Should I say hello?

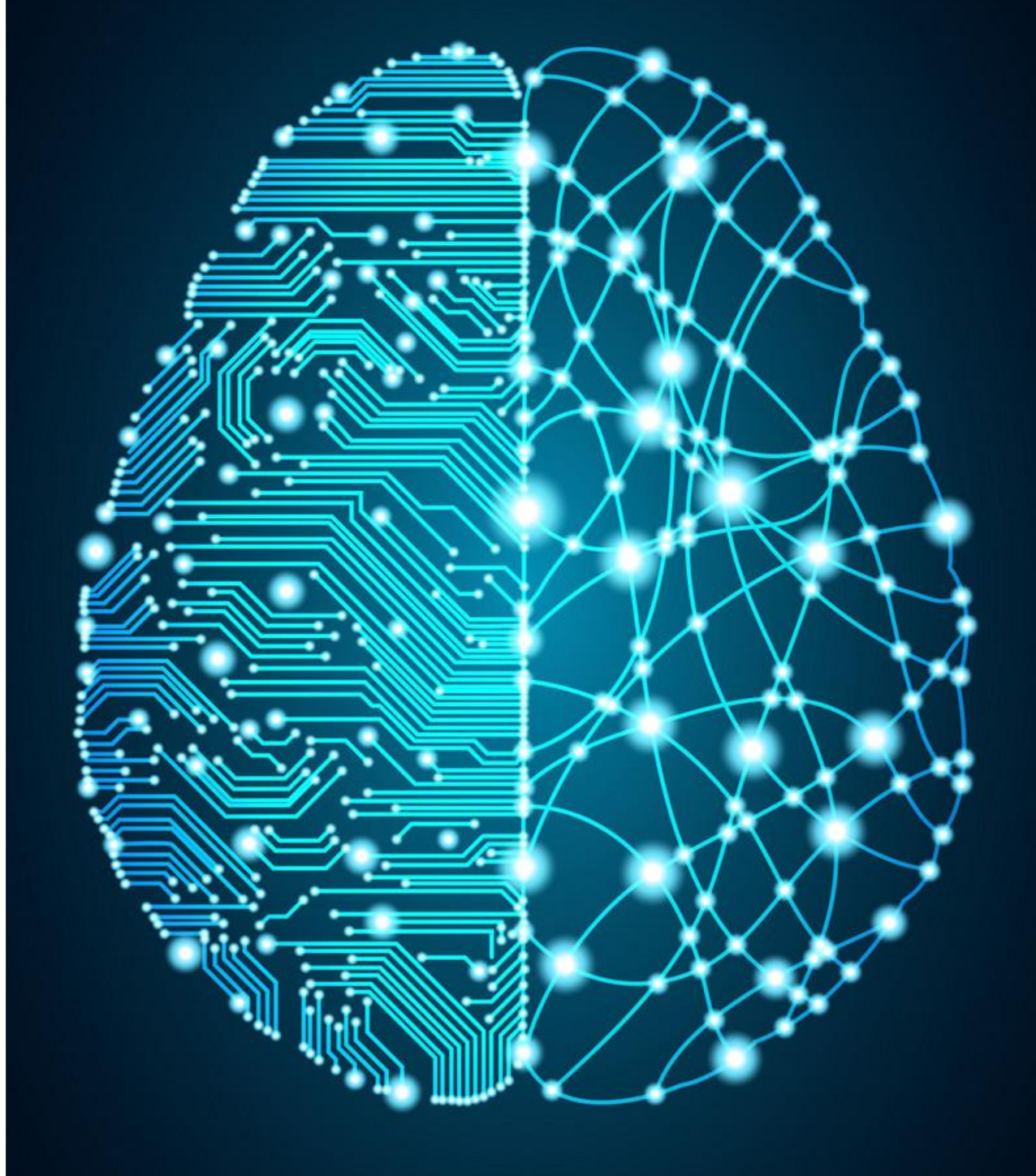
The very basics of human-robot interaction

- Who should I greet? Not all persons might be interested in a conversation.
- As humans we do not have to think about this.
- The robot should be able to start the interaction.
- It needs intelligence to do so!
- Social AI comes into play.

How smart am I?

The requirements for greeting

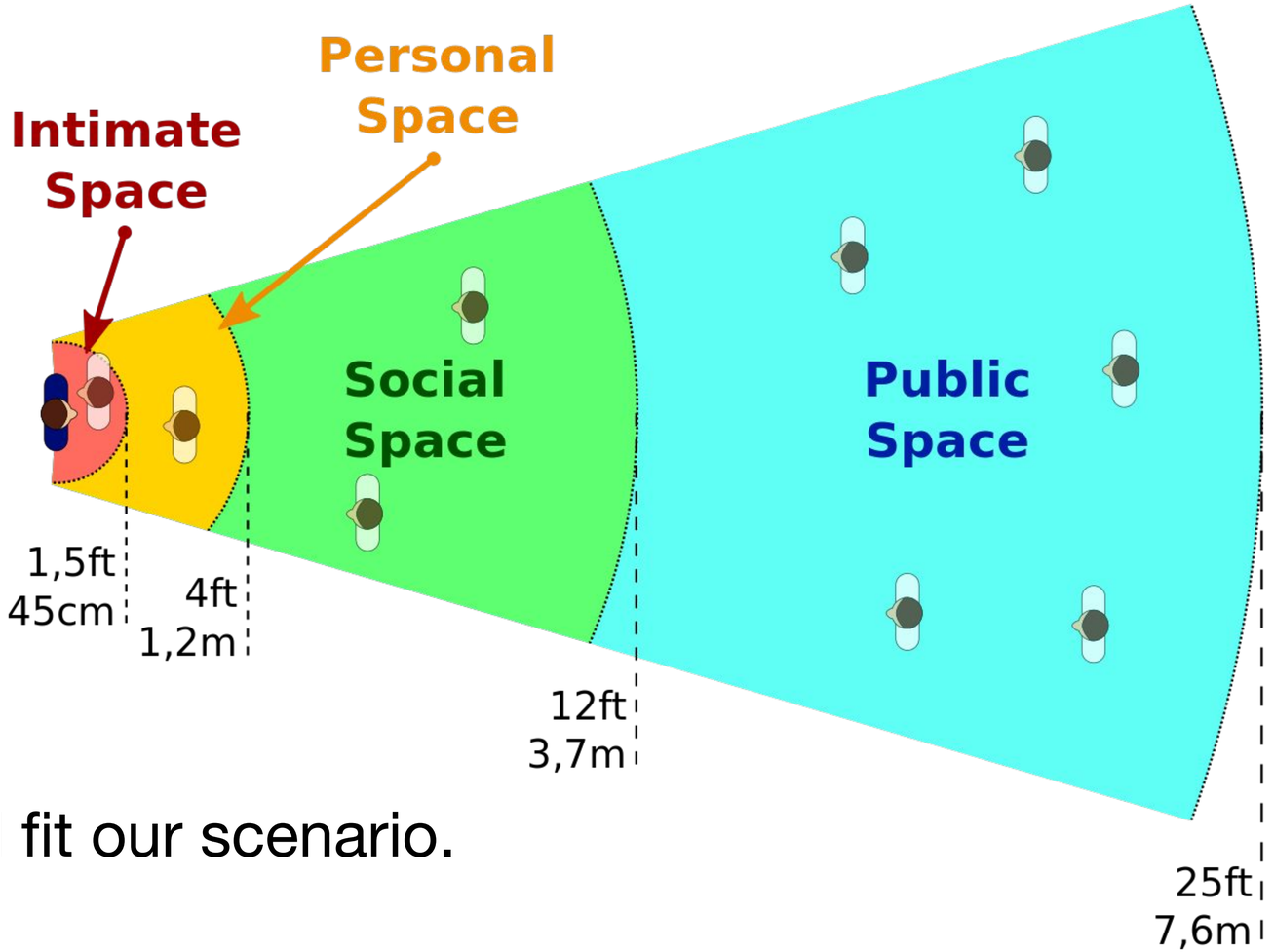
- Detect the presence of a person.
  - How many persons are there?
- Locate and identify the person(s).
- Decide to greet a person or not
  - Which person do I greet?
  - When?
- Do the actual greeting action within an appropriate timespan.



Shall I greet this person?

Theoretical foundation from social psychology

- Hall's Proxemic Theory[1]
- *Intimate relationship; e.g. lovers*
- *Good friends, family*
- *Impersonal business; acquaintances*
- *Public speaking*
- Social space / personal space could fit our scenario.
- Additional requirement: distance to a person.




Person 1
at 2.34m
Person 0
at 2.35m

How to perceive depth from 2D images?

A human-inspired approach

- We as humans need the signal from both eyes to perceive depth —> use stereo images instead of mono images with robots!

- Objects closer to camera ‘move’ more between two images.

- Basic technique, cost-efficient and fast.

How to perceive depth from 2D images?

- **f**: Focal length
- **B**: Distance between camera's
- **X**: Observed point
- **x-x'**: Disparity
- **z**: Depth

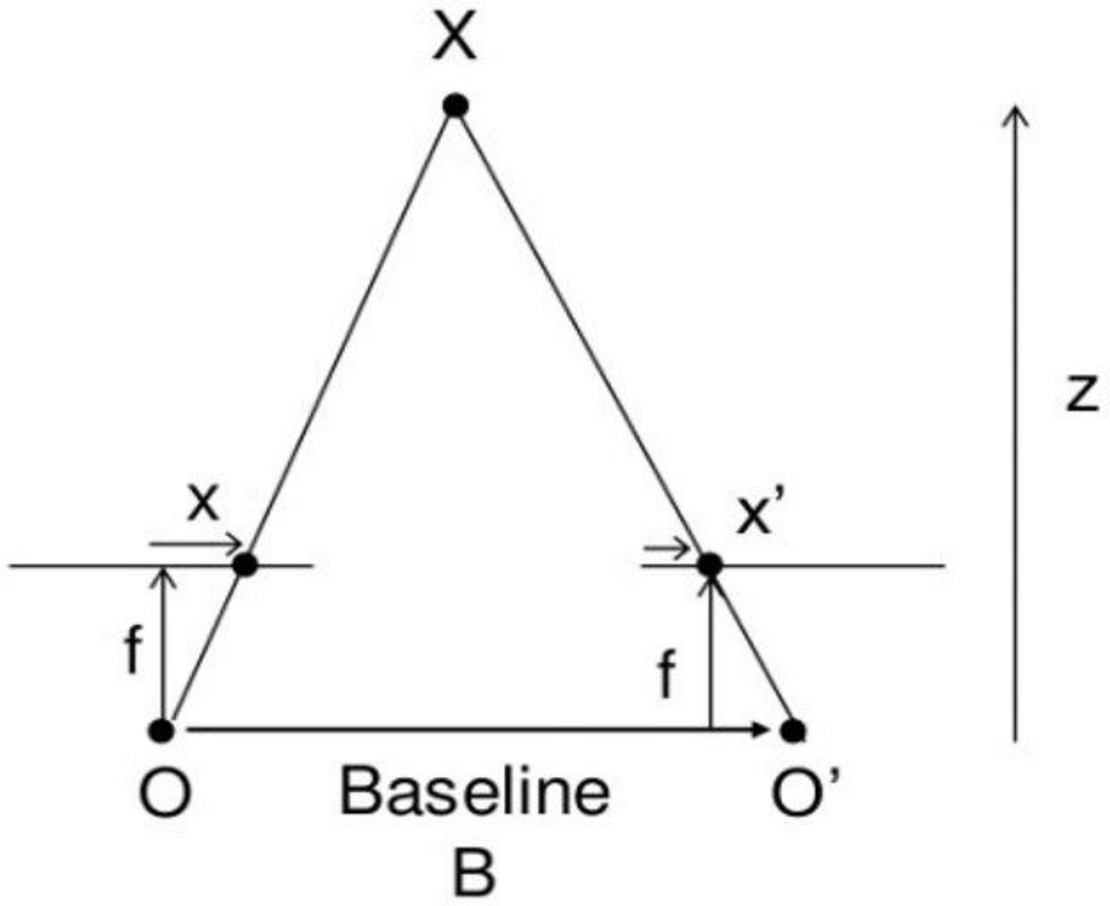


Image source: opencv.org

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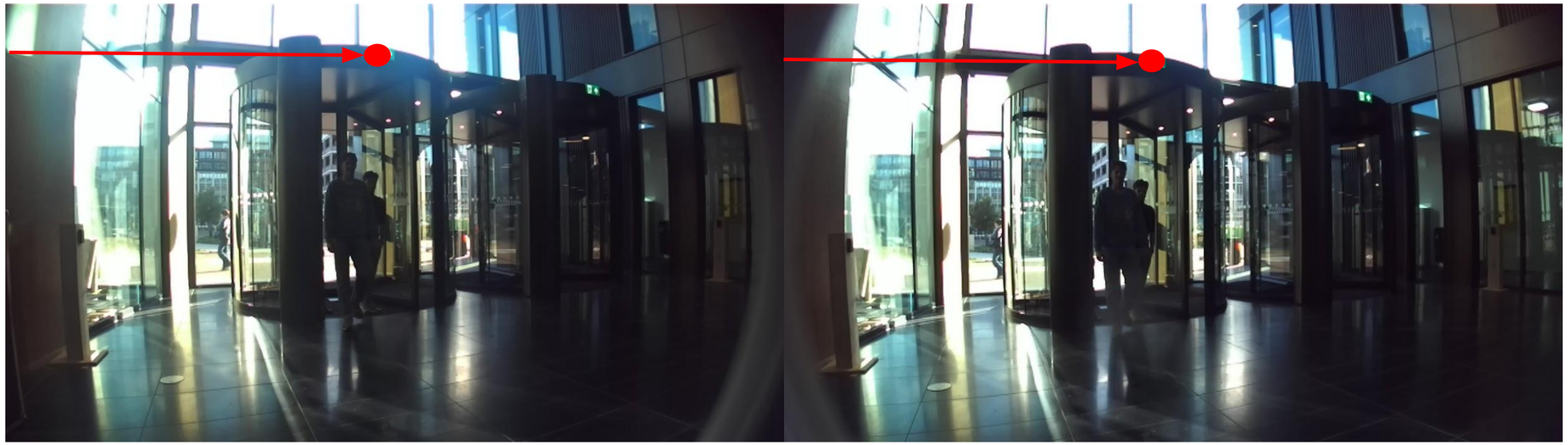

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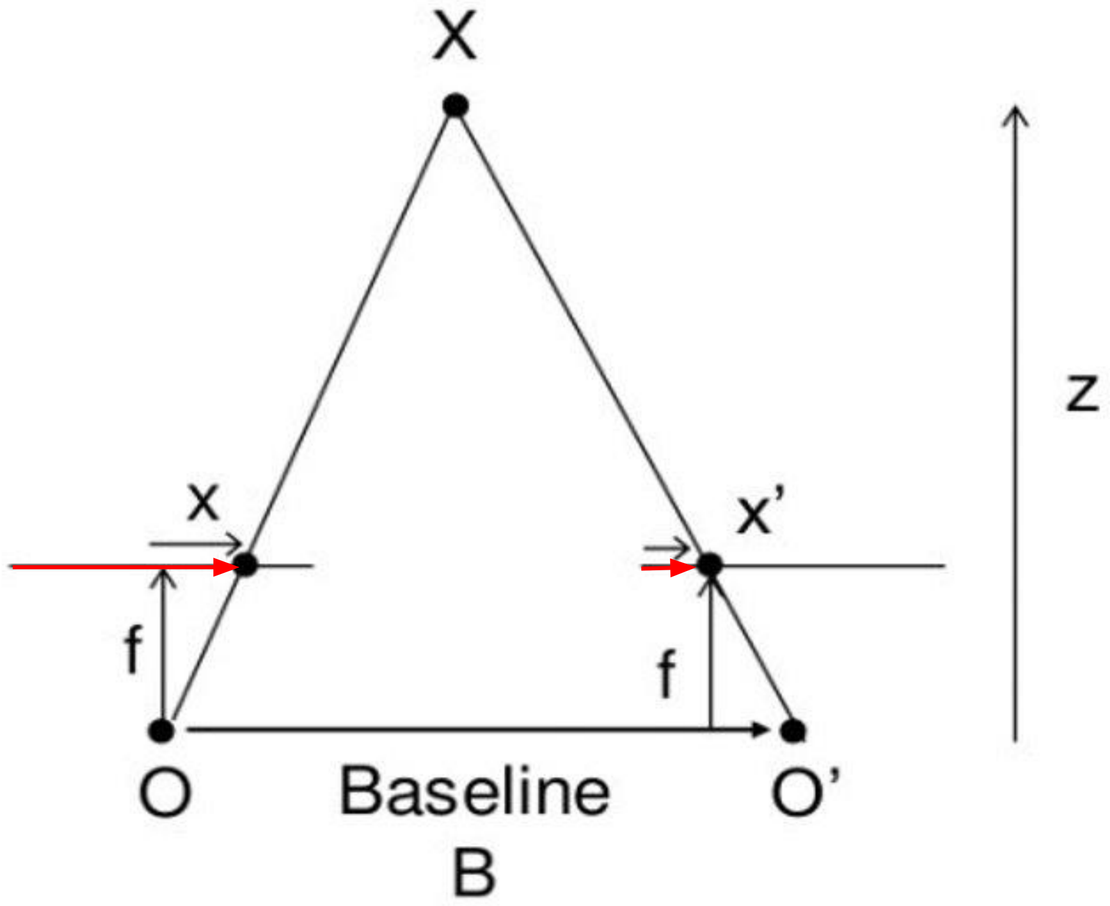

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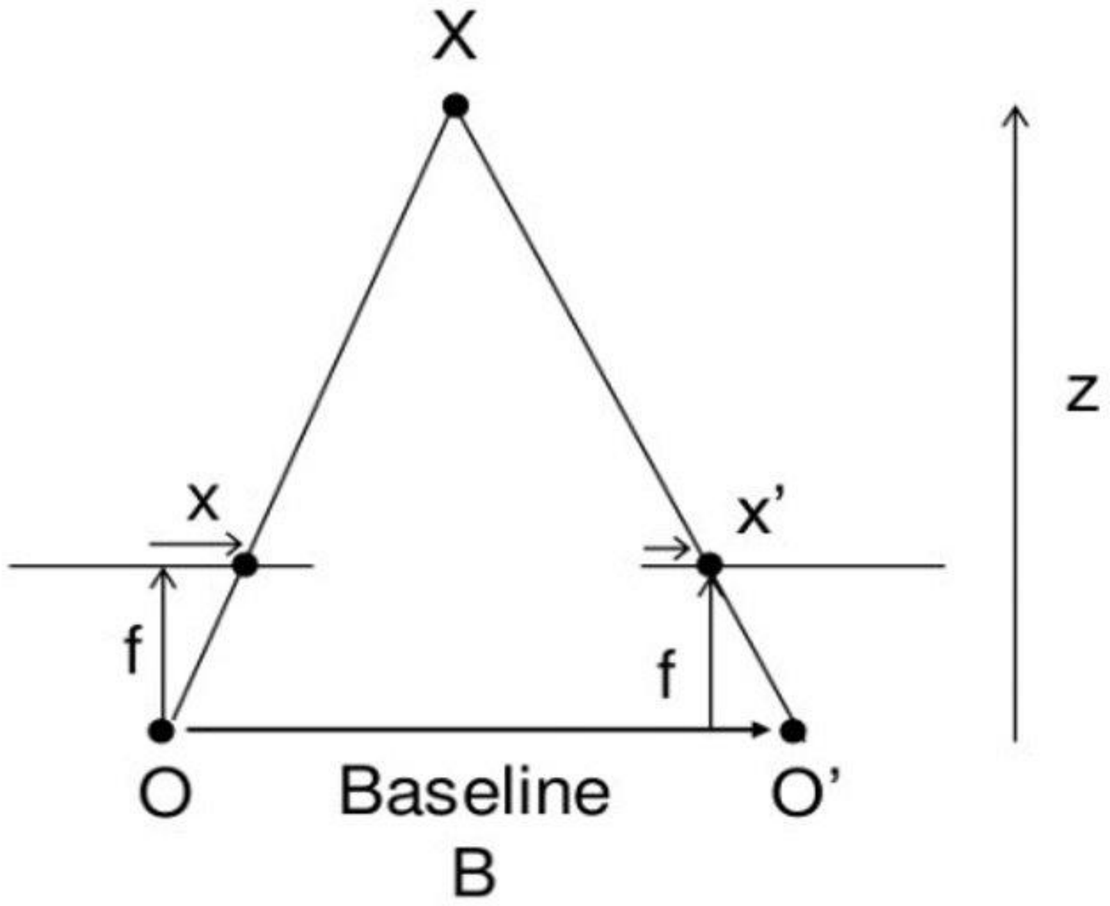
$$z = \frac{f \cdot B}{x - x'} = \frac{f \cdot B}{d}$$



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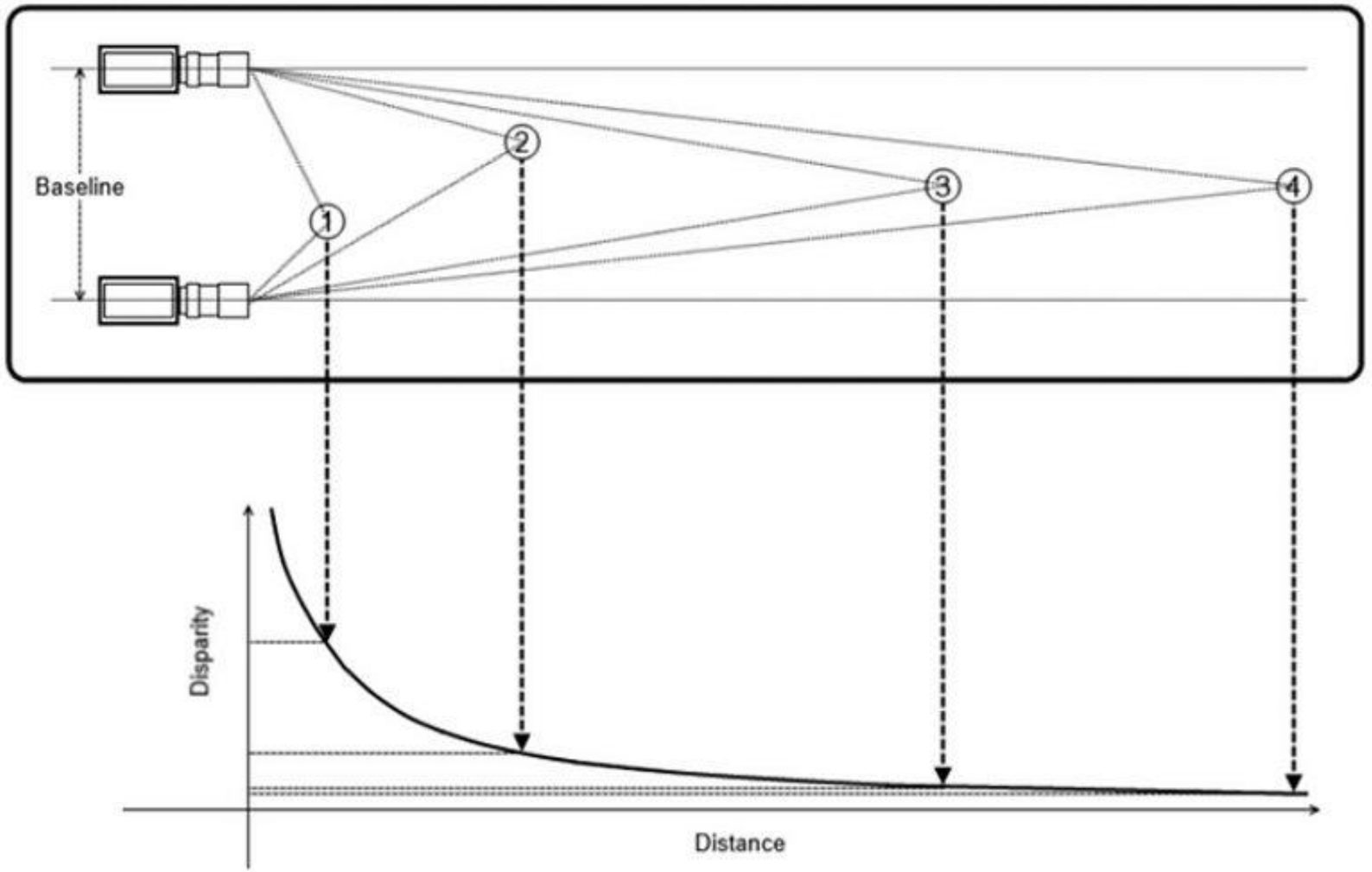
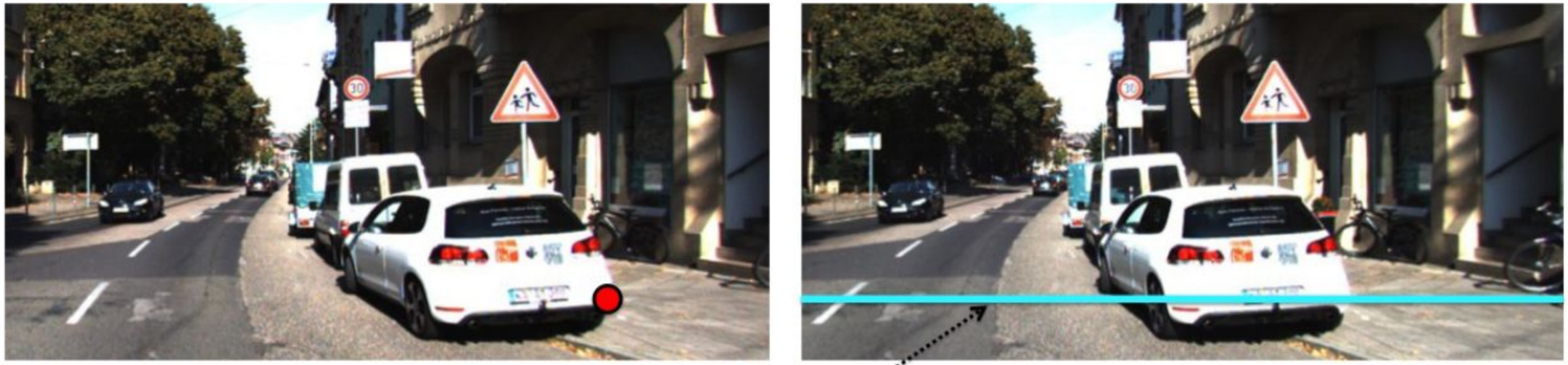


1
2

Image source: https://www.oreilly.com/library/view/learning-opencv-3/9781491937983/

How to perceive depth from 2D images?



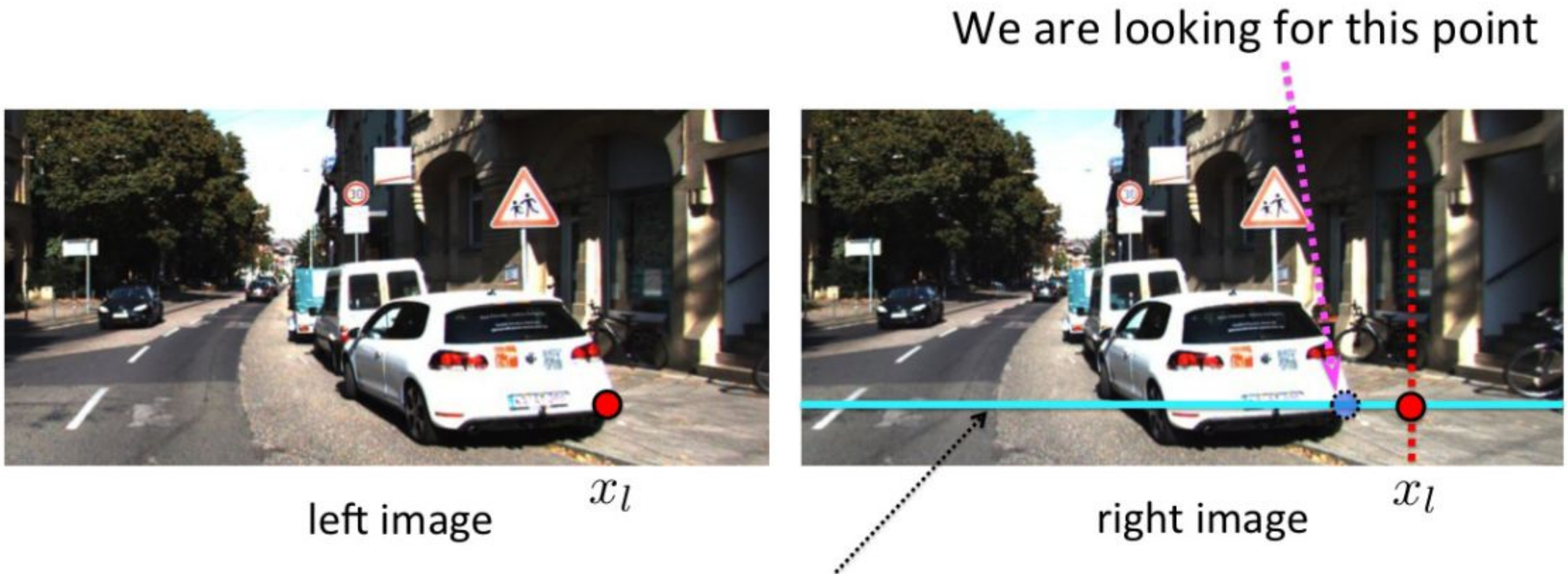
left image

right image

the match will be on this line (same y)

source: http://www.cs.toronto.edu/~fidler/slides/2015/CSC420/lecture12_hres.pdf

How to perceive depth from 2D images?



source: http://www.cs.toronto.edu/~fidler/slides/2015/CSC420/lecture12_hres.pdf

Pipeline for stereo depth

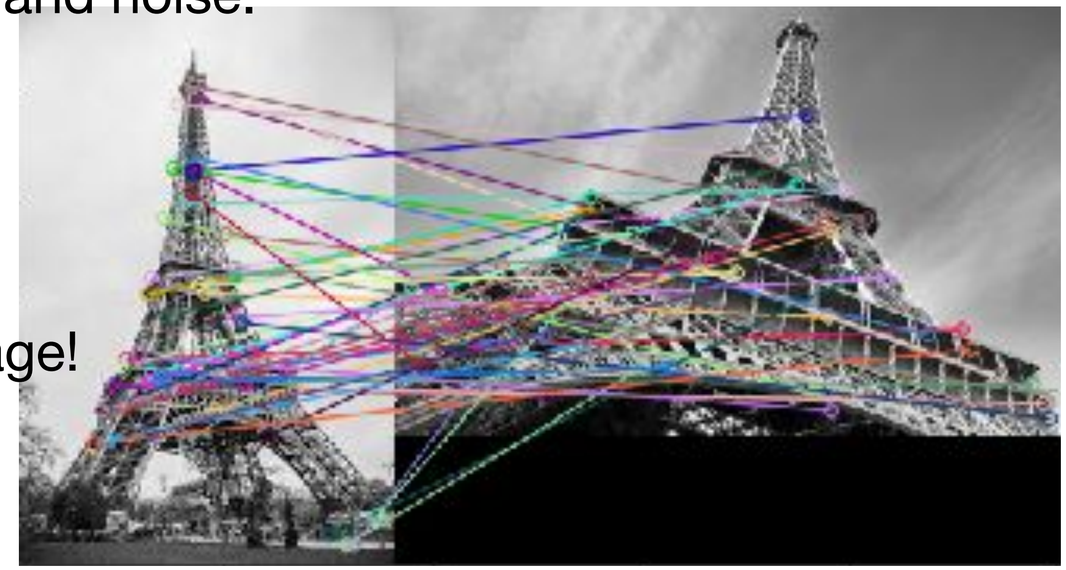
The devil is in the details

- Calibrate the camera (checkerboard)
- Take stereo image
- Split image into two separate images
- Align both images with calibration matrices
- Match every pixel in left image with a pixel in right image (occlusion is a problem)
- Create disparity map to obtain per-pixel depth information:
- Calibration and alignment are great challenges. Use more points for calibration!

$SIFT^2$ for calibration

Distinctive Image Features from Scale-Invariant Keypoints

- Checkerboard ± 70 points, but not uniformly spread across the image!
- Keypoint descriptor based on local image gradients.
- Very robust descriptor due to invariance to rotation and scale.
  - Also robust to changes in lighting, affine distortion, and noise.
- Match keypoints from both images and find the transformation matrix.
- Can use hundreds of keypoints, across the whole image!

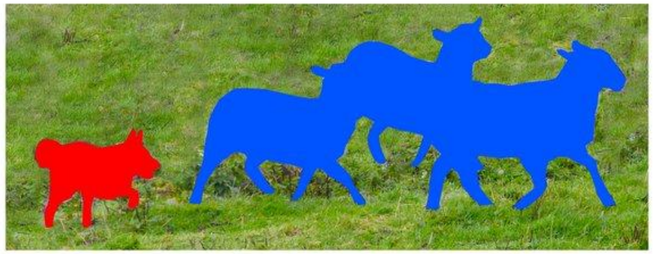


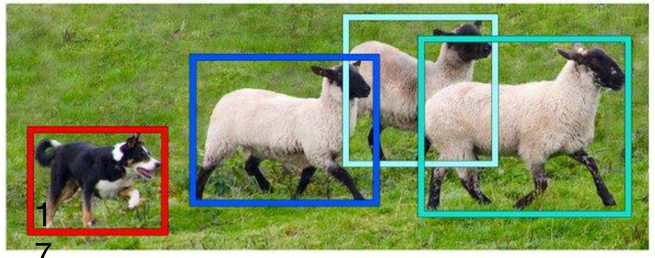
Depth is cool, but what is a person?

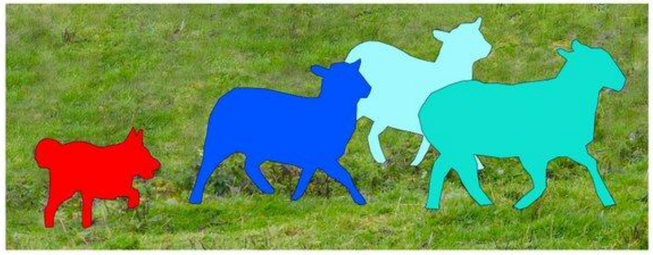
Instance segmentation in a nutshell

- From image recognition to instance segmentation.
- We need to be able to distinguish between people.
- Object instance detection not sufficient; why not?
- Use the instance mask for depth.
- But, what if the mask is not perfect?

Image Recognition

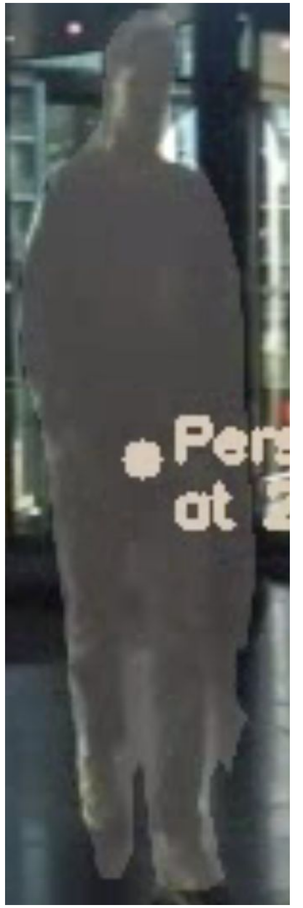

Semantic Segmentation


Object Detection


Instance Segmentation

What metric to use?

A: Mean
B: Median
C: Maximum



What metric to use?

A: Mean

B: Median

C: Maximum

How to do instance segmentation?

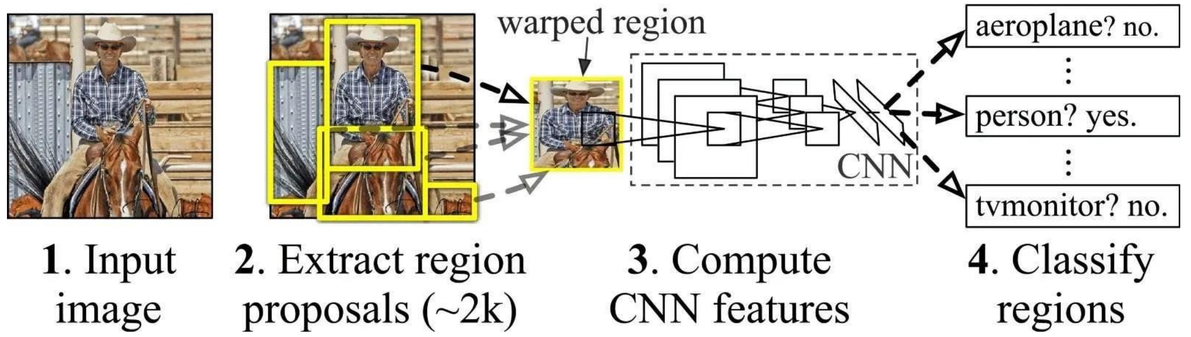
Lots of research done in CV field

- Detectron2[3] library from Facebook Research.
- Mask-RCNN[4] structure with ResNet50[5] backbone.
- Many pretrained models are available.

A little dive into Mask-RCNN

It is all based on Convolutional Neural Networks

- R-CNN[6] foundation of Mask-RCNN.
- Many forward passes make it slow.



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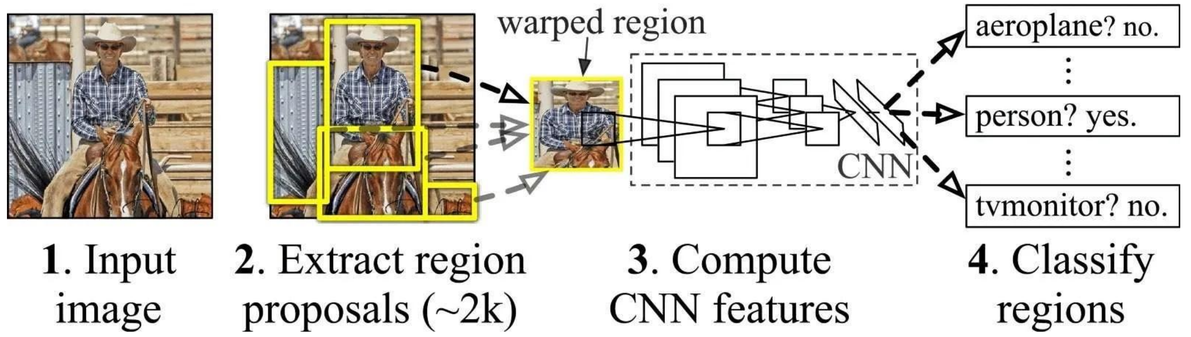
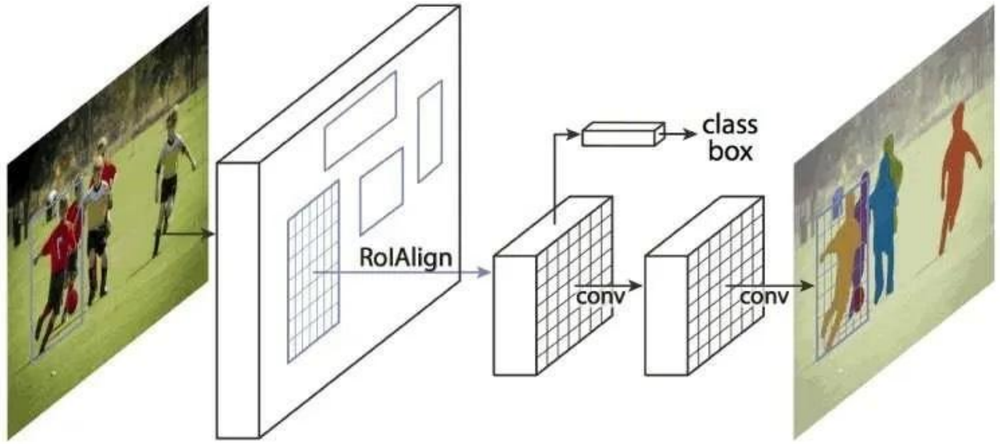


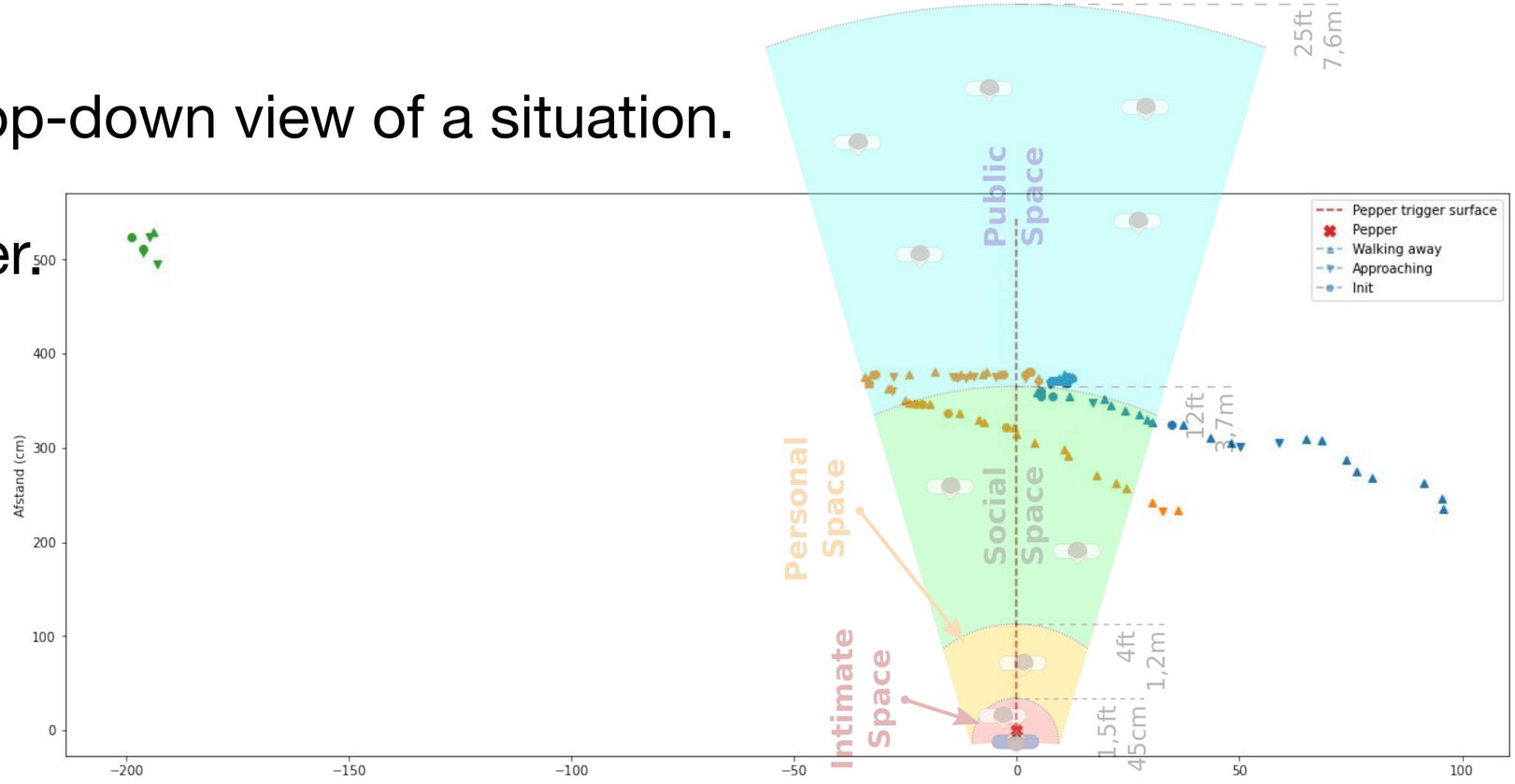
- Re-use features from conv layers + RPN.
- Additional branch for mask prediction.



Combining it all

Depth, instance segmentation, Hall's Proxemic…

- We can now generate a top-down view of a situation.
- Distance relative to Pepper.
- Distinguish persons.
- Approaching or not.
- Hall's spaces.
- Path prediction.
- Shall I say hello?



Remaining challenges

We have still some work to do

- How reliable is the pipeline?
- How can we make the whole pipeline fast enough to run in real-time?
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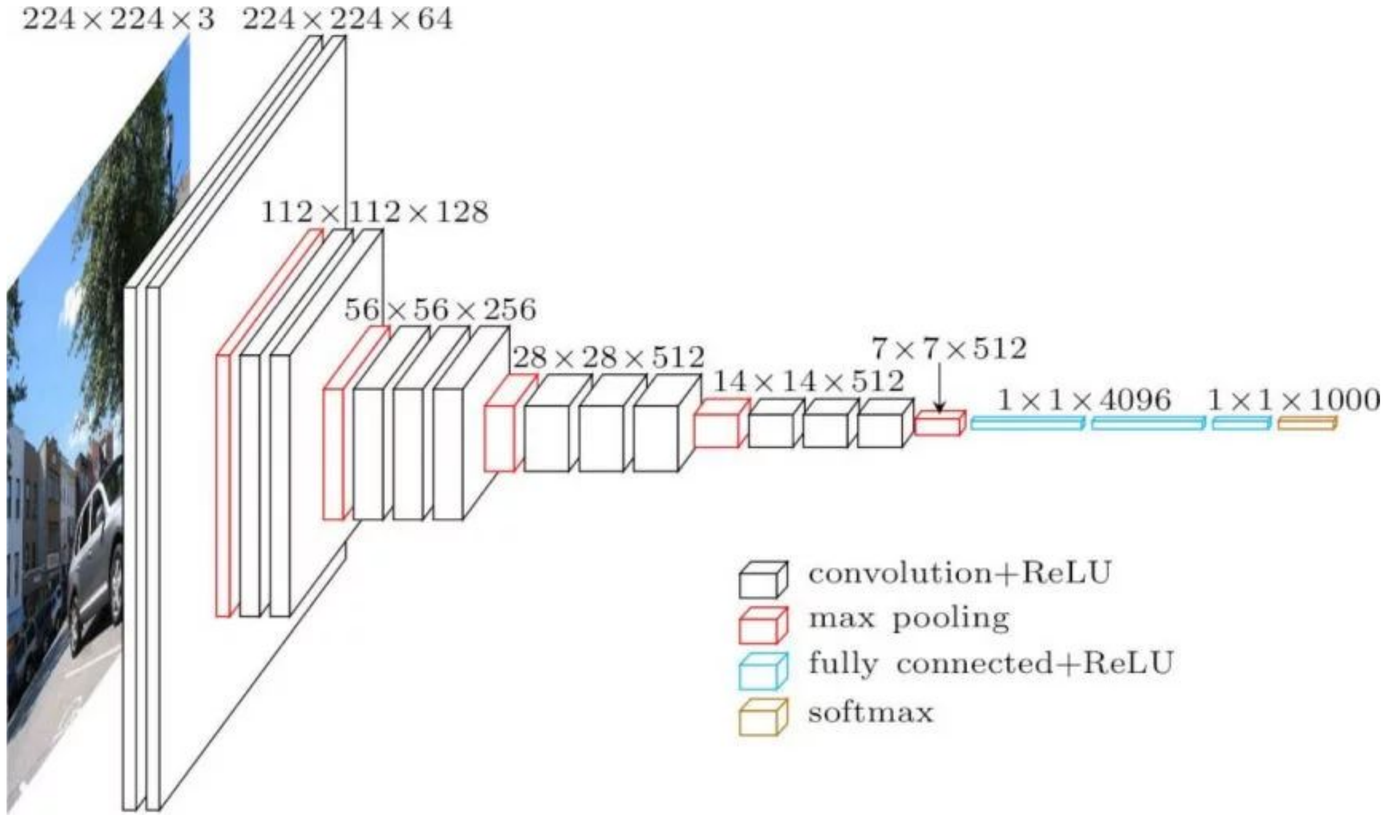
- What happens when more people (e.g. 5+) enter the frame?
- How can we track people better?

Next step: Face recognition

- Trained using large datasets of faces
  Learn to identify faces of the same person



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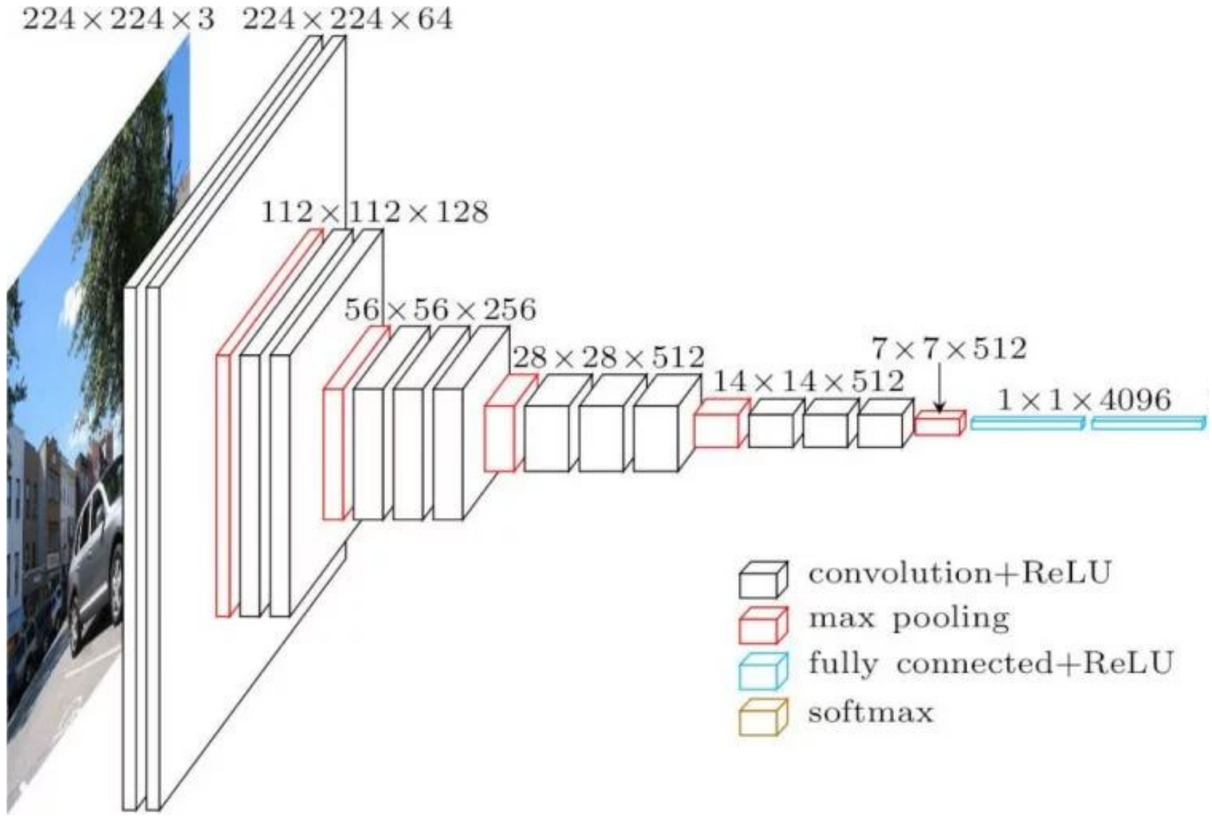

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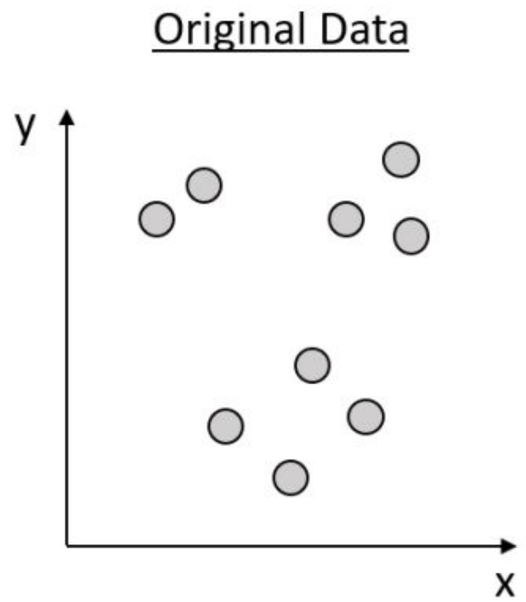
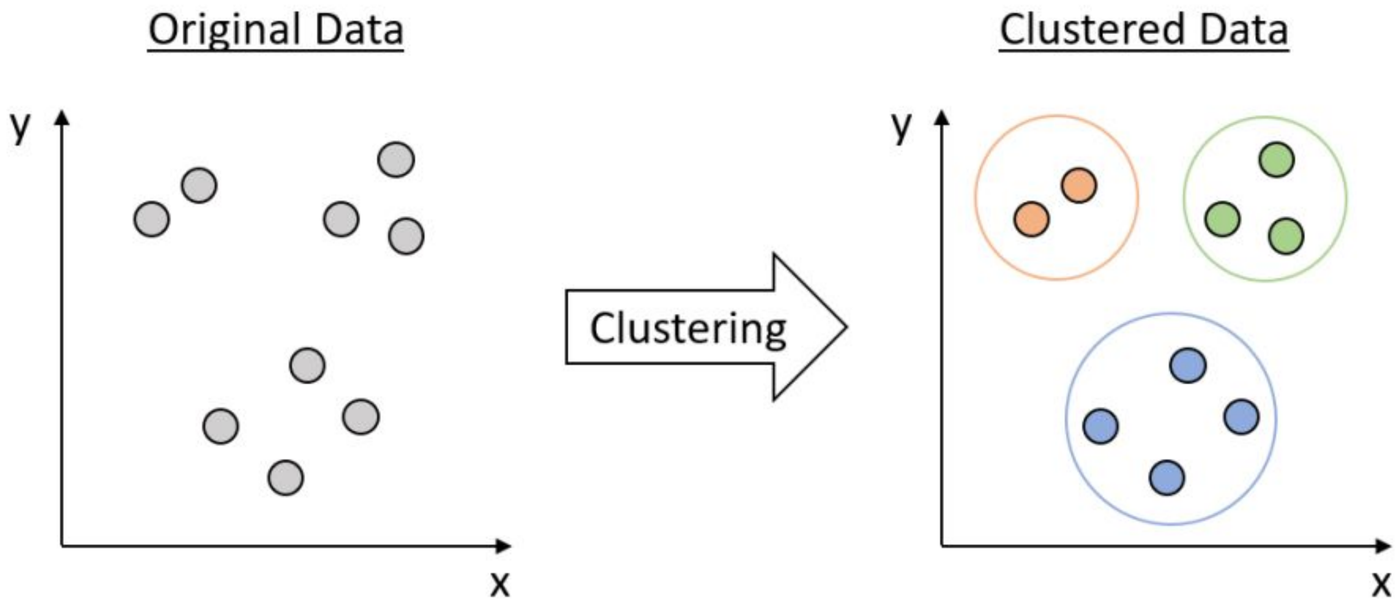


Next step: Face recognition

- Use clustering to recognize persons



The Social Interaction Cloud Framework

Provides components:

- Face detection
- Face recognition

```
# Connect to the services
desktop = Desktop()
face_rec = DNNFaceDetection()

# Feed the camera images into the face recognition component
face_rec.connect(desktop.camera)

# Send back the outputs to this program
desktop.camera.register_callback(on_image)
face_rec.register_callback(on_faces)

while True:
    img = imgs_buffer.get()
    faces = faces_buffer.get()

    for face in faces:
        draw_bbox_on_image(face, img)

    cv2.imshow('', img)
    cv2.waitKey(1)
```

References

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3. Wu, Y., Kirillov, A., Massa, F., Lo, W. Y., & Girshick, R. (2019). Detectron2. GitHub. Retrieved November 30, 2021, from https://github.com/facebookresearch/detectron2

4. He, K., Gkioxari, G., Dollar, P., & Girshick, R. (2017). Mask R-CNN. 2017 IEEE International Conference on Computer Vision (ICCV). Published. https://doi.org/10.1109/iccv.2017.322

5. He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep Residual Learning for Image Recognition. 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR). Published. https://doi.org/10.1109/cvpr.2016.90R-CNN

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