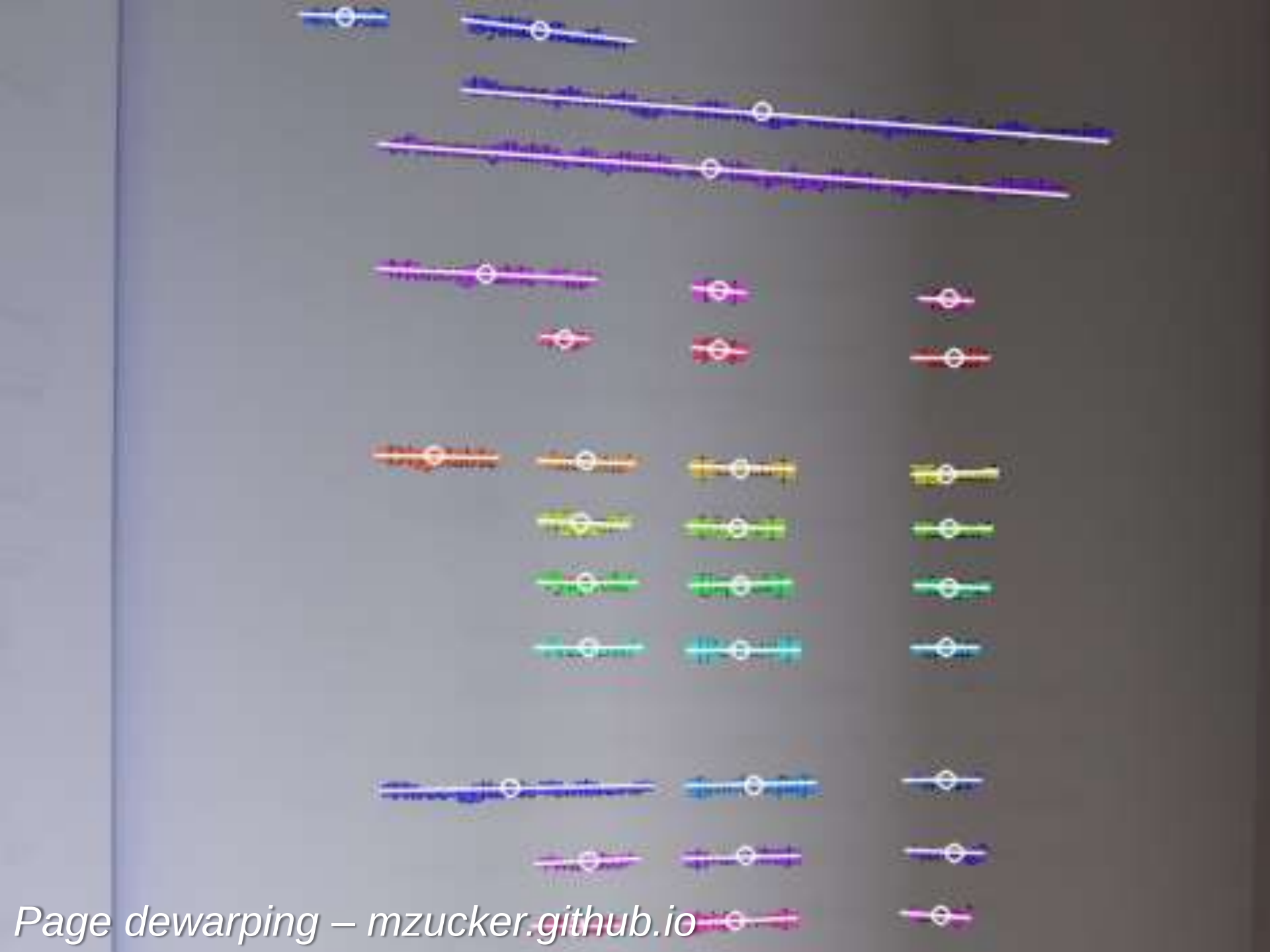
Dusner phonology is allowing a word to phonologically consist of monosyllable, disyllable, and the polysyllable up to six syllables.

Monosyllable	/ in/	[in]	'fish'
	/ki/	[kī]	'small'
Disyllable	/snontu/	[snon.tu]	'person'
	/ripyor/	[ri.pjor]	'in law'
	/yaprok/	[jap.rok]	'forget'
	/vemow/	[βe.mow]	'child'
Three syllable	/embreva/	[em.bre.βa]	'water'
	/watako/	[wa.ta.ko]	'strong'
		[ri.βe.wu]	'sorry'

4.1.1.2. Syllabification

Dusner phonology is allowing a word to phonologically consist of monosyllable, disyllable, and the polysyllable up to sex syllables.

Monosyllable	/ʃin/	[ʃin]	'fish'
	/ʃkiʃ/	[ʃkiʃ]	'small'
Disyllable	/snwntw/	[snwn.tu]	'person'
	/ʃipyor/	[ʃi.pjor]	'in law'
	/vɐprok/	[βɐp.rok]	'forget'
	/vɐmow/	[βɐ.mow]	'child'
Three syllable	/ombrevɐ/	[om.bɾɐ.βɐ]	'water'
	/wɐtako/	[wɐ.ta.ko]	'strong'
	/ʃiβɐwu/	[ʃi.βɐ.wu]	'sorry'



Page dewarping – mzucker.github.io


Automatic Visual Weed Recognition – Øystein Grændnes

Peter Corke: Robotics, Vision and Control (free for students!)

http://petercorke.com/wordpress/rvc/

Page dewarping

https://mzucker.github.io/2016/08/15/page-dewarping.html

Lipman's Artificial Intelligence Directory

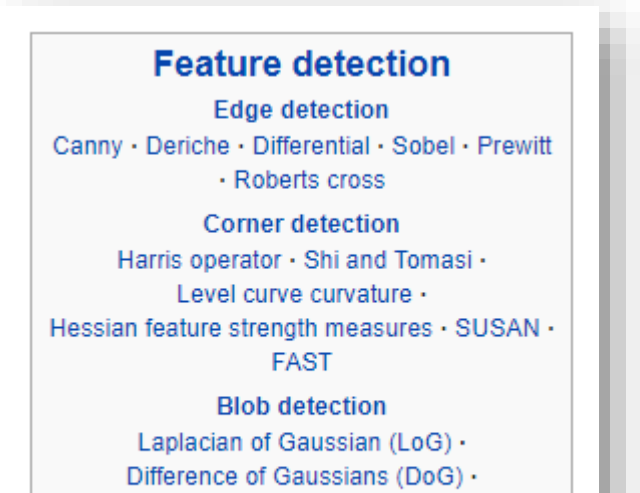
http://laid.delanover.com/tag/ellipse-detection/

http://laid.delanover.com/hough-transform-line-detection-cartesian-polar-and-space-reduction/

http://laid.delanover.com/hough-transform-circle-detection-and-space-reduction/

Wikipedia: Hough Transform

https://en.wikipedia.org/wiki/Hough_transform



Finding objects

Machine learning / Deep learning

Recognition, Detection, Classification

Semantic segmentation

Model-based computer vision

Inverse rendering, Optimization

Object Detection with Deep Learning and OpenCV – PyImageSearch

yuxng.github.io

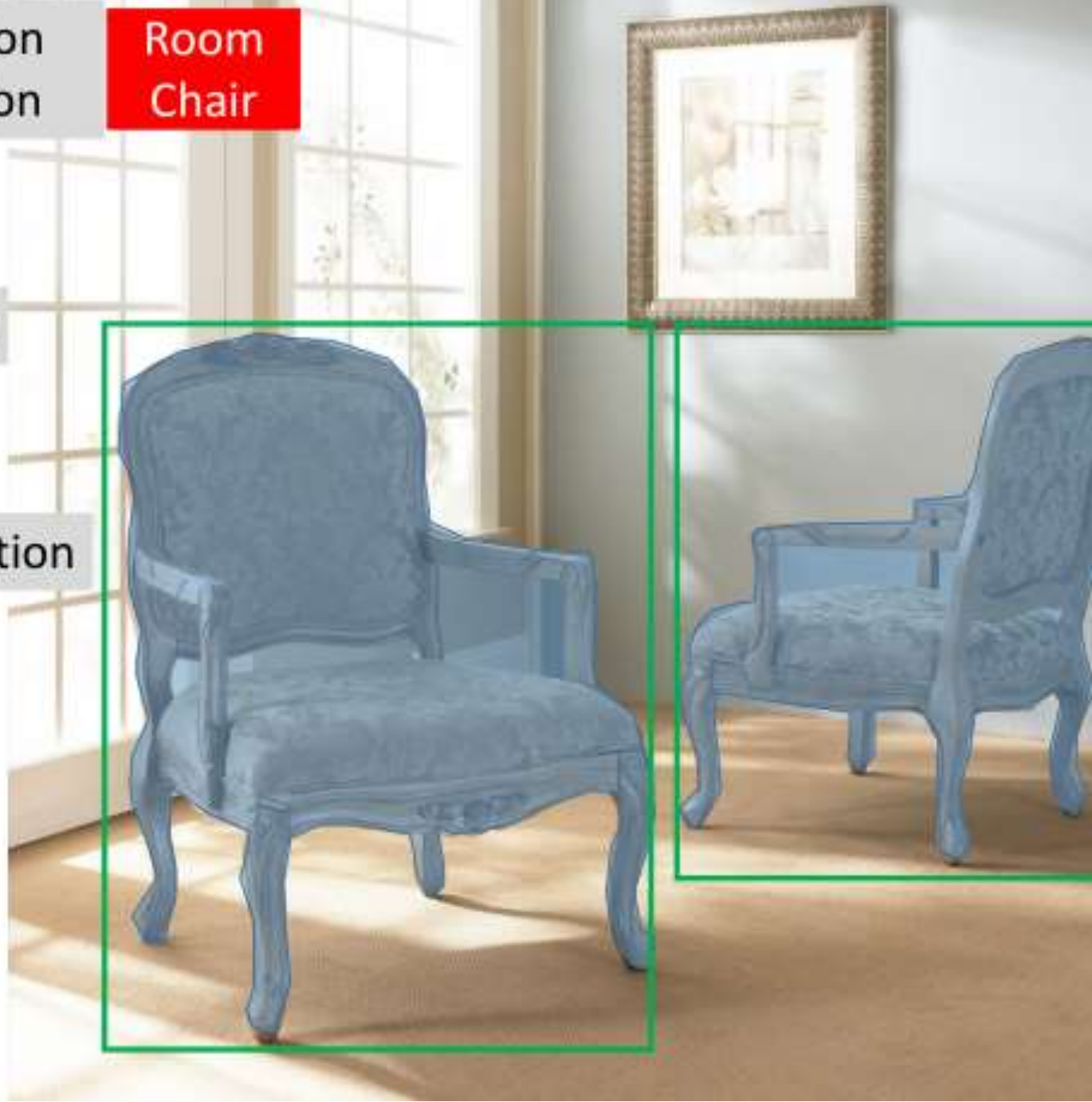
- Image classification tagging/annotation

- Image classification tagging/annotation

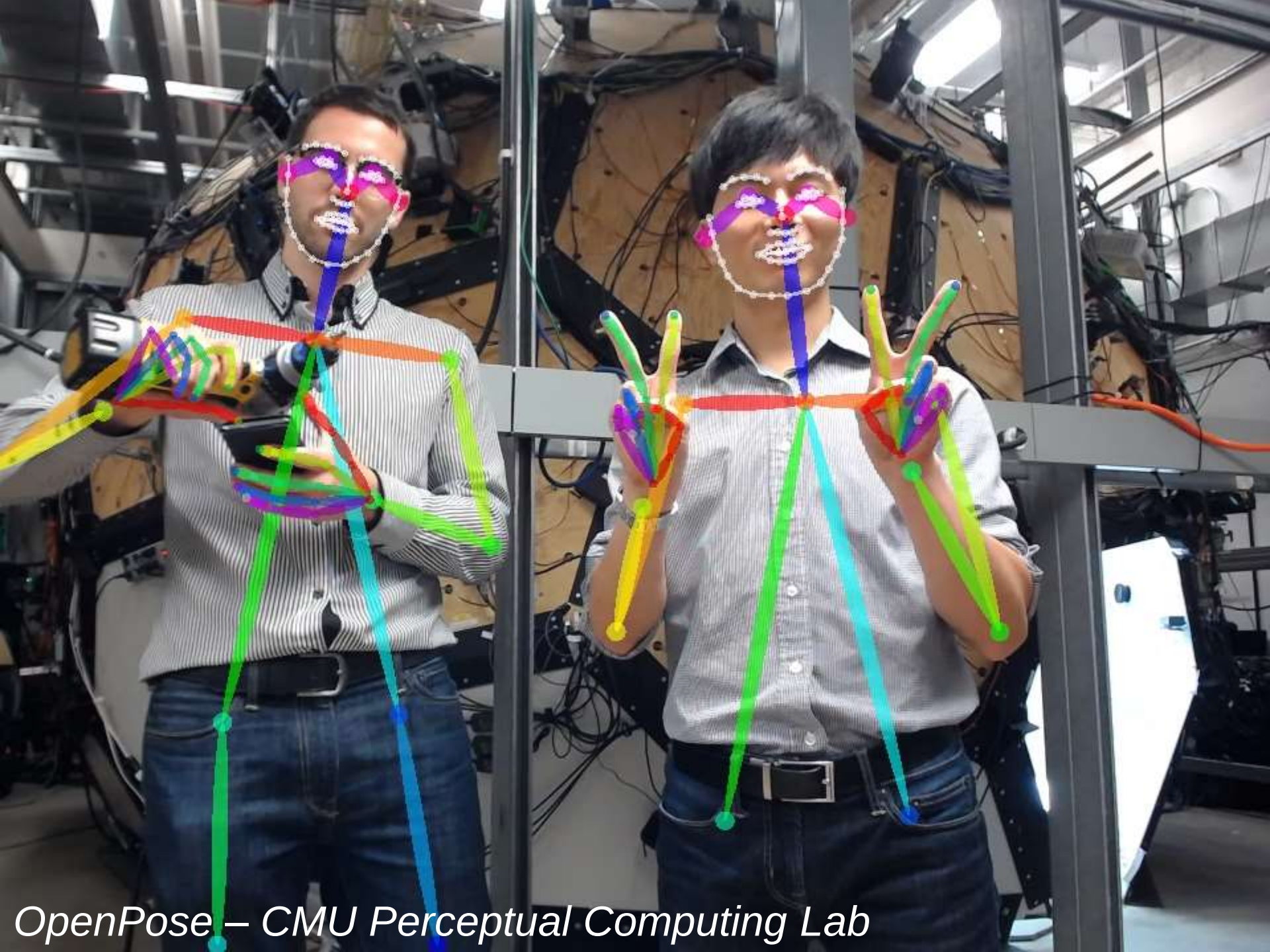
- Object detection

yuxng.github.io

- Image classification tagging/annotation



- Object detection
- Object segmentation


OpenPose – CMU Perceptual Computing Lab

Computer Vision - StAR Lecture Series: Object Recognition

https://www.youtube.com/watch?v=fbFYdzatOMg

Object detection with deep learning and OpenCV

https://www.pyimagesearch.com/2017/09/11/object-detection-with-deep-learning-and-opencv/

Google Scholar

scholar.google.com

Simen

Object detection with deep

Sikker | https://www.pyimagesearch.com/2017/09/11/...

Navigation

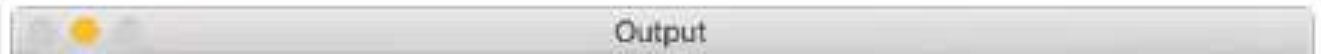
pyimagesearch

be awesome at building image search engines

Object detection with deep learning and OpenCV

by Adrian Rosebrock on September 11, 2017 in Deep Learning, OpenCV 3, Tutorials

Tweet Like 0 G+ Share 210



Where is this thing in 3D space?

Pose estimation (6D)

Object detection

Perspective-n-Point (PnP)

Visual tracking

cmp.felk.cvut.cz/sixd/workshop_2017

Peter Corke: Robotics, Vision and Control (free for students!)

http://petercorke.com/wordpress/rvc/

Pose Estimation for Augmented Reality: A Hands-On Survey

https://hal.inria.fr/hal-01246370/document

Monocular Model-Based 3D Tracking of Rigid Objects: A Survey

http://icwww.epfl.ch/~lepetit/papers/lepetit_ftcgv05.pdf

Research papers on 3D object detection

Deep Sliding Shapes for Amodal 3D Object Detection in RGB-D Images

3DMatch: Learning Local Geometric Descriptors from RGB-D Reconstructions

Where is my camera?

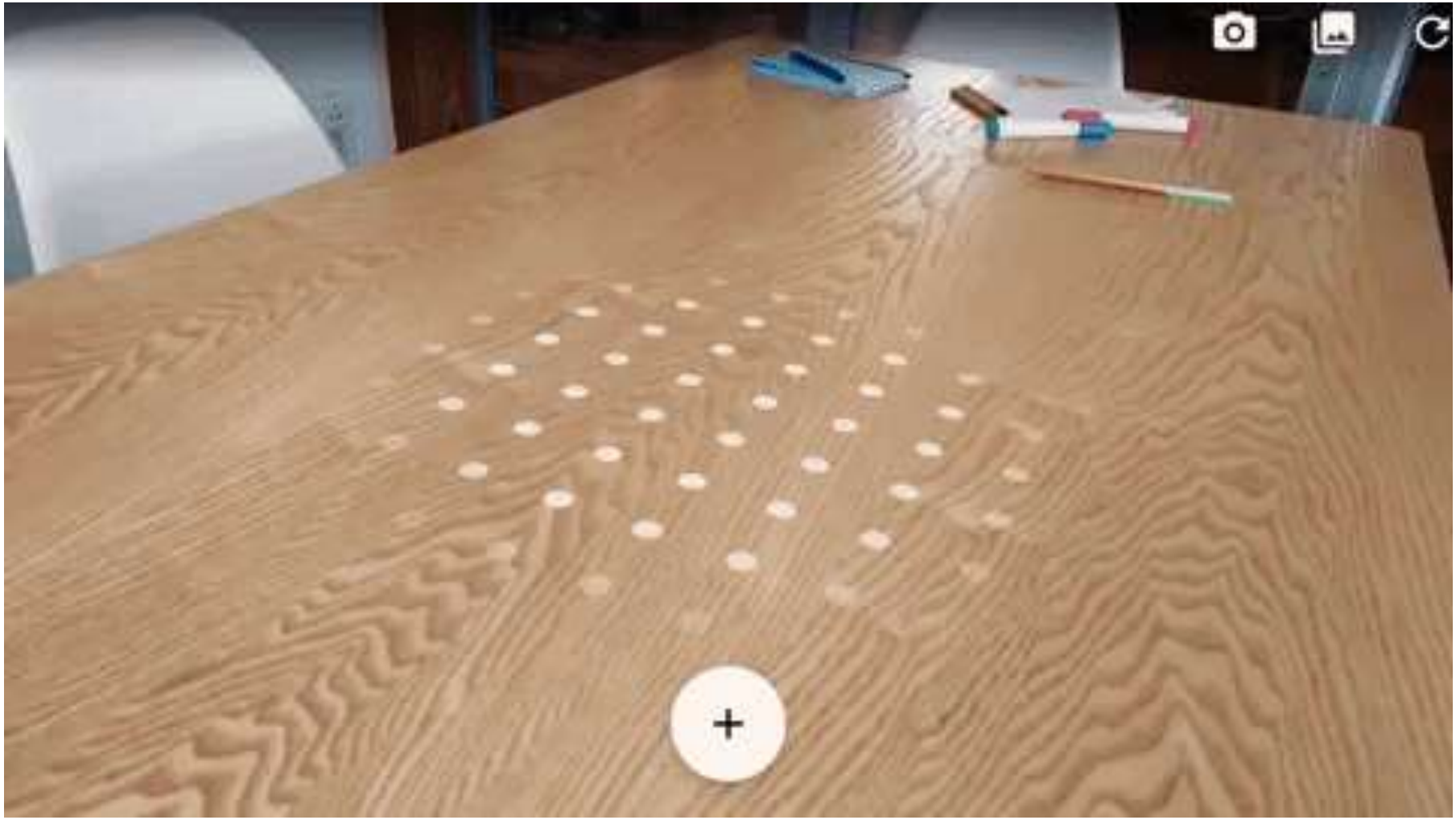
Pose estimation

Camera tracking

Visual odometry

Optical flow

SLAM



developers.google.com/ar

Why is ARKit better than the alternatives?

https://medium.com/super-ventures-blog/why-is-arkit-better-than-the-alternatives-af8871889d6a

Pose Estimation for Augmented Reality: A Hands-On Survey

https://hal.inria.fr/hal-01246370/document

Monocular Model-Based 3D Tracking of Rigid Objects: A Survey

http://icwww.epfl.ch/~lepetit/papers/lepetit_ftcgv05.pdf

Tutorial on Visual Odometry – by Davide Scaramuzza

http://rpg.ifi.uzh.ch/visual_odometry_tutorial.html

What does the world look like?

SLAM

Photogrammetry

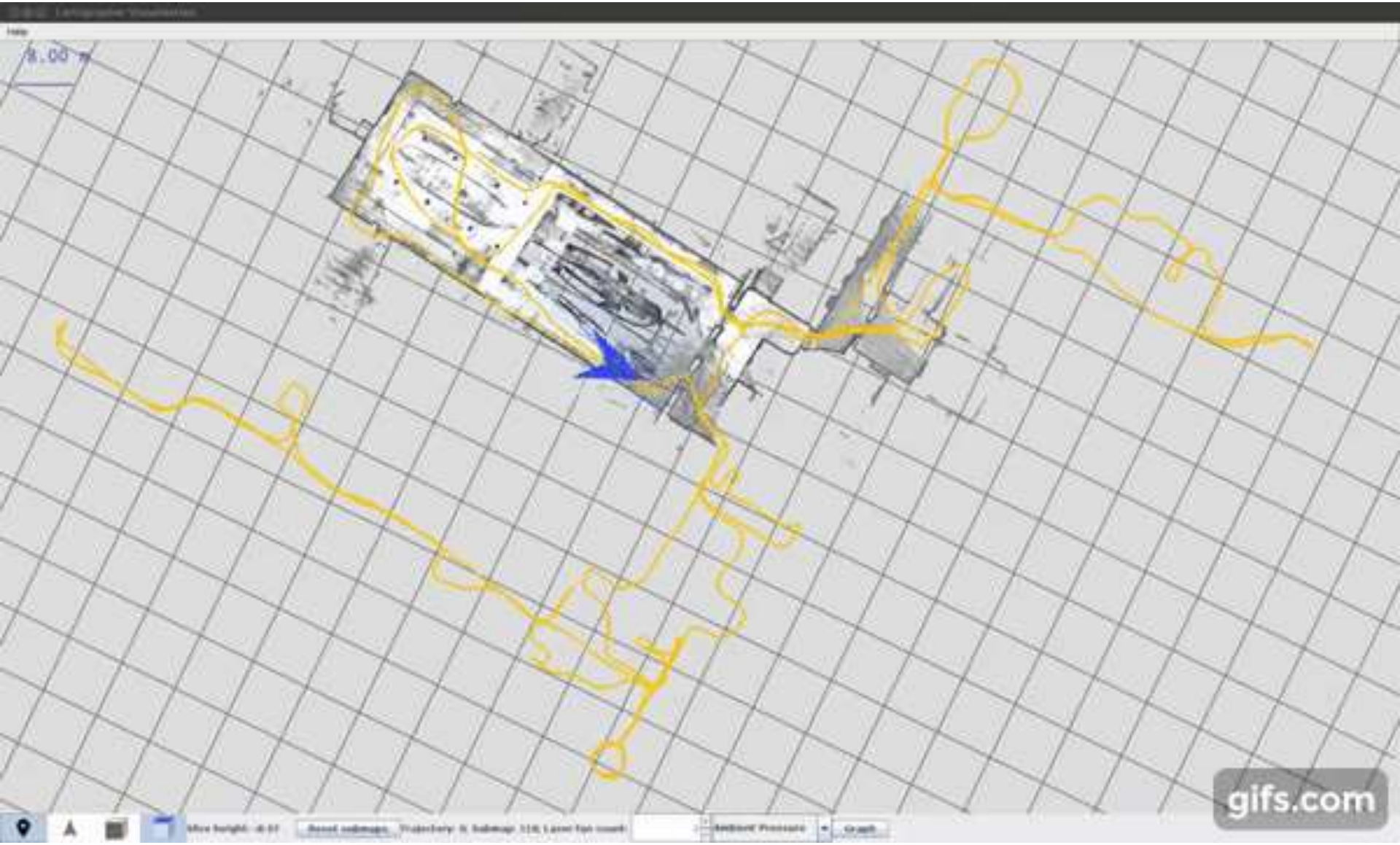
Multiple View Geometry

Structure from Motion

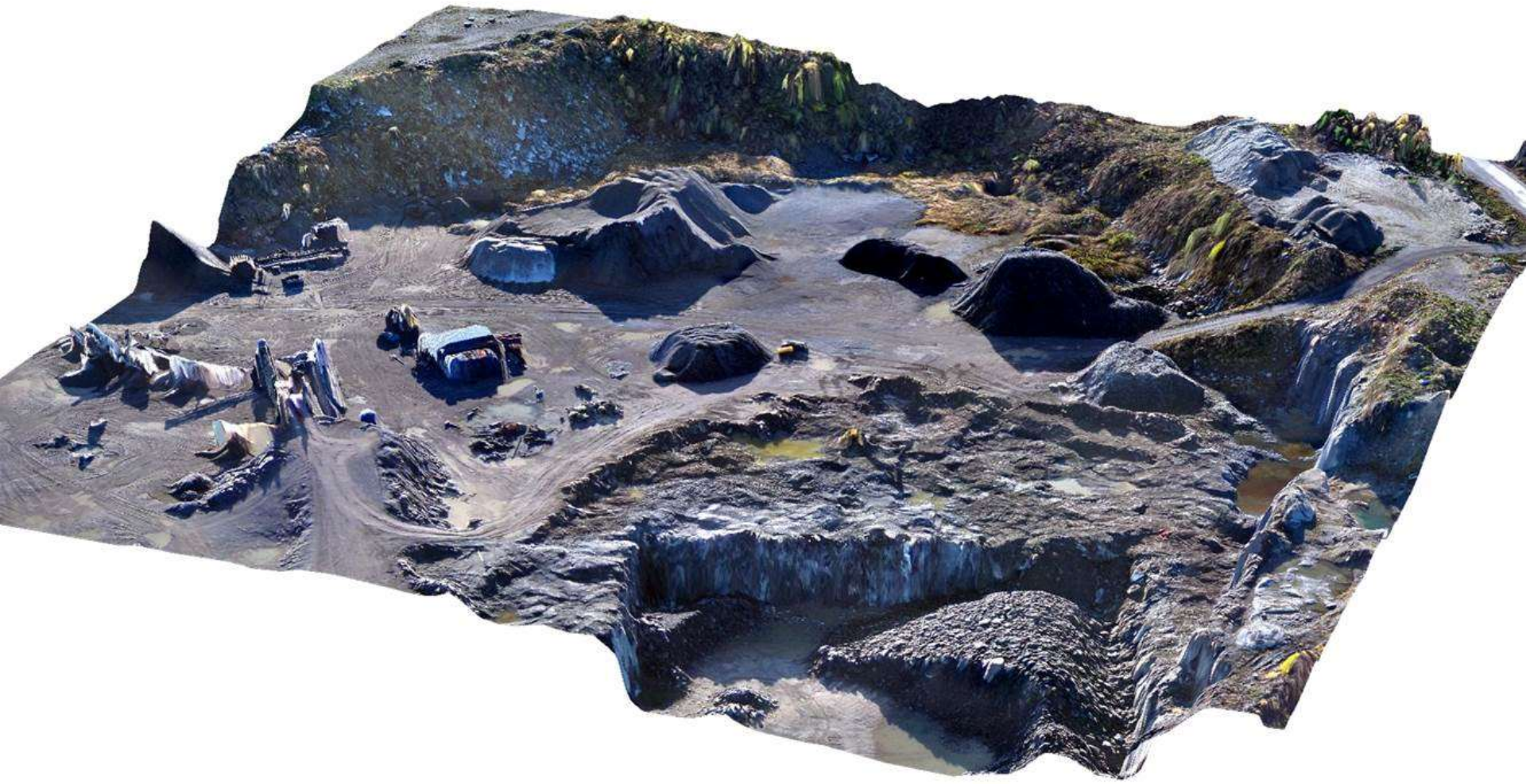
Localization and mapping

Semantic segmentation

3D scene understanding



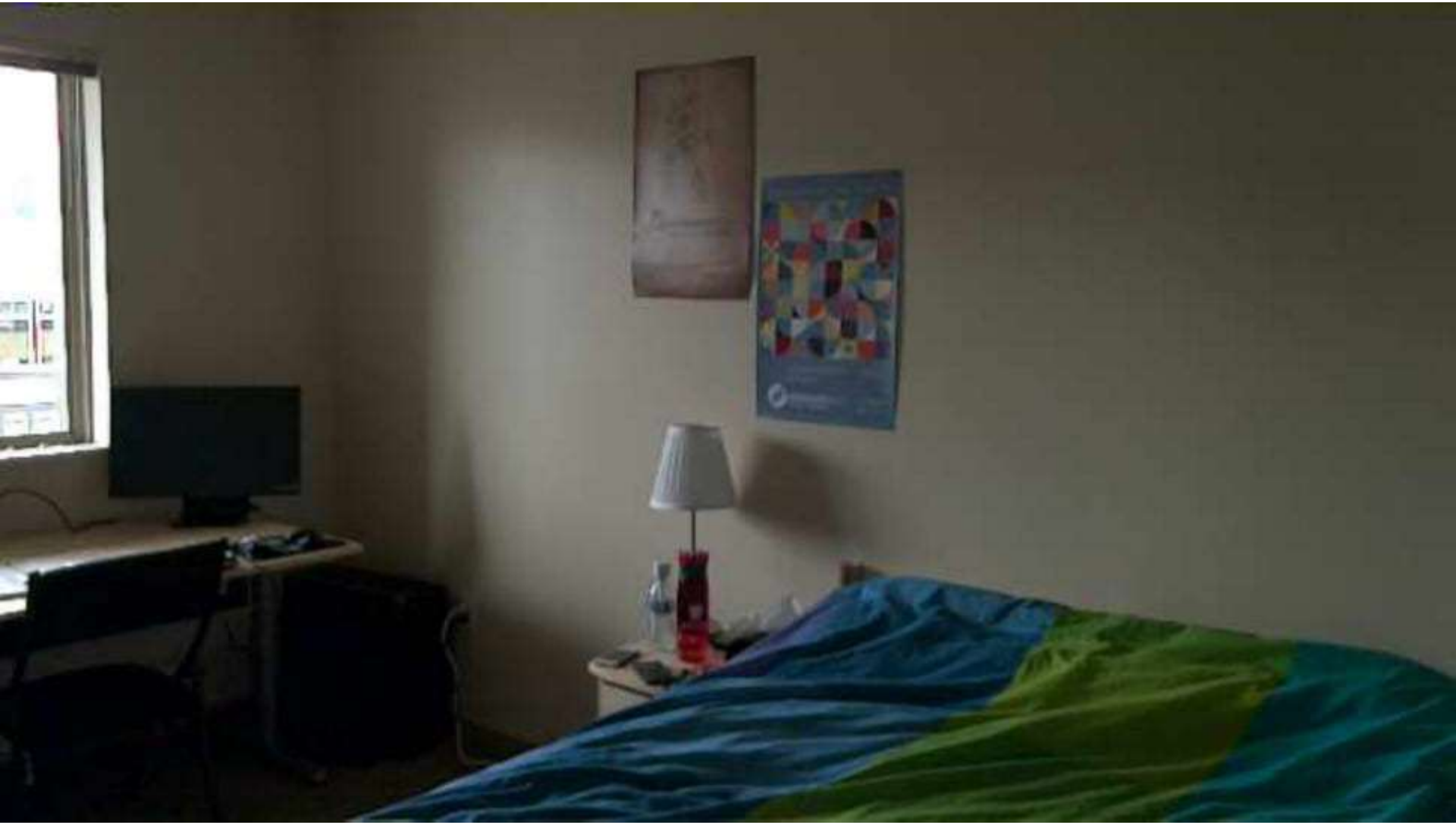
github.com/googlecartographer/cartographer



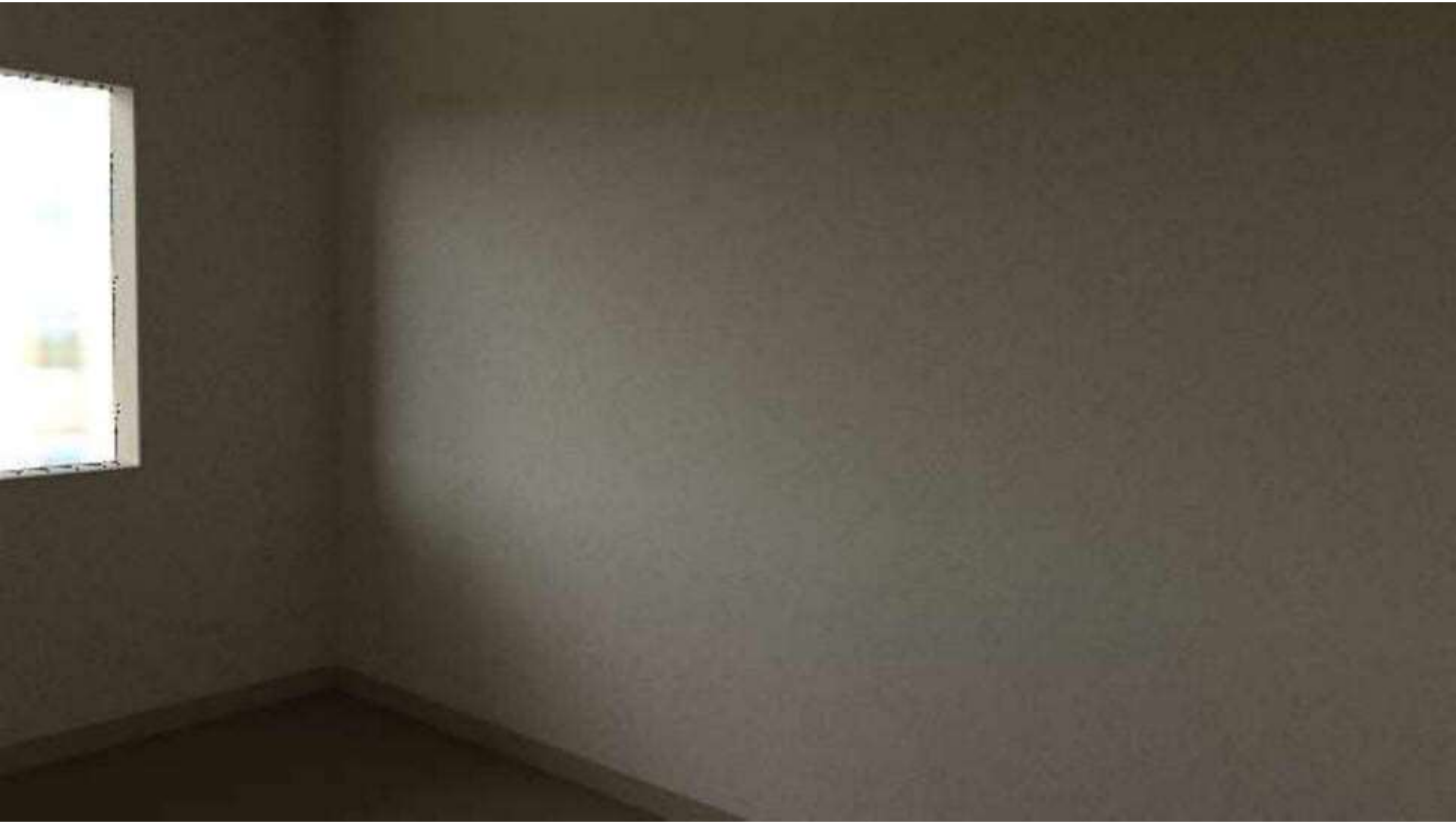
ta-survey.nl/page.php?id=316&lang=EN

- 3D Scene Understanding

yuxng.github.io



Emptying, Refurnishing, and Relighting Indoor Spaces



Emptying, Refurnishing, and Relighting Indoor Spaces

Emptying, Refurnishing, and Relighting Indoor Spaces

Peter Corke: Robotics, Vision and Control (free for students!)

http://petercorke.com/wordpress/rvc/

A curated list of papers and resources

https://github.com/openMVG/awesome_3DReconstruction_list

SLAM Course by Cyrill Stachniss

https://www.youtube.com/watch?v=wVsfCnyt5jA

Multi-View Stereo: A Tutorial

https://www.cse.wustl.edu/~furukawa/papers/fnt_mvs.pdf

Step 2: Don’t panic

Step 3: Solve your problem

A little of everything: **OpenCV**

Maths: **Eigen**

Tracking/mapping: **ORBSLAM, SVO, Cartographer**

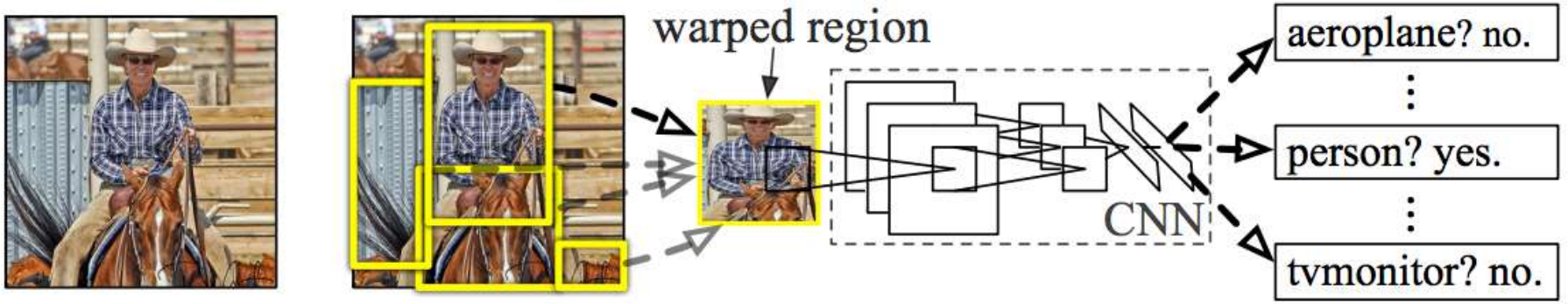
Faces/Hands/Body: **OpenPose**

A curated list of software

https://github.com/jbhuang0604/awesome-computer-vision#software

Solve your problem

R-CNN: *Regions with CNN features*



1. Input image

2. Extract region proposals (~2k)

3. Compute CNN features

4. Classify regions

Can you find a research paper?

Finding research papers

Google your problem

Skim the "related work" section

Google Scholar – Follow citation trail

Phd reports – Easier to read

Look up author’s homepage

Step 3: Solve your problem

Thank you!

simen.haugo@ascendntnu.no

@uint9