ECES435 Project 2

Image alignment and stacking for random noise reduction

Problem Statement

- Simplified model: $\mathrm{SNR} = \frac{\mathrm{Signal}}{\mathrm{Noise}} = \frac{\sim \mathrm{ExposureTime} * \left(\frac{\mathrm{Aperture}}{\mathrm{FocalLength}}\right)}{\mathrm{Noise}}$

- In most scenarios, longer exposure leads to higher SNR
  However, exposure time can be limited due to shaking hands, moving targets etc.

- How to produce better looking pictures with smartphone under low-light condition?

Proposed Solution

- Averaging of multiple pictures of the same scene
  Mean of independent and identical districbuted random variables has smaller variance

$$\bar{X} = \frac{X_1 + X_2 + \ldots X_n}{n} = \left(\frac{1}{n}\right)(X_1 + X_2 + \ldots + X_n)$$

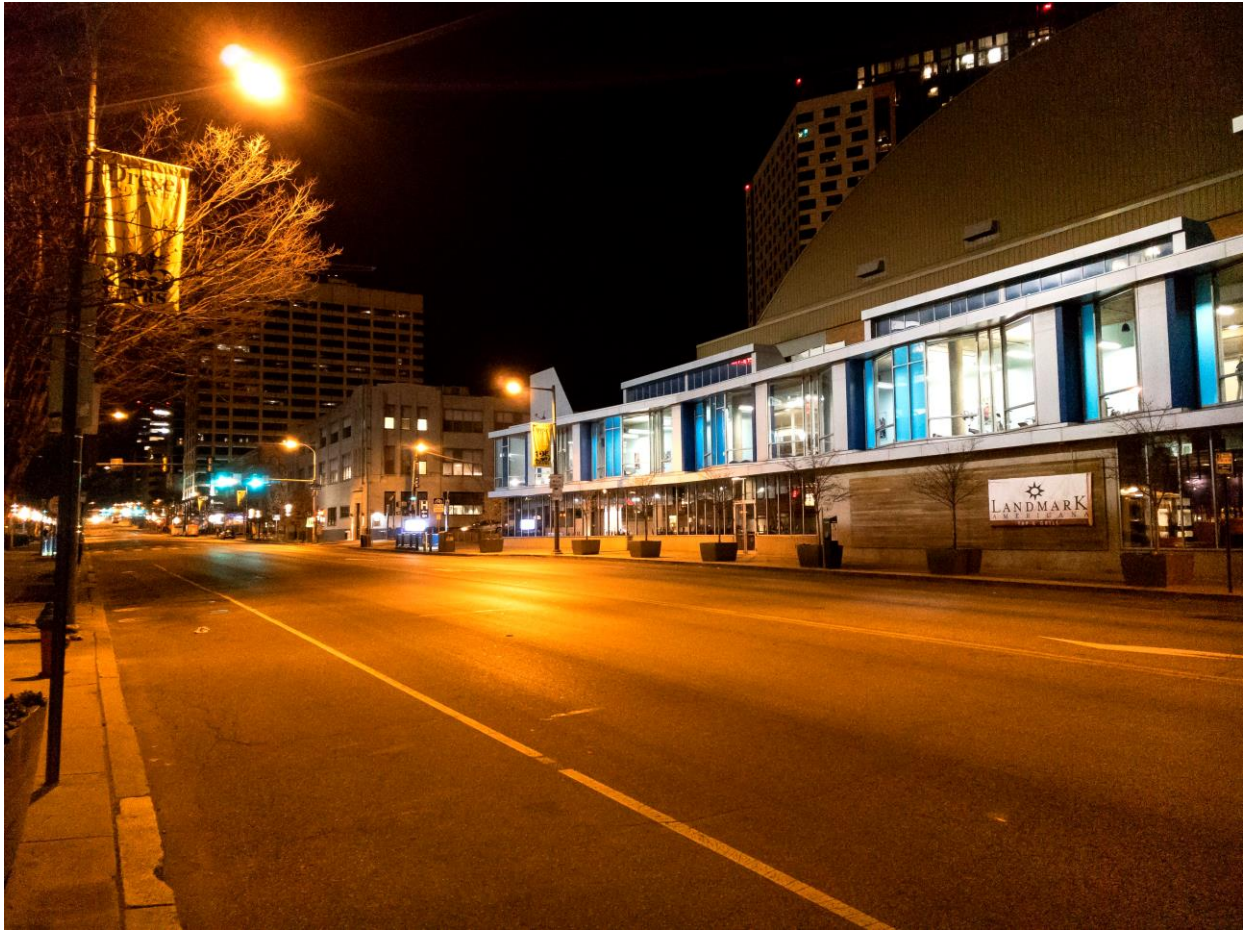
$$\mathrm{Var}(\bar{X}) = \mathrm{Var}\left[\left(\frac{1}{n}\right)(X_1 + X_2 + \ldots + X_n)\right] = \left(\frac{1}{n}\right)^2 \mathrm{Var}\,(X_1 + X_2 + \ldots + X_n)$$

$$\mathrm{Var}(\bar{X}) = \left(\frac{1}{n}\right)^2 \mathrm{Var}\,(X_1 + X_2 + \ldots + X_n) = \left(\frac{1}{n}\right)^2 (n\sigma^2) = \frac{\sigma^2}{n}$$

Proposed Solution Continue

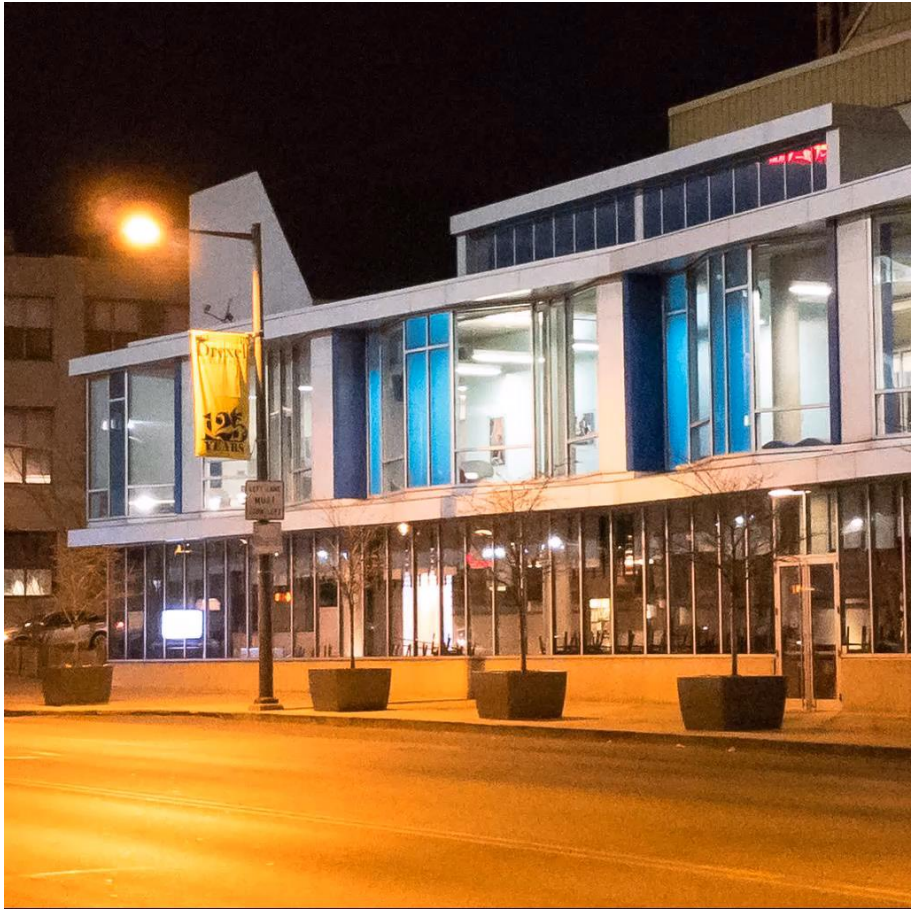
- Problem with averaging: Images are not usually aligned when taken with smartphone and hands
- Alignment Procedures
  - Preprocess images
  - Perform analysis on luma channel
  - Extract features from both images
  - Obtain matching relation between features
  - Find alpine transform that best fit these points

Raw Image Sequence



Preprocessing: Cropping and Picking

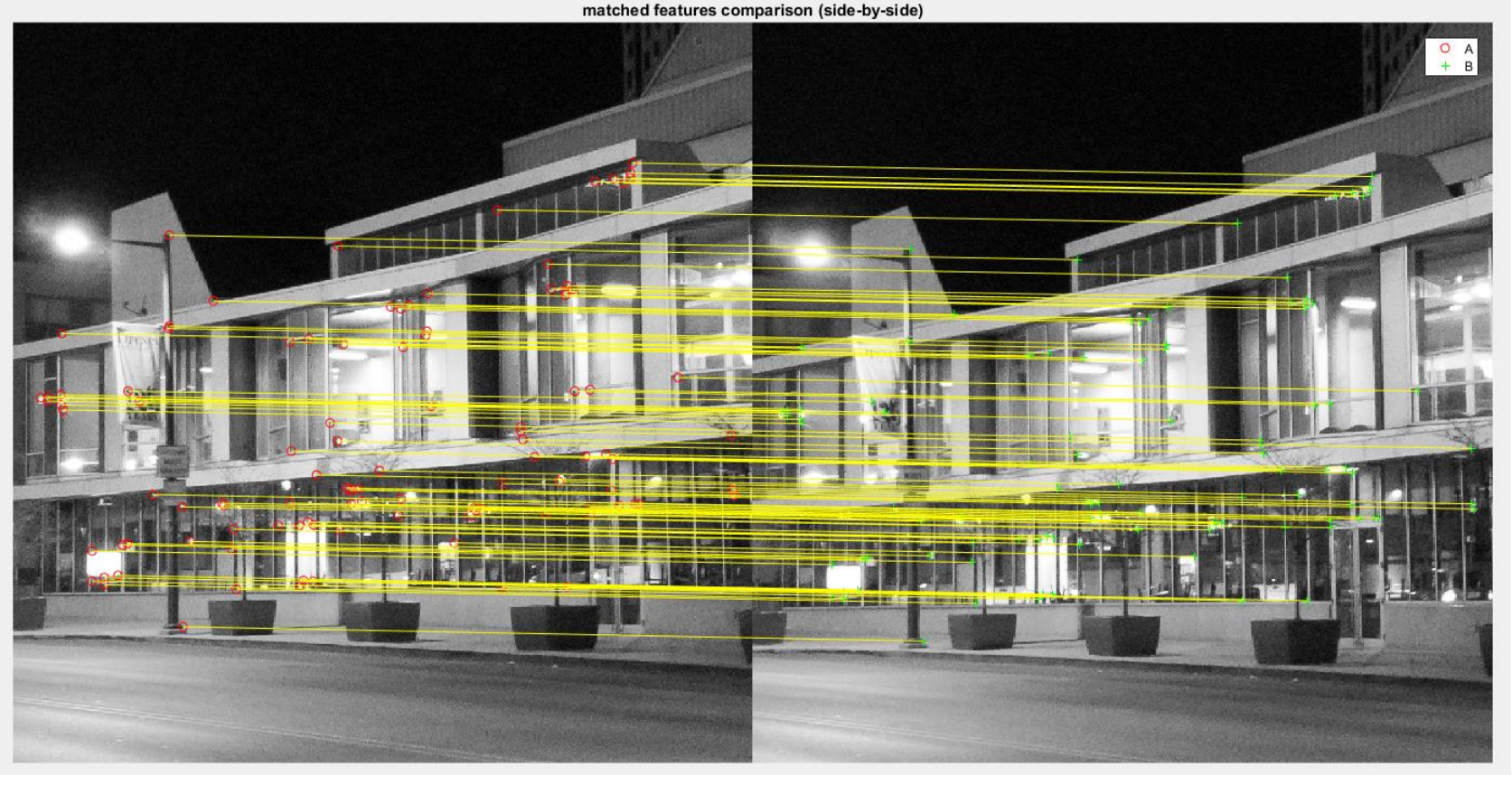
- 1024px square in the center
- 9 images in this sequence
- Last 5 images are used



Feature (Corner) extraction

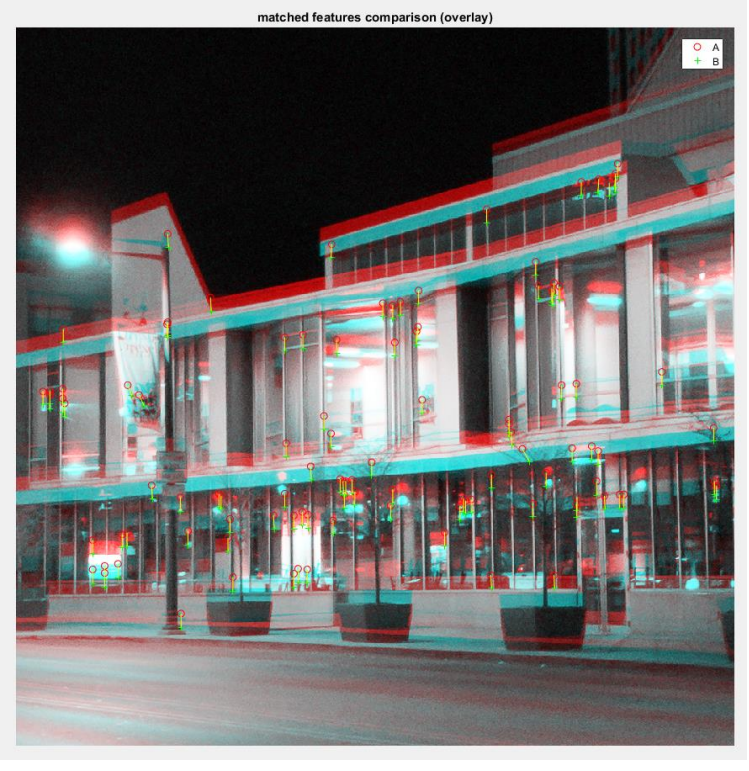
Features from Accelerated Segment Test (FAST) algorithm

Find matching point pairs



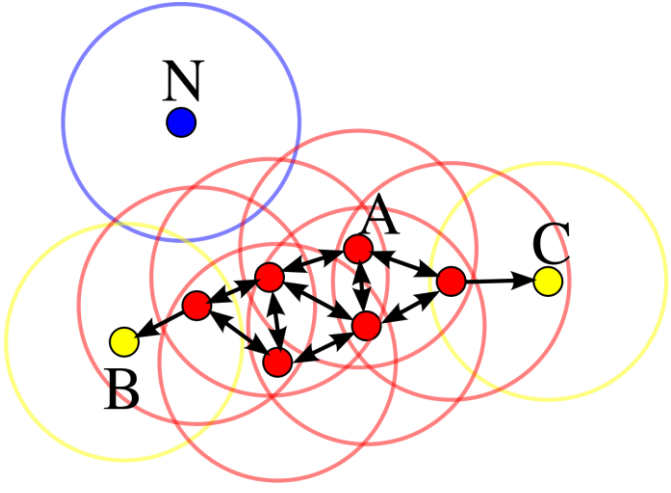
Matching points continue

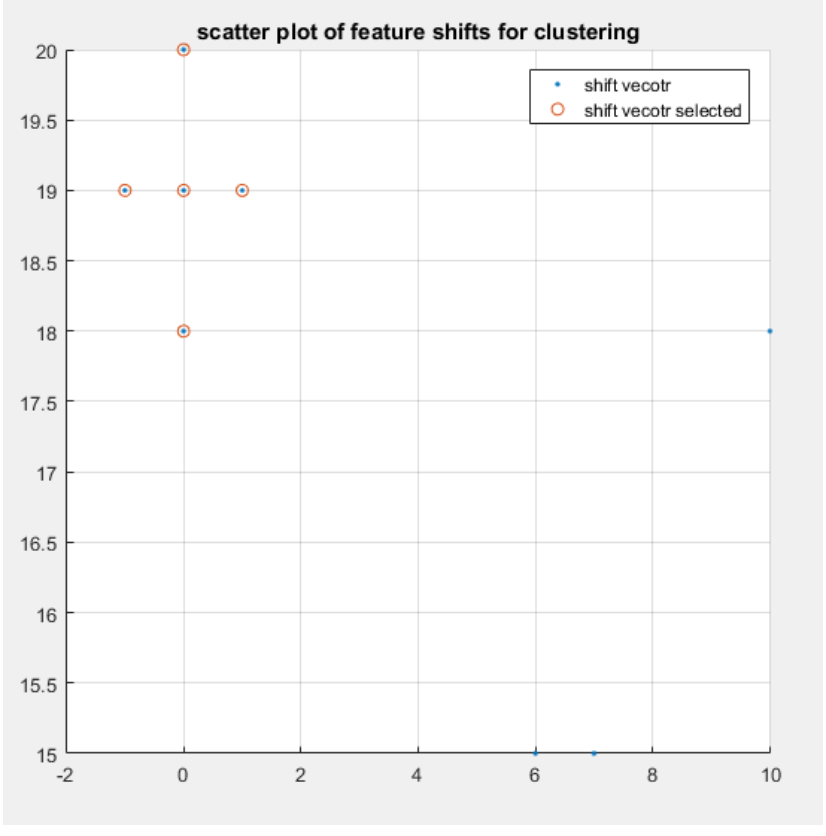
finding pairs of interest point using local neighborhoods and Harris algorithm



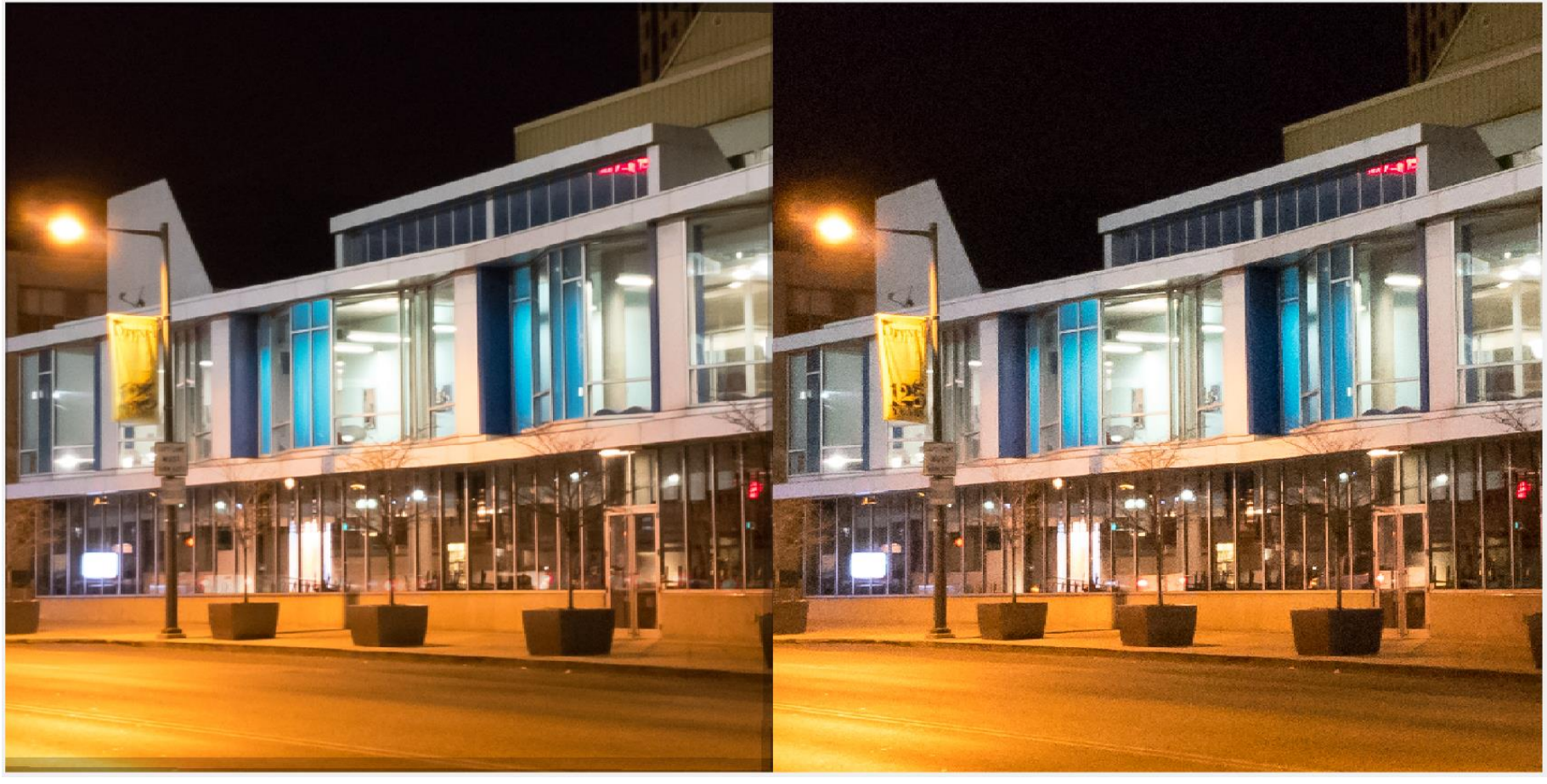
Matching points continue, clustering

- Clustering is used to remove outliers
- Density-based spatial clustering of applications with noise (DBSCAN)
- Radius of 2 pixels in this case; minimum points of 5



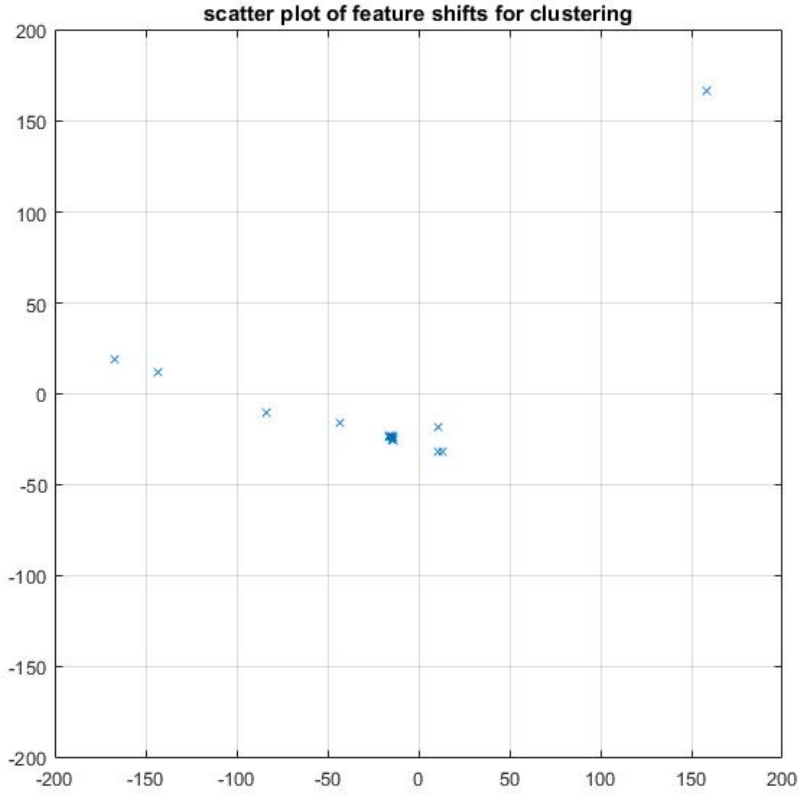


Results Comparison



- Possible future improvements
  - Upsampling before processing (so that alignment can reach precision below 1 pixel)
  - Evaluate picture quality before alignment, so blurry picture can be discarded
  - Make use of dark frames for systematic error reduction
  - Different clustering techniques
  - Different image wrapping techniques to compensate lens distortion

Questions?


scatter plot of feature shifts for clustering
200
150
100
50
0
-50
-100
-150
-200
-200
-150
-100
-50
0
50
100
150
200