Carnegie Mellon ROBOTICS CLUB

Computer Vision

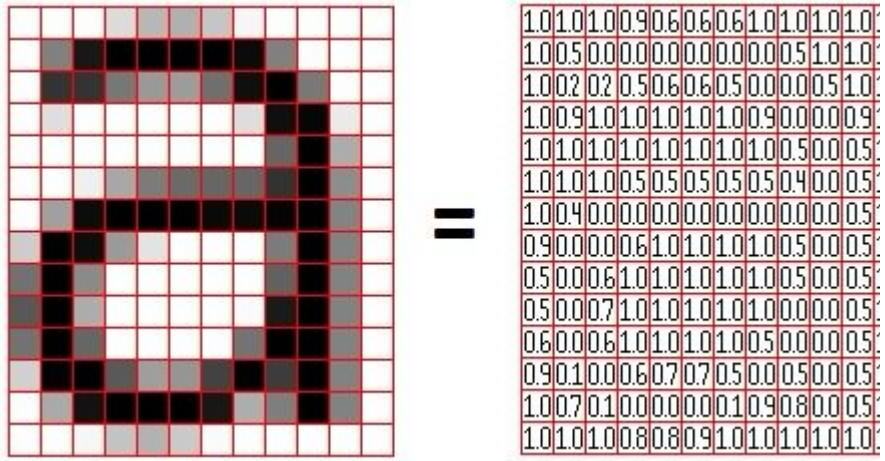
Spring 2026

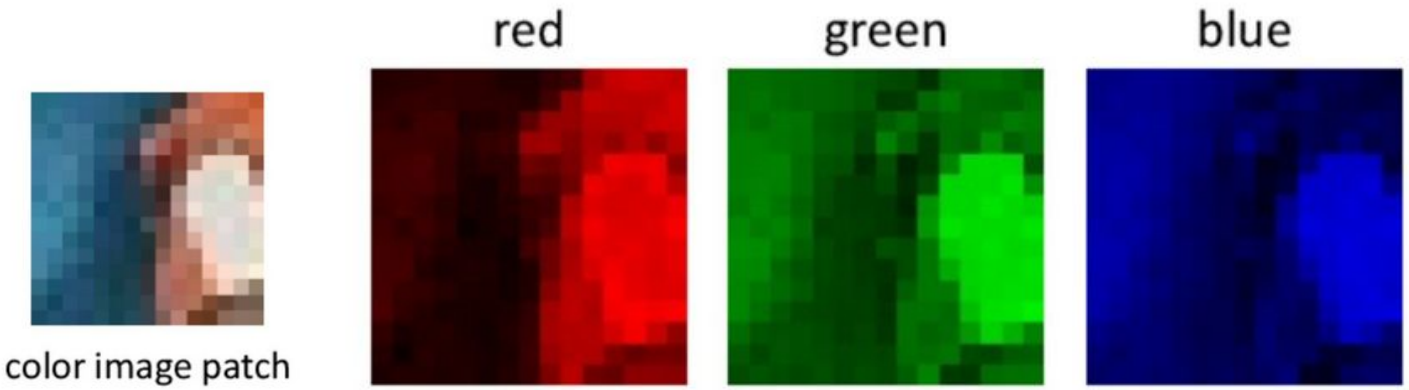
Overview

- Filters & Convolutions
- Panoramas
- Stereo
- Object Tracking

Images

- 2D matrix/grid of values
  - 1 = light, 0 = dark
  - Alt: 0 to 256
- Color images with 3 channels(red, green, blue)





Point Operation

- do some operation to each pixel value in the image

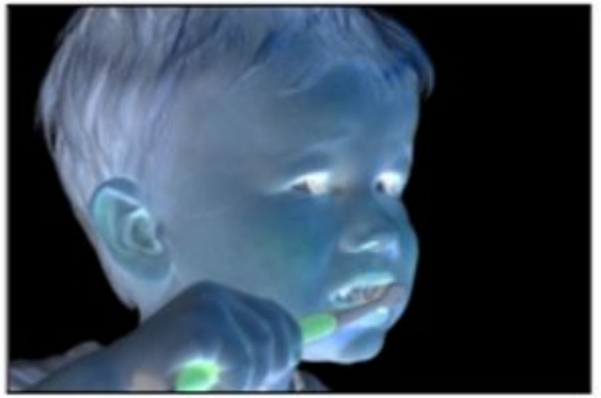
original

x

darken

$x - 128$

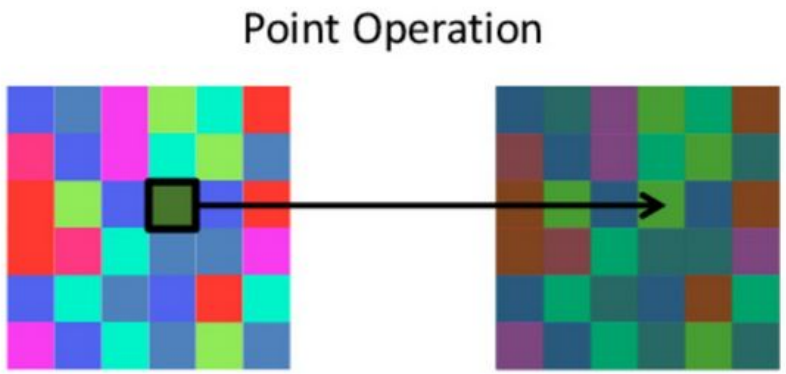
invert



$255 - x$

Filtering

- neighborhood operation



point processing

“filtering”

Box Filter

$g[\cdot,\cdot]$

kernel

$\frac{1}{9}$

1	1	1
1	1	1
1	1	1

$f[\cdot,\cdot]$

image

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$h[\cdot,\cdot]$

output

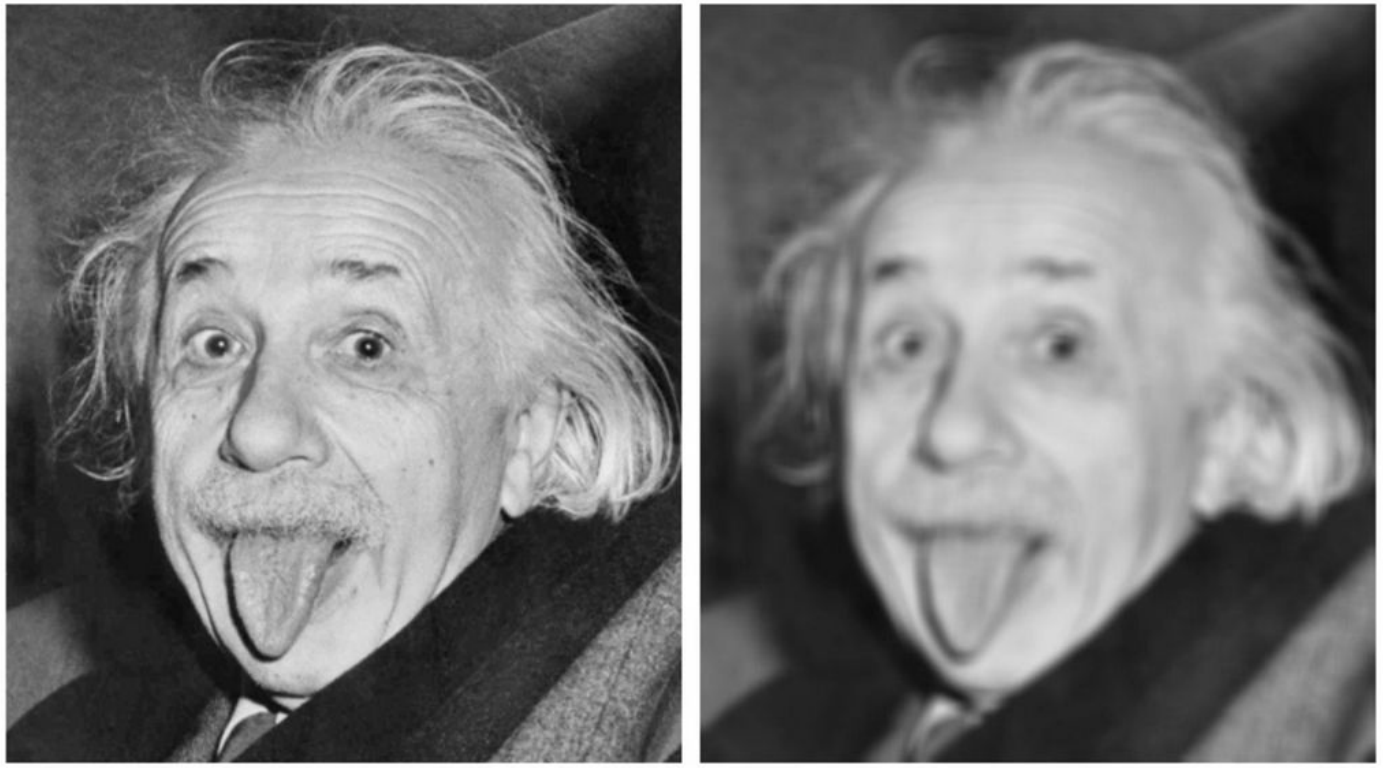
	0	10	20						

$$h[m,n] = \sum_{k,l} g[k,l] f[m+k, n+l]$$

output — k,l — filter — image (signal)

Candy Question

What does this filter do?



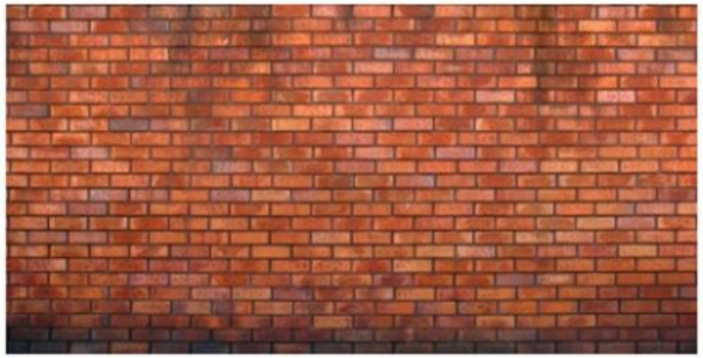
Sobel Filter

Horizontal Sober filter:

1	0	-1
2	0	-2
1	0	-1

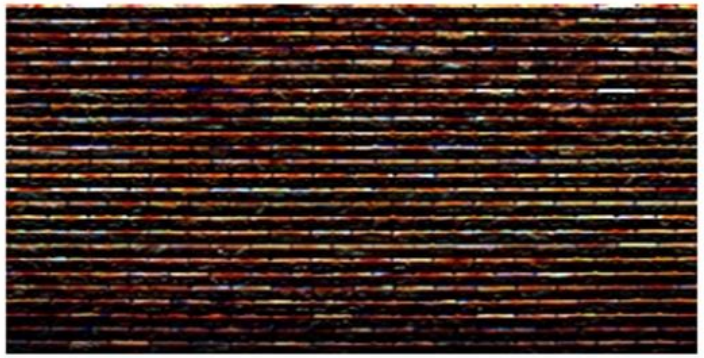
Vertical Sobel filter:

1	2	1
0	0	0
-1	-2	-1



original

horizontal Sobel filter

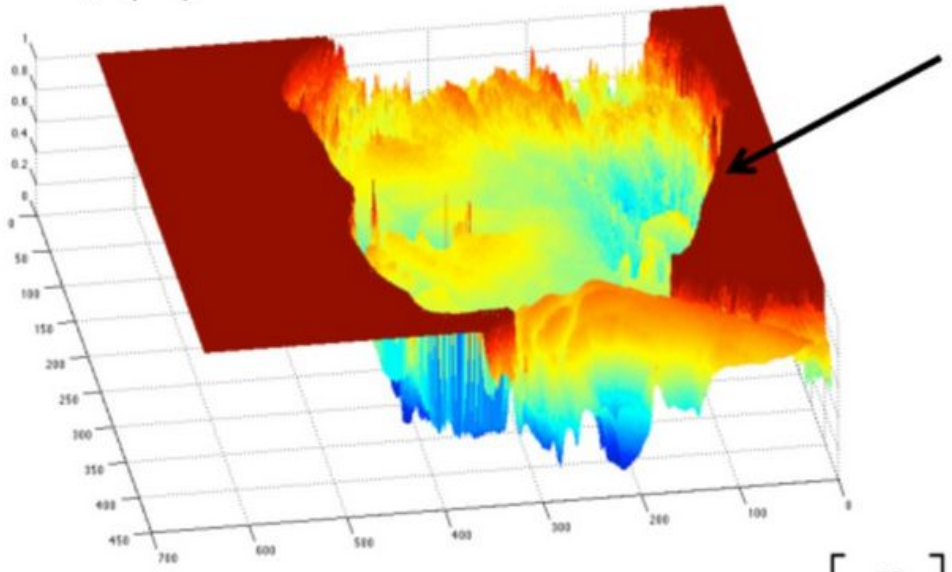


vertical Sobel filter

Gradient = Edge

grayscale image

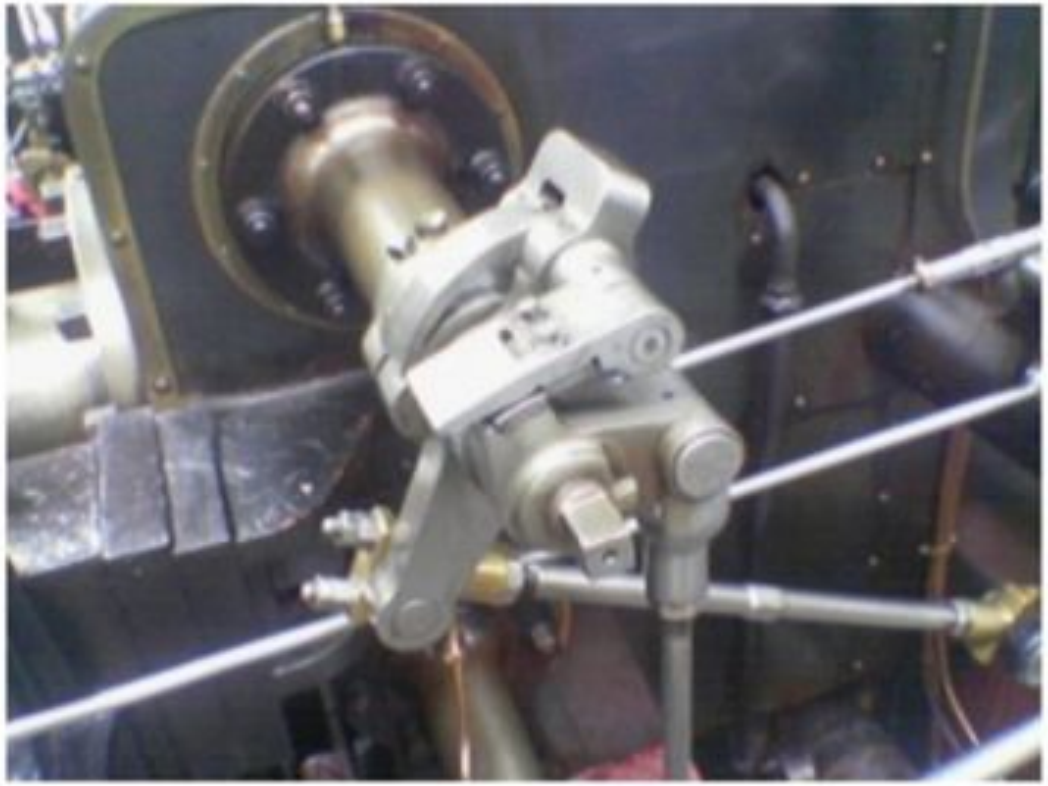
$f(\boldsymbol{x})$

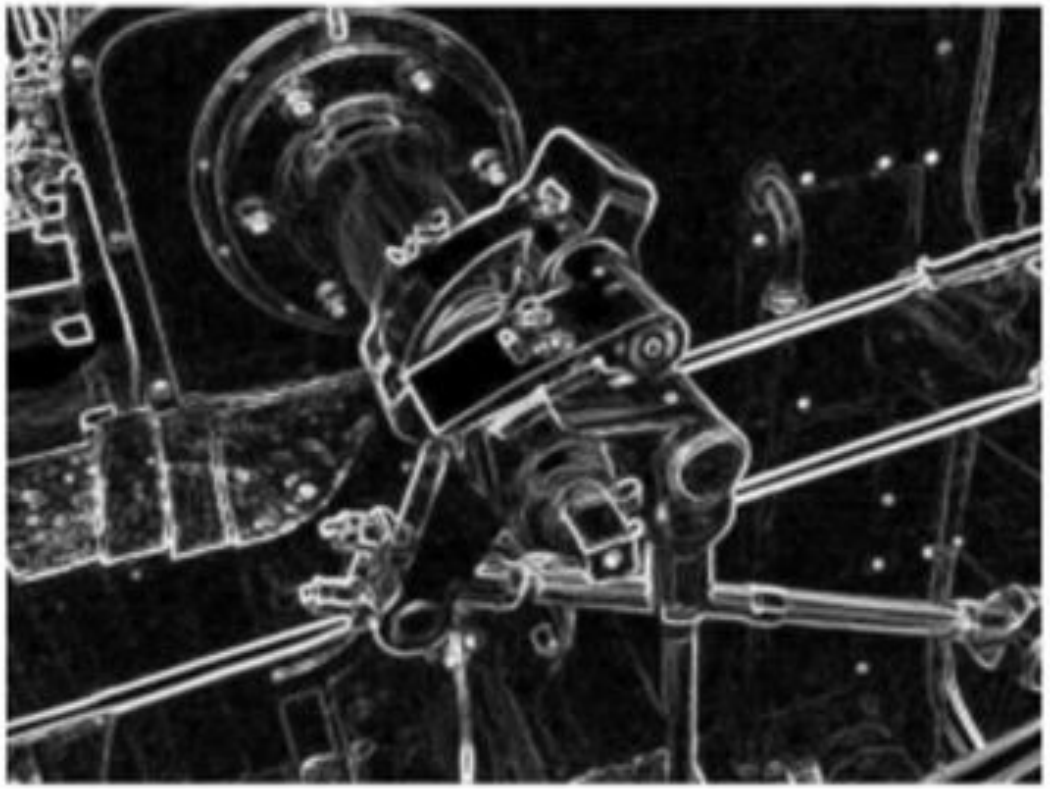


Very sharp discontinuities in intensity.

domain $\boldsymbol{x} = \begin{bmatrix} x \\ y \end{bmatrix}$

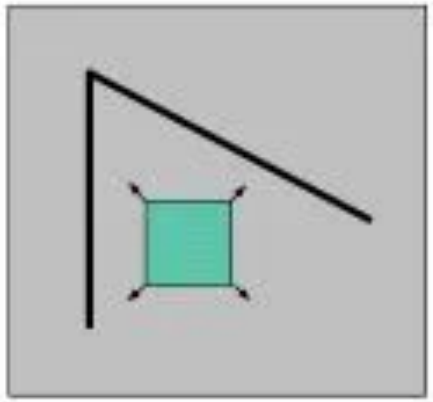
Line Detection



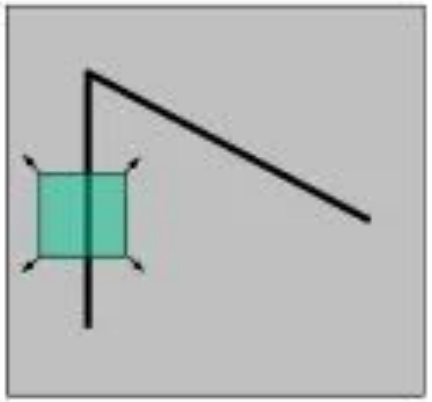


Corner Detection

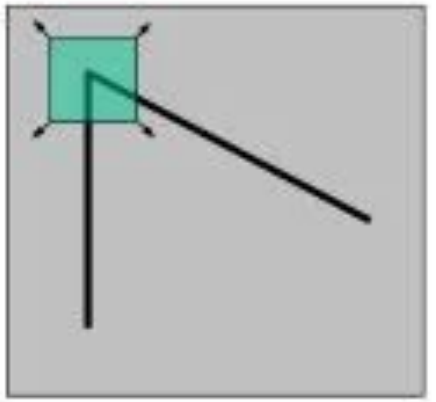
- Sobel Vertical & Horizontal Filter + Linear Algebra = Corners!
- Points of Interest(for CV algorithms)



"flat" region:
no change in all directions



"edge":
no change along the edge direction

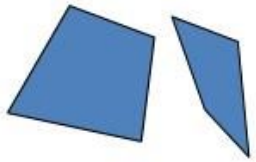


"corner":
significant change in all directions

Transformations

Projective
8 dof

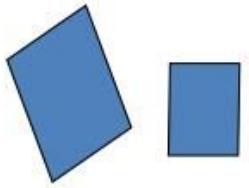
$$\begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix}$$



Views of a plane from different viewpoints, any view of a scene from the same viewpoint.

Affine
6 dof

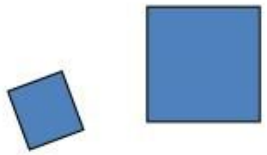
$$\begin{bmatrix} a_{11} & a_{12} & t_x \\ a_{21} & a_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$



Images of a "far away" object under any rotation

Similarity
4 dof

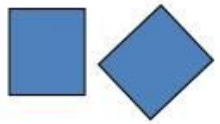
$$\begin{bmatrix} sr_{11} & sr_{12} & t_x \\ sr_{21} & sr_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$



Camera looking at an assembly line w/ zoom.

Euclidean
3 dof

$$\begin{bmatrix} r_{11} & r_{12} & t_x \\ r_{21} & r_{22} & t_y \\ 0 & 0 & 1 \end{bmatrix}$$

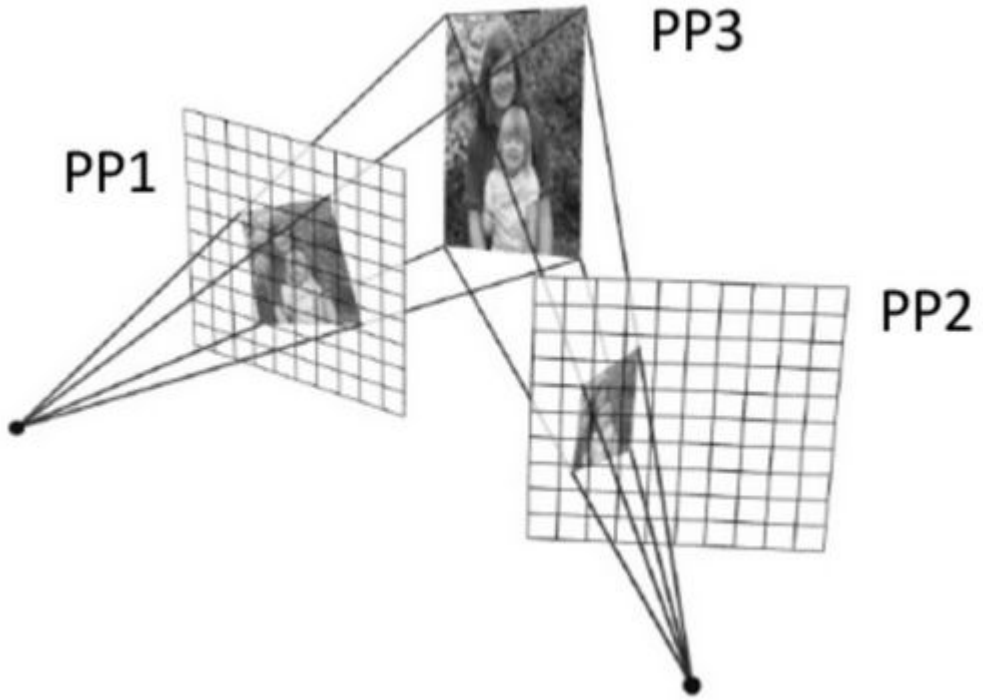


Camera looking at an assembly line.

Computer Vision, Robert Pless

Homography

- Projective
- A 3x3 matrix that maps 2D pts from different projective planes to 3D and vice versa.
- Think of it as a function that maps a 3D point(on the object) into the 2D pt on an image
- What points? Corners!

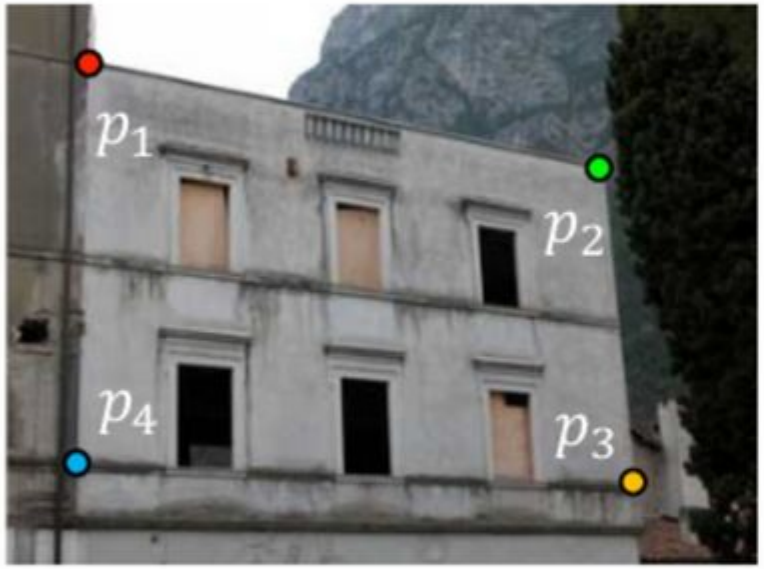


Application: Panorama

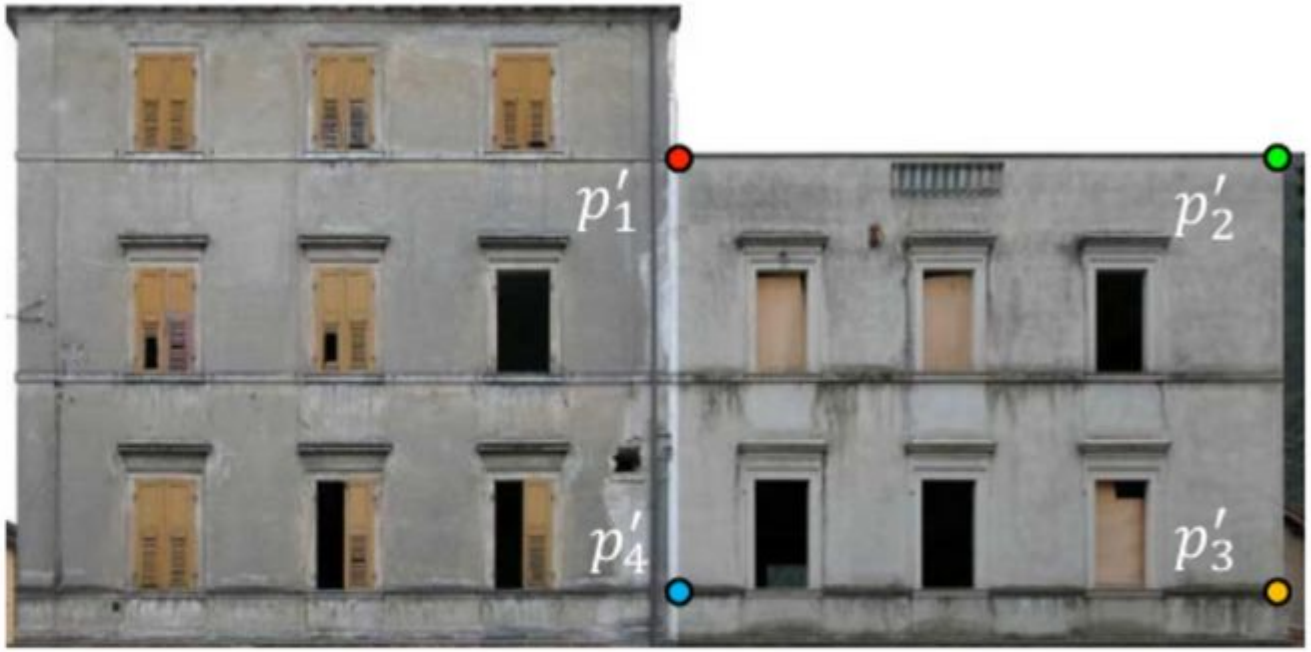
How do we stitch images from different viewpoints?

Use image homographies.

Application: Panoramas



original image



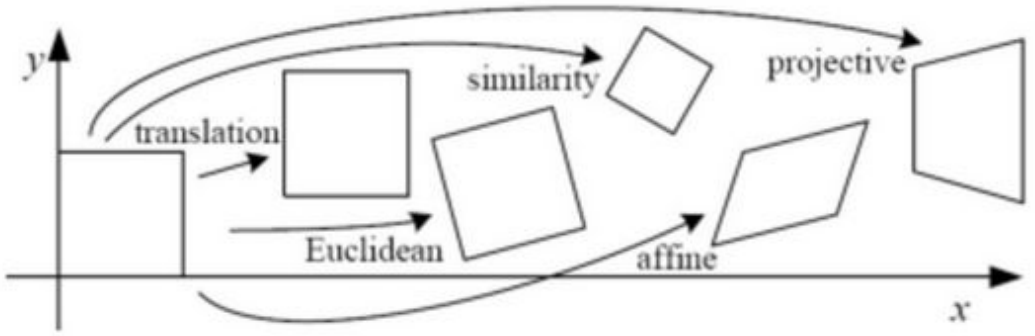
target image

Application: AR

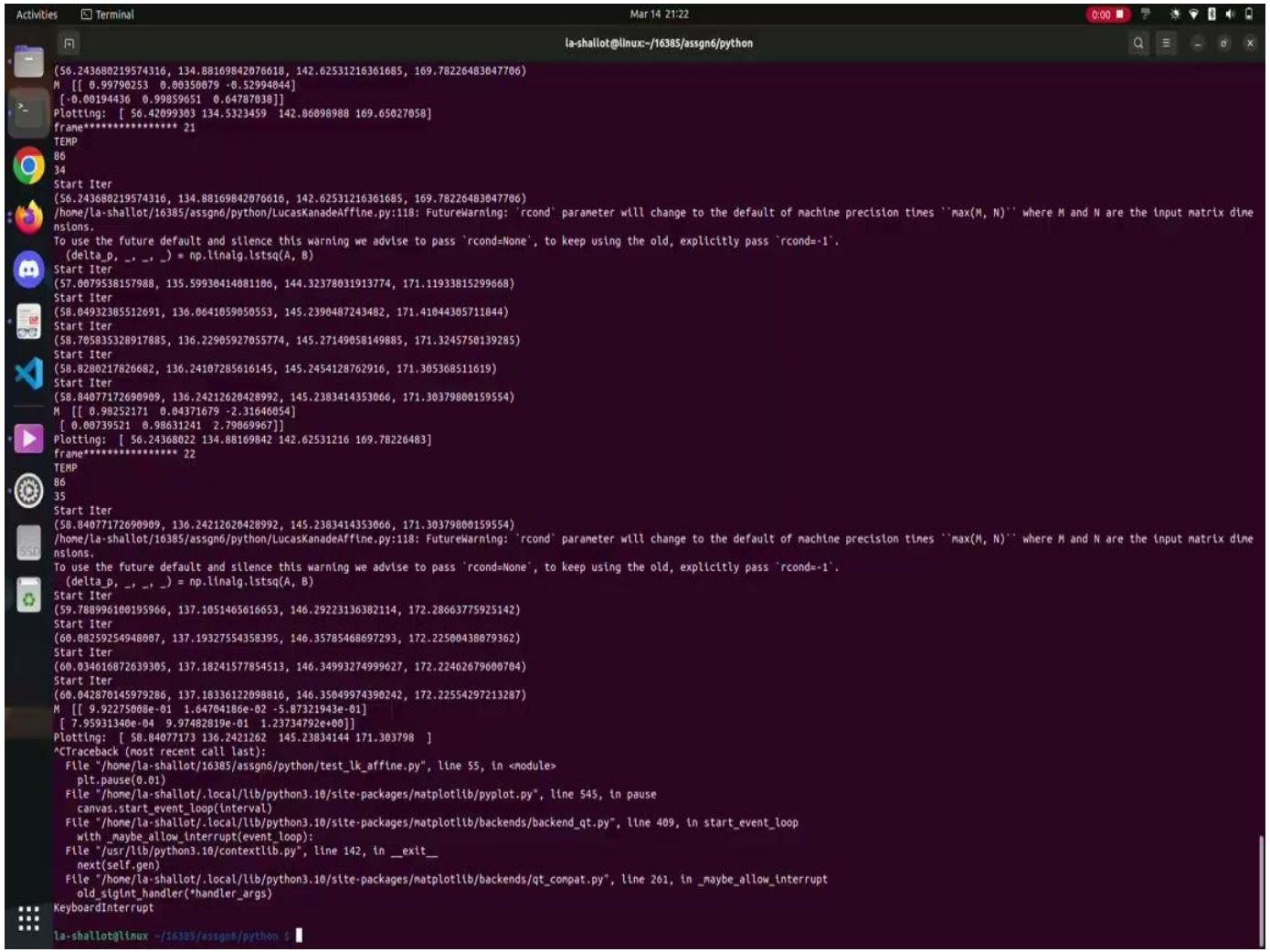
Object Tracking

Optical Flow: Tracking movement of pixels in a template(ex. a car) from frame to frame in a video

Limits to affine transformations = Less work(less degrees of freedom)



Small Demo



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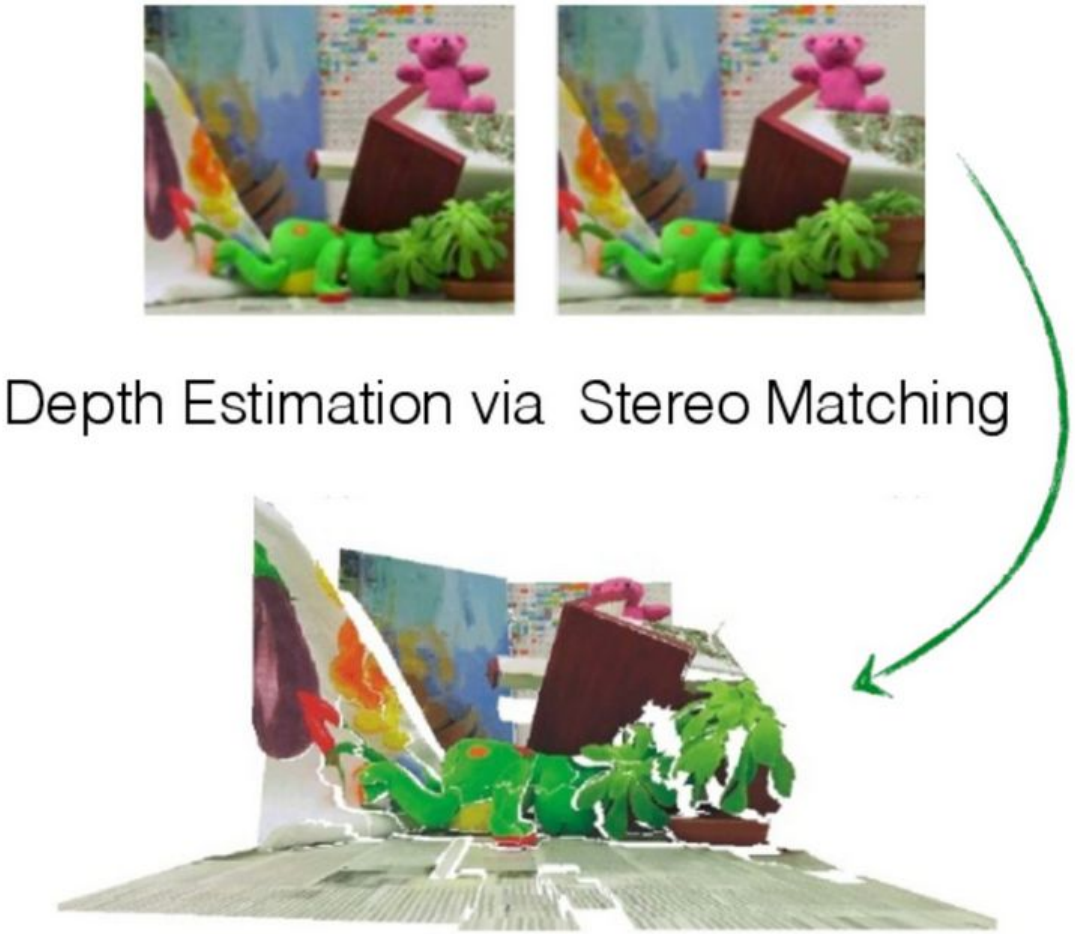
Stereo

The amount of horizontal movement is inversely proportional to …

… the distance from the camera.

2 Images -> Depth Perception!

Stereo: Result



Candy Question:

What are some applications of depth perception via stereo you can think of?

Answers

Stereoscopes: A 19th Century Pastime

Subaru
Eyesight system

Pre-collision
braking

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Want to Learn More?

Computer Vision (CMU 16-385)

This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems.

more at this link! http://vision.cs.cmu.edu/courses.html

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