University at Buffalo
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Image Processing to Vision based navigation for Autonomous Vehicles

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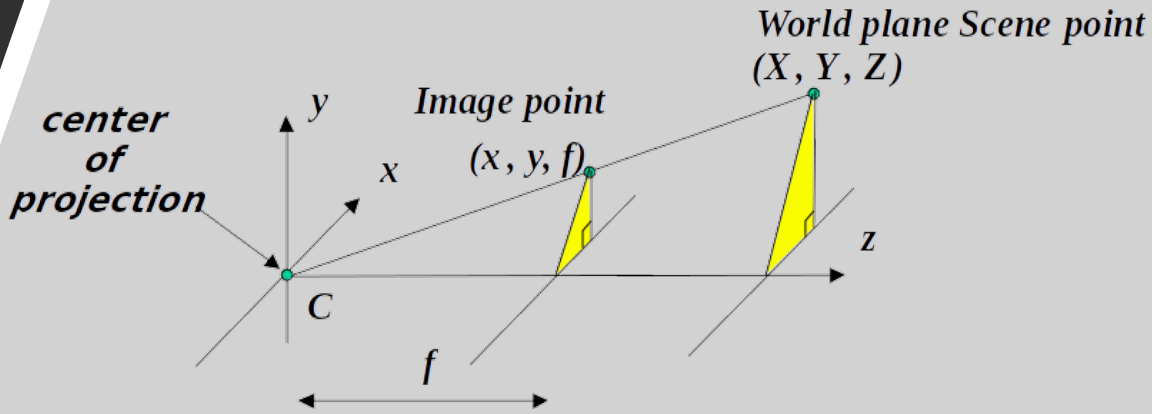
Basic Pinhole Model

(X,Y,Z)-> (fX/Z, fY/Z)

x = PX

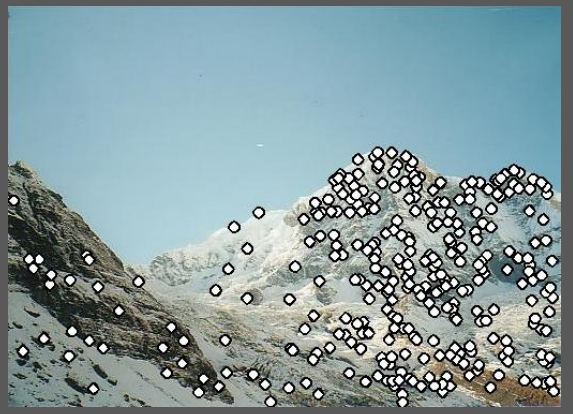
P = 3 x 4 homogeneous camera projection matrix



Feature Matching: Example

Detect feature points in both images

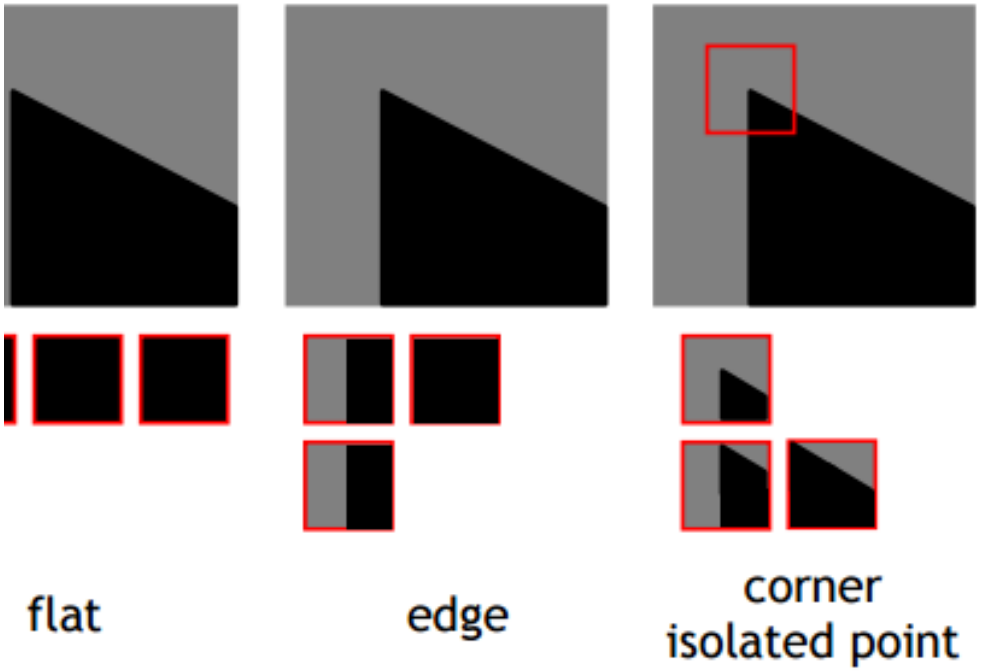
Find corresponding pairs



Feature Matching

Using corresponding pairs to align images

Single Scale Detectors

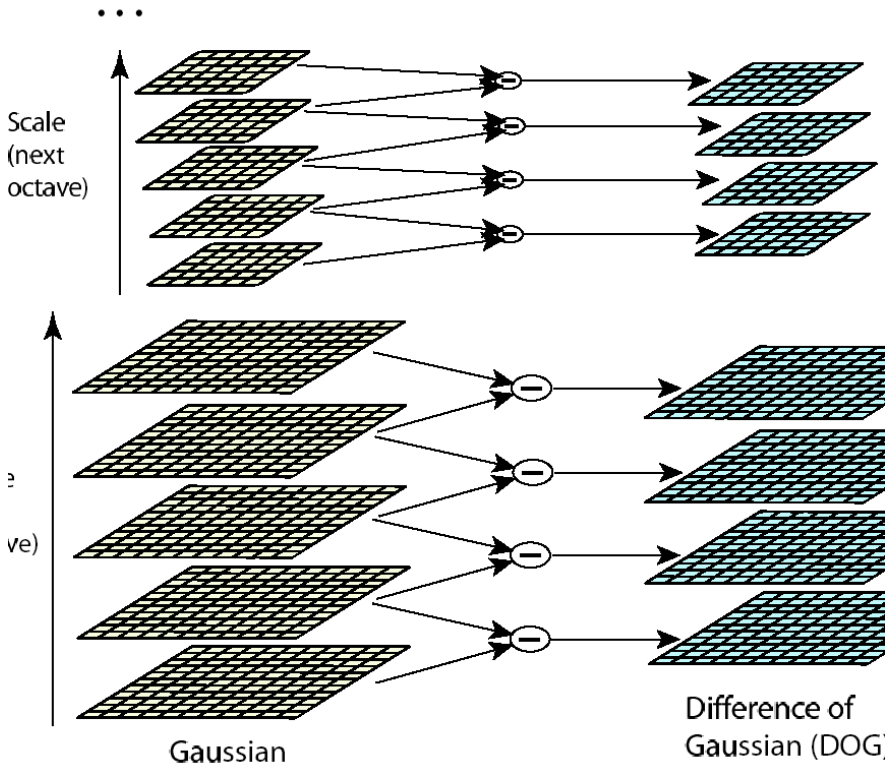


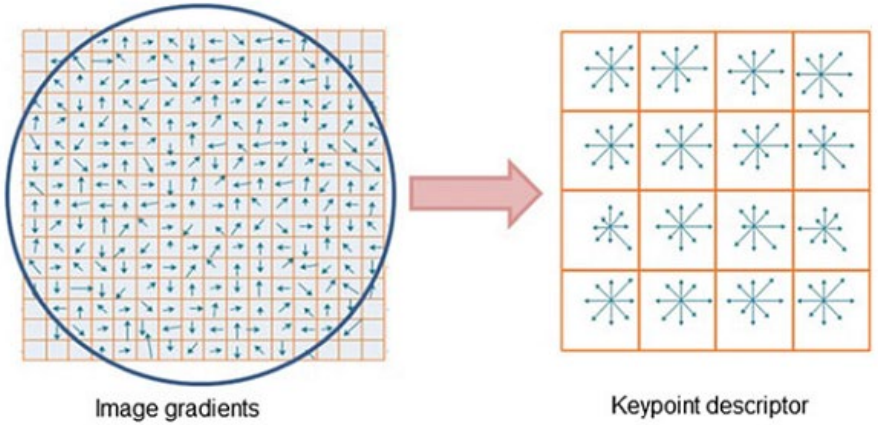
Moravec's detector (Corner detector)

- Determines similarity between the patch and the nearby patches.
- Corner point is detected when the SSD reaches a local maxima.

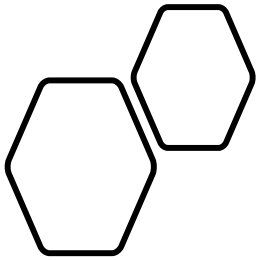
SIFT (Scale invariant feature descriptors)

4 × 4 histograms each with 8 bins, the feature vector has 4 × 4 × 8 = 128 elements for each keypoint





Feature matching



Exhaustive search

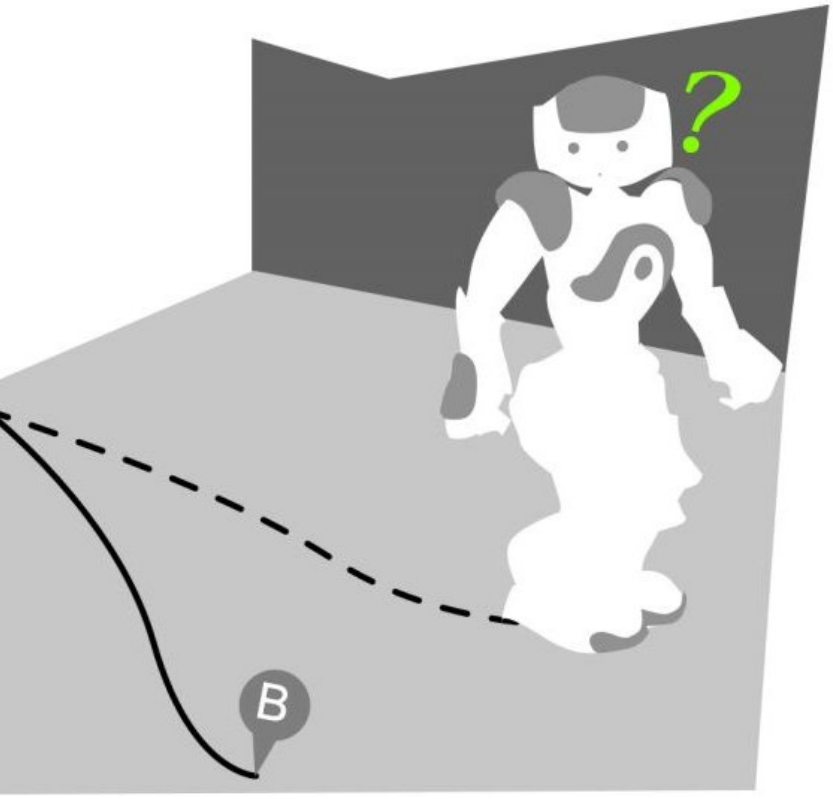
- for each feature in one image, look at all the other features

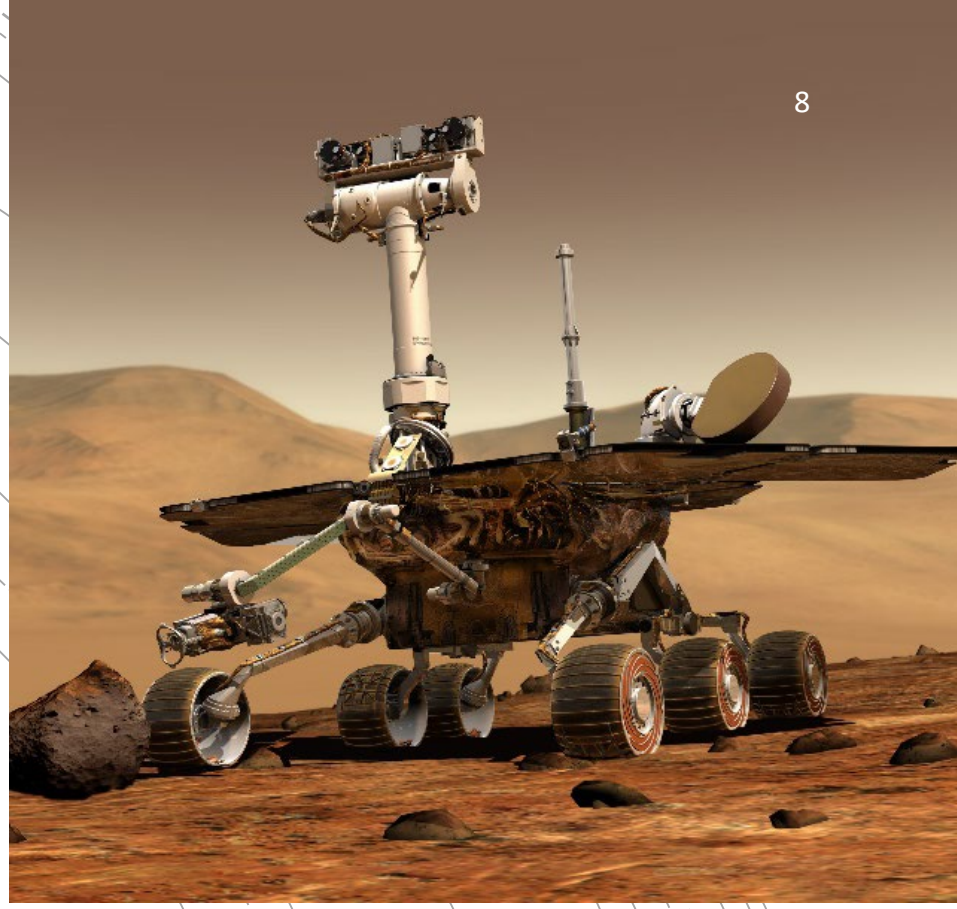
Hashing

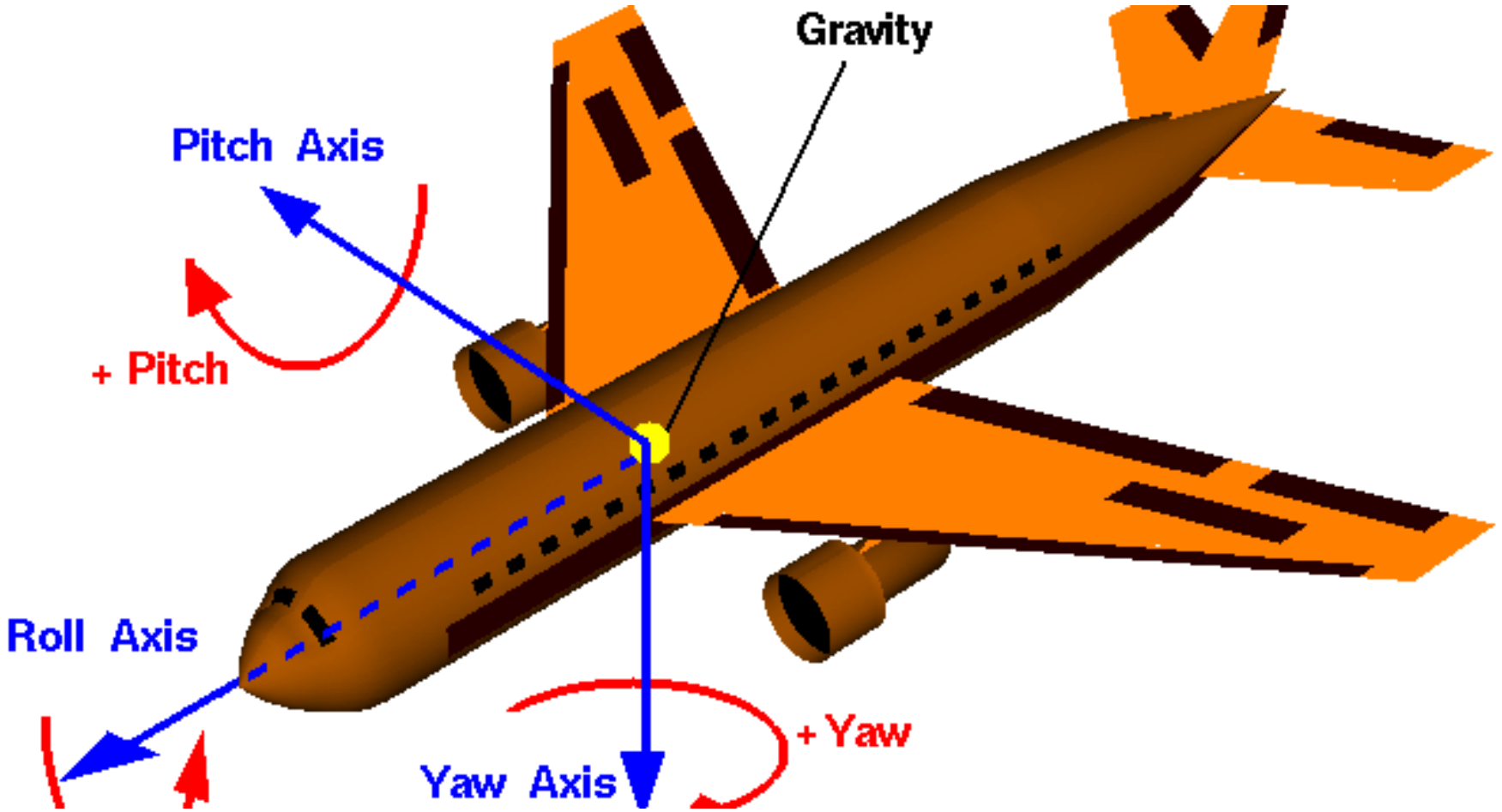
- compute a short descriptor from each feature vector (randomly)

Nearest neighbor techniques

- k-trees and their variants (Best Bin First)

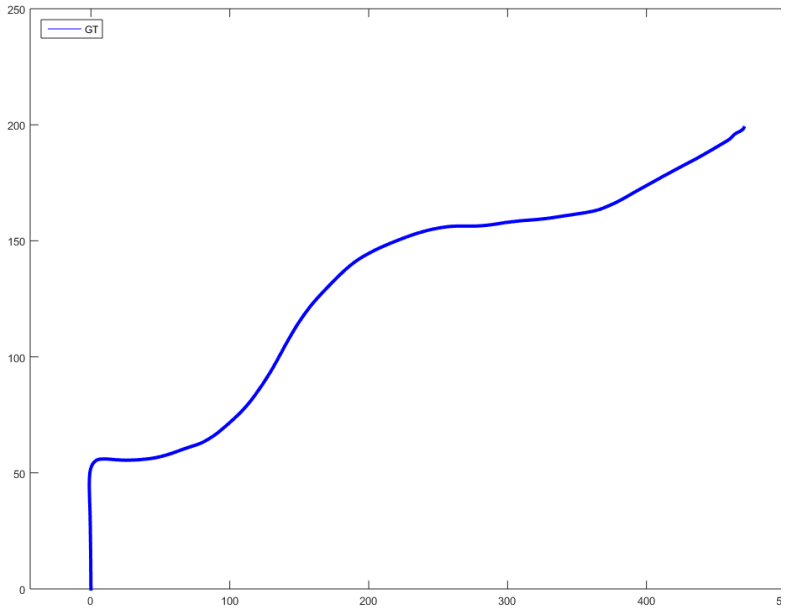

?
B





Attitude Angles

Roll, Pitch, and Yaw



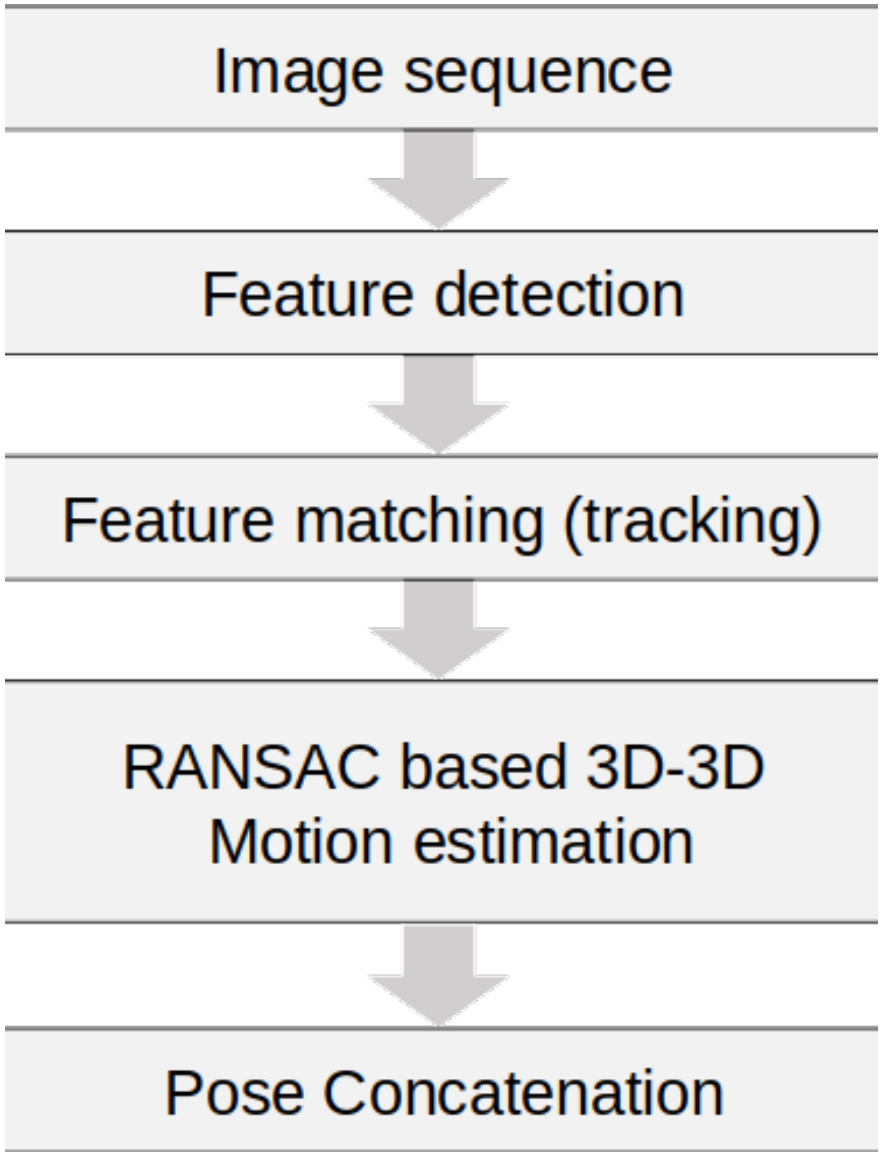
$$R_0, R_1, \ldots, R_i$$

$$t_0, t_1, \ldots, t_i$$

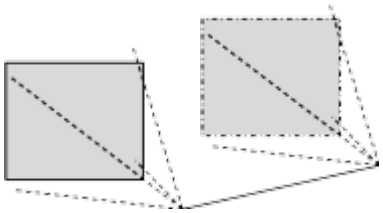
Vison Based Navigation

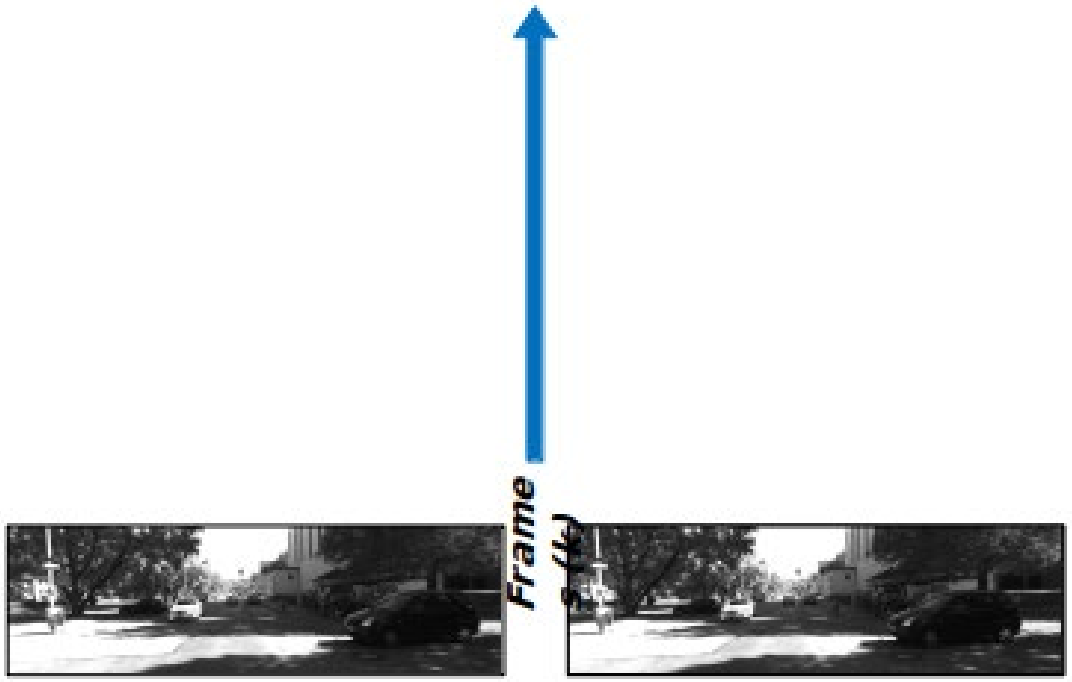
- Image Sequence (Input)
- Vehicle Trajectory (Output)

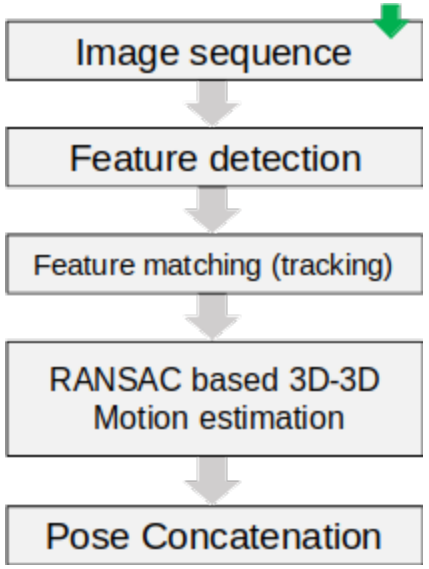
Visual Odometry Pipeline



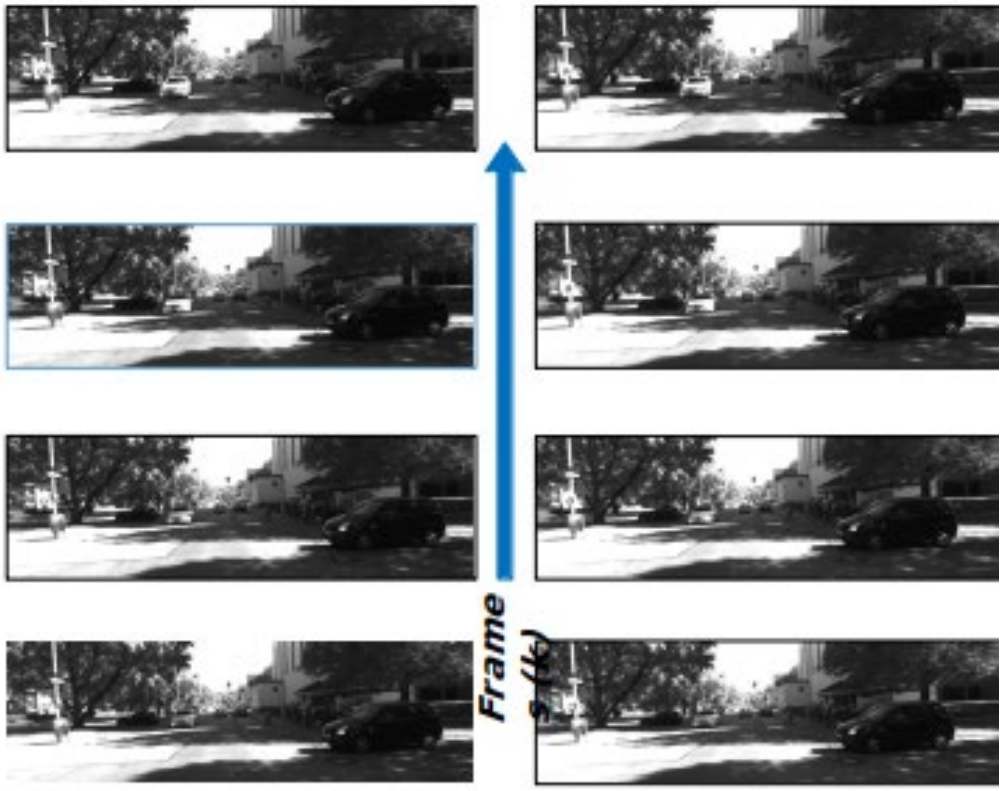
Visual Odometry Pipeline

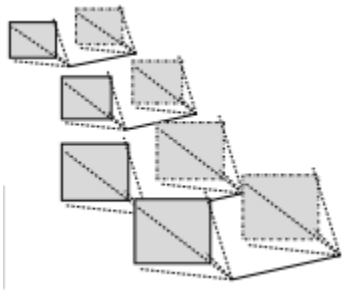


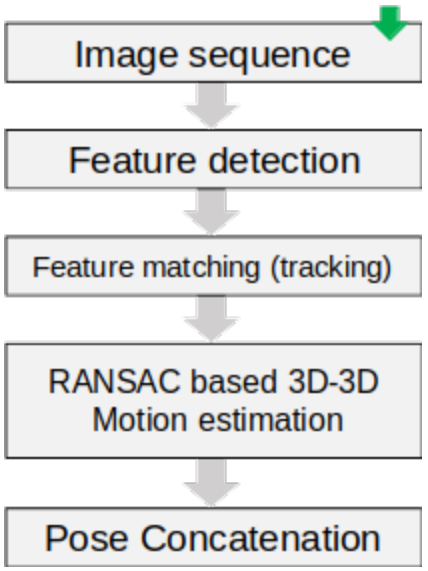




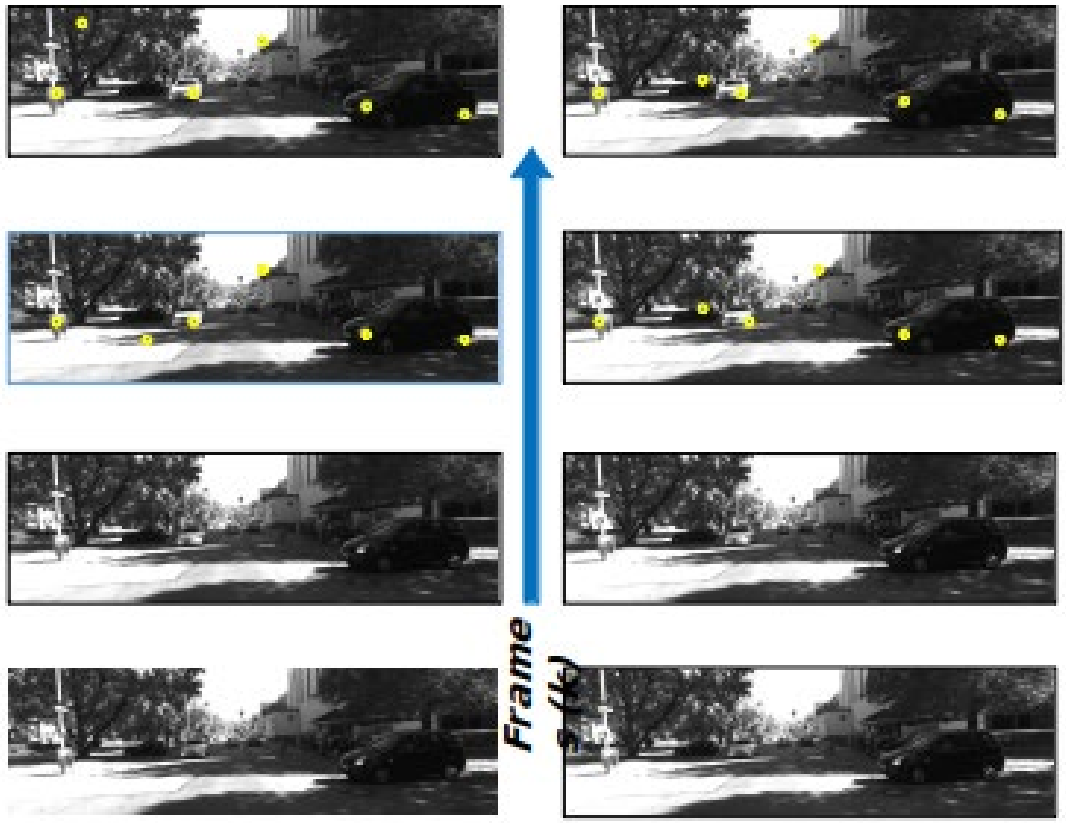
Visual Odometry Pipeline

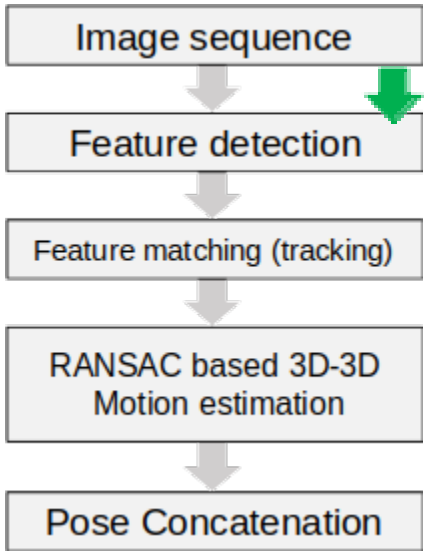




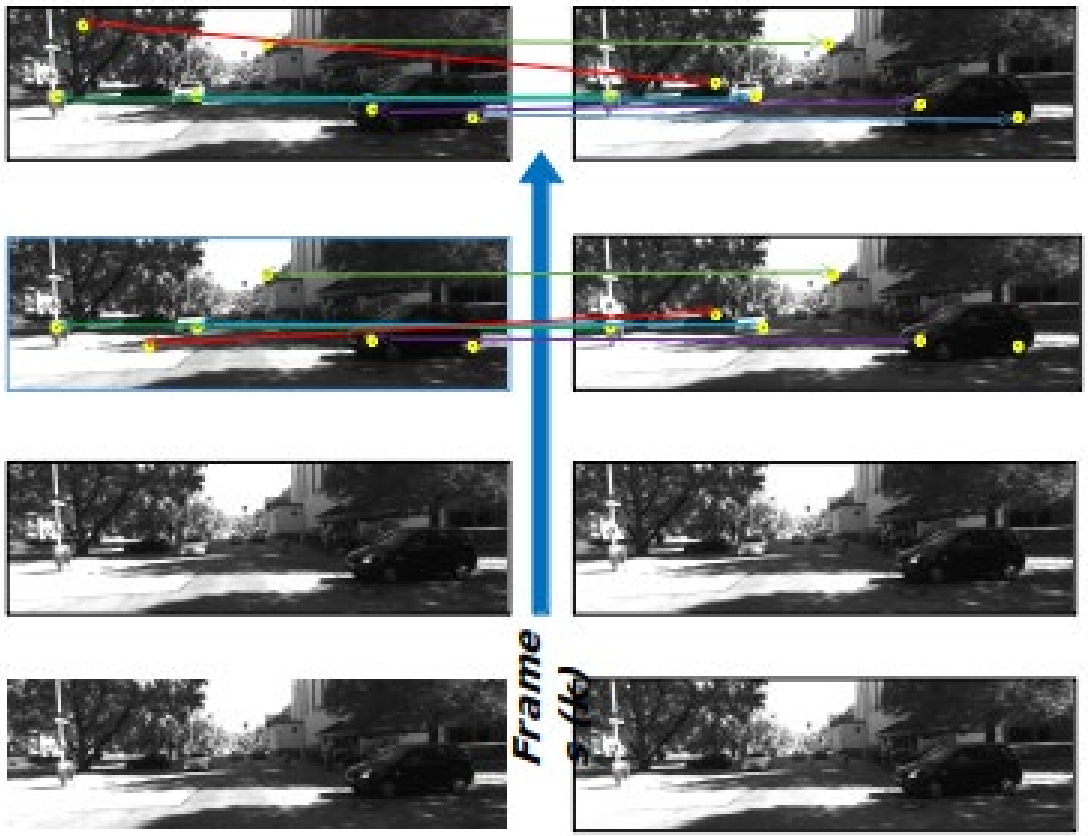


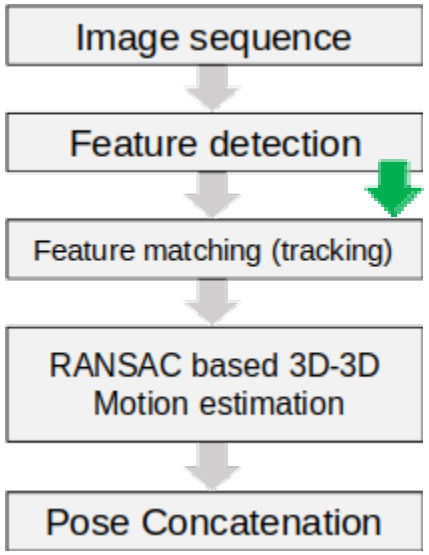
Visual Odometry Pipeline



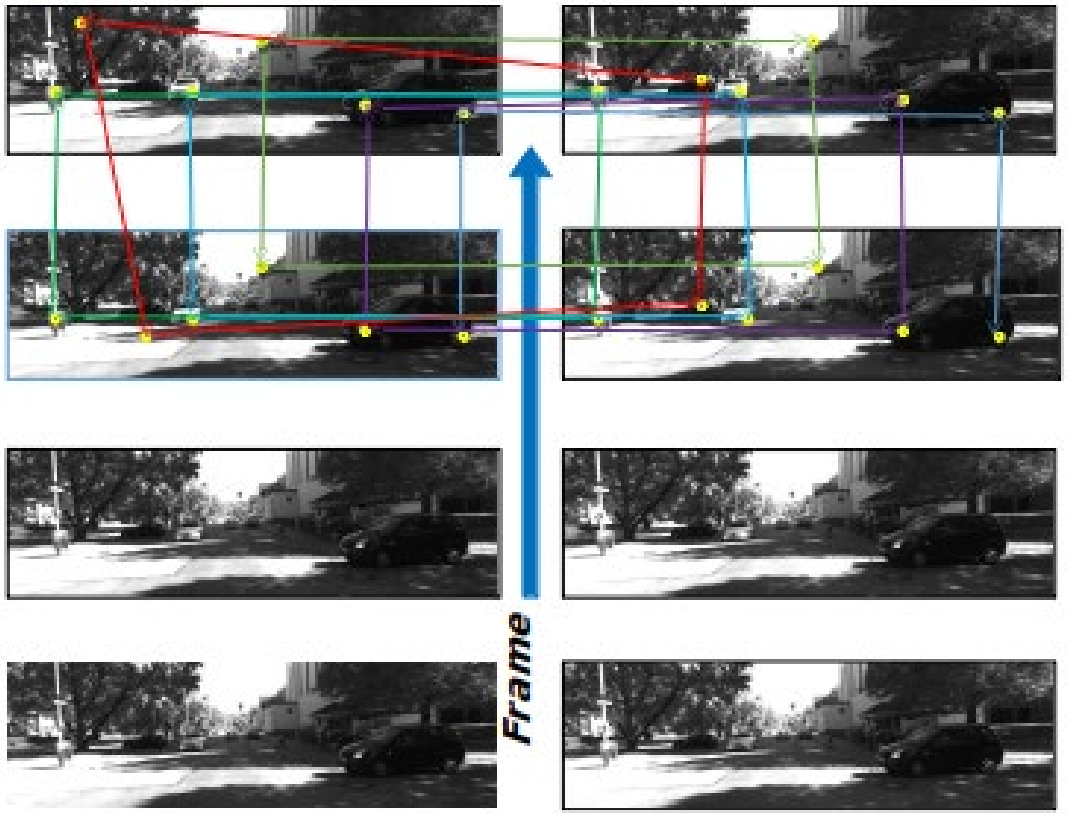


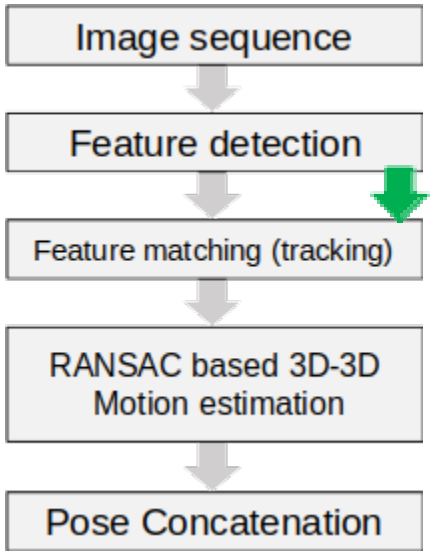
Visual Odometry Pipeline



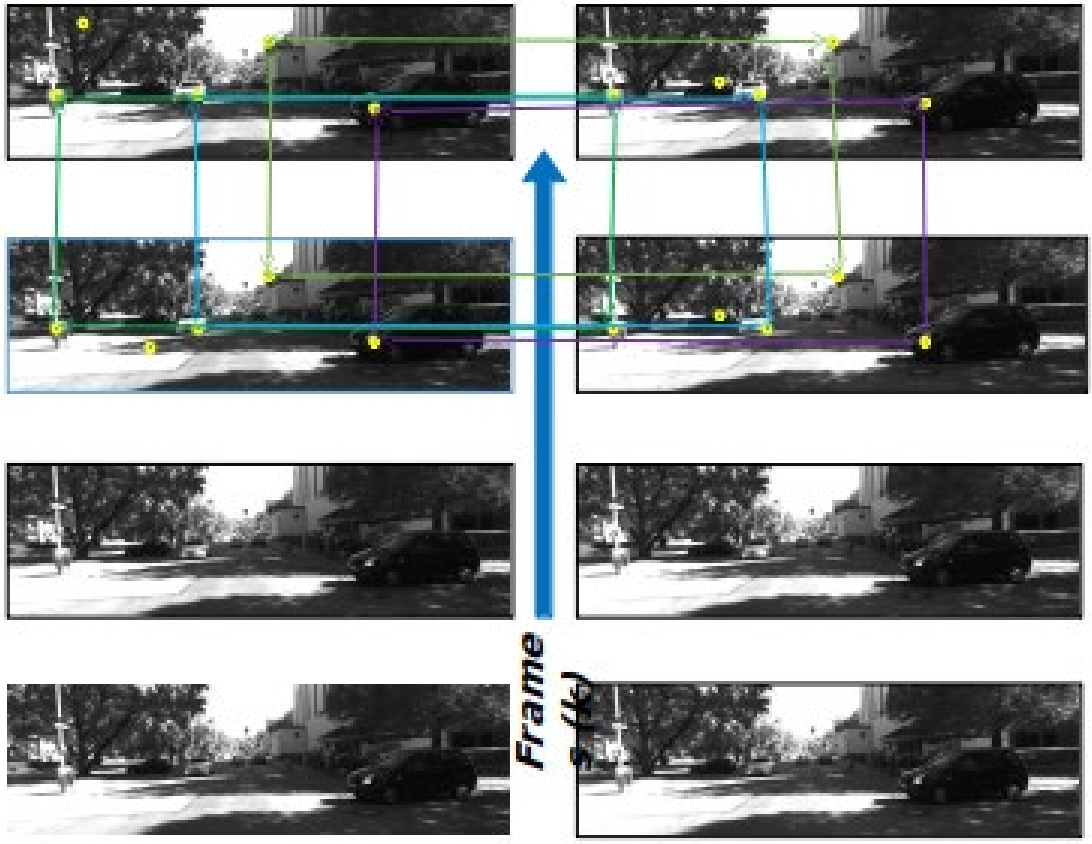


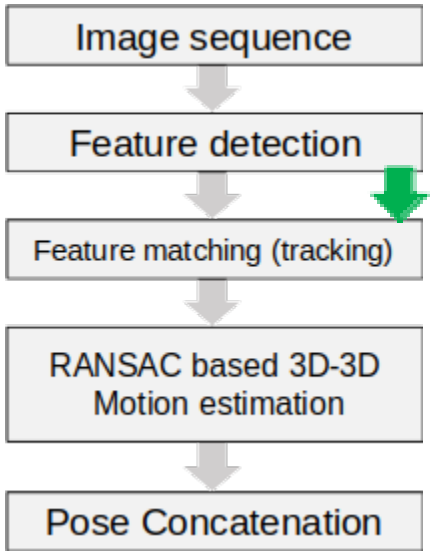
Visual Odometry Pipeline



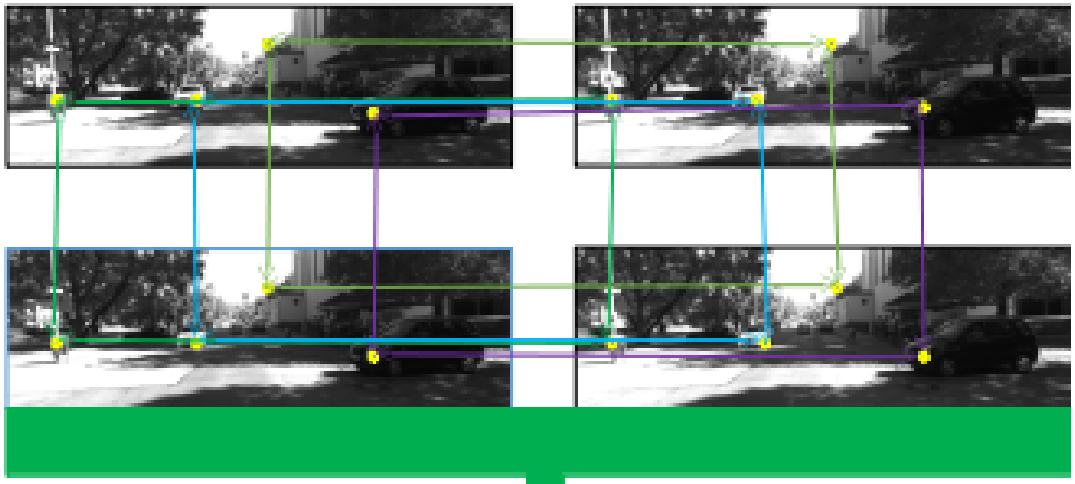


Visual Odometry Pipeline





Visual Odometry Pipeline



RANSAC based 3D-3D Motion estimation

Image sequence

Feature detection

Feature matching (tracking)

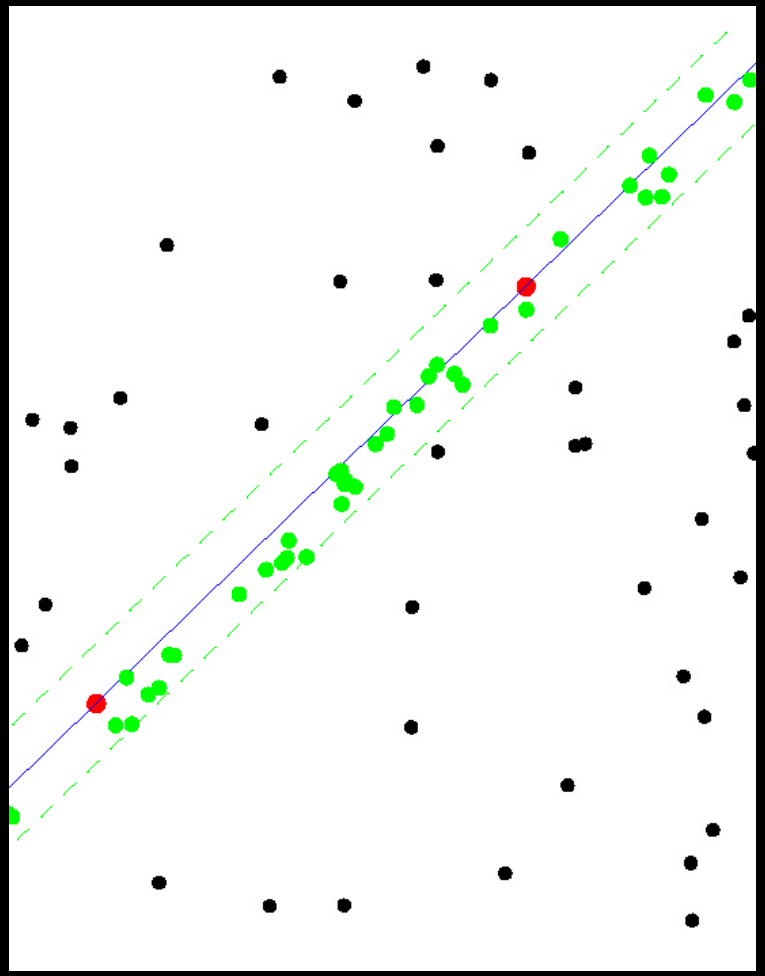
RANSAC based 3D-3D Motion estimation

Pose Concatenation

Importance of RANSAC

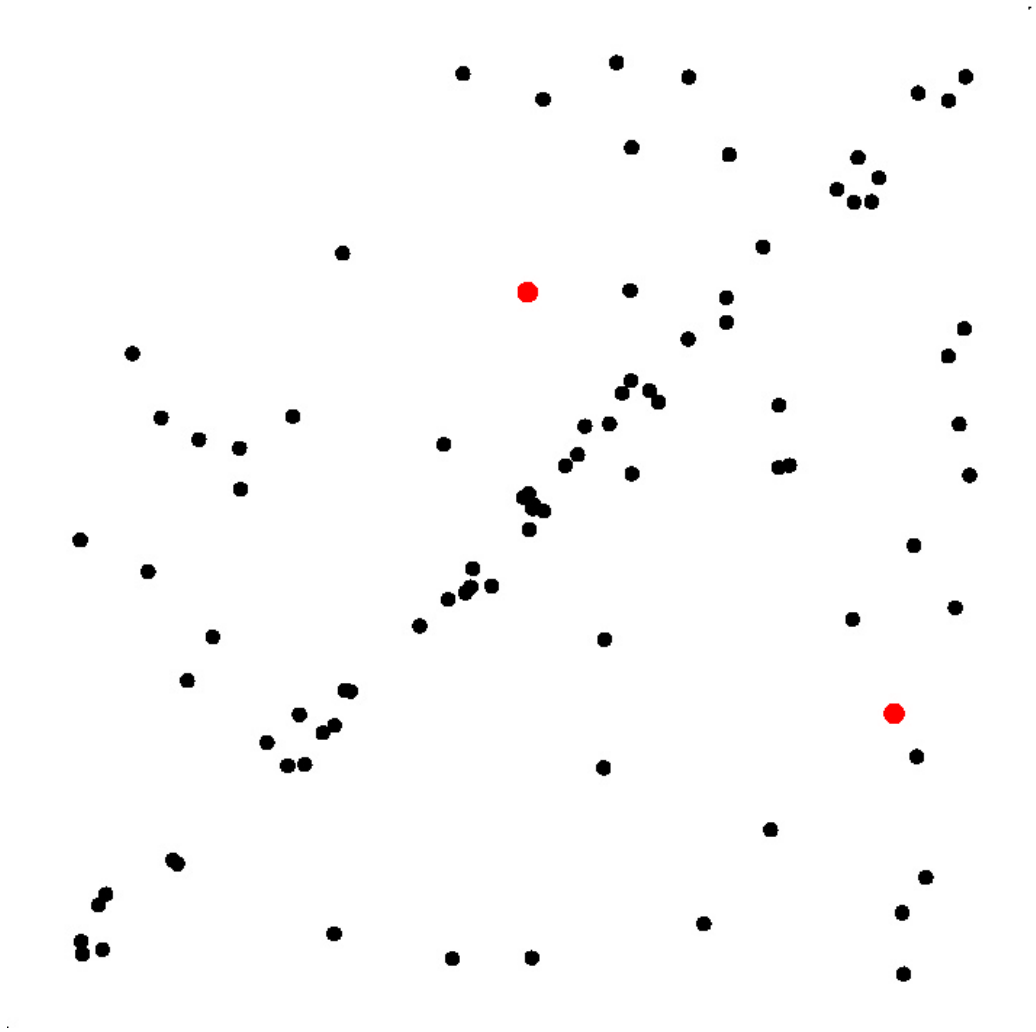
Matched points
are contaminated by outliers

- image noise
- occlusions
- blur
- changes in view point and illumination



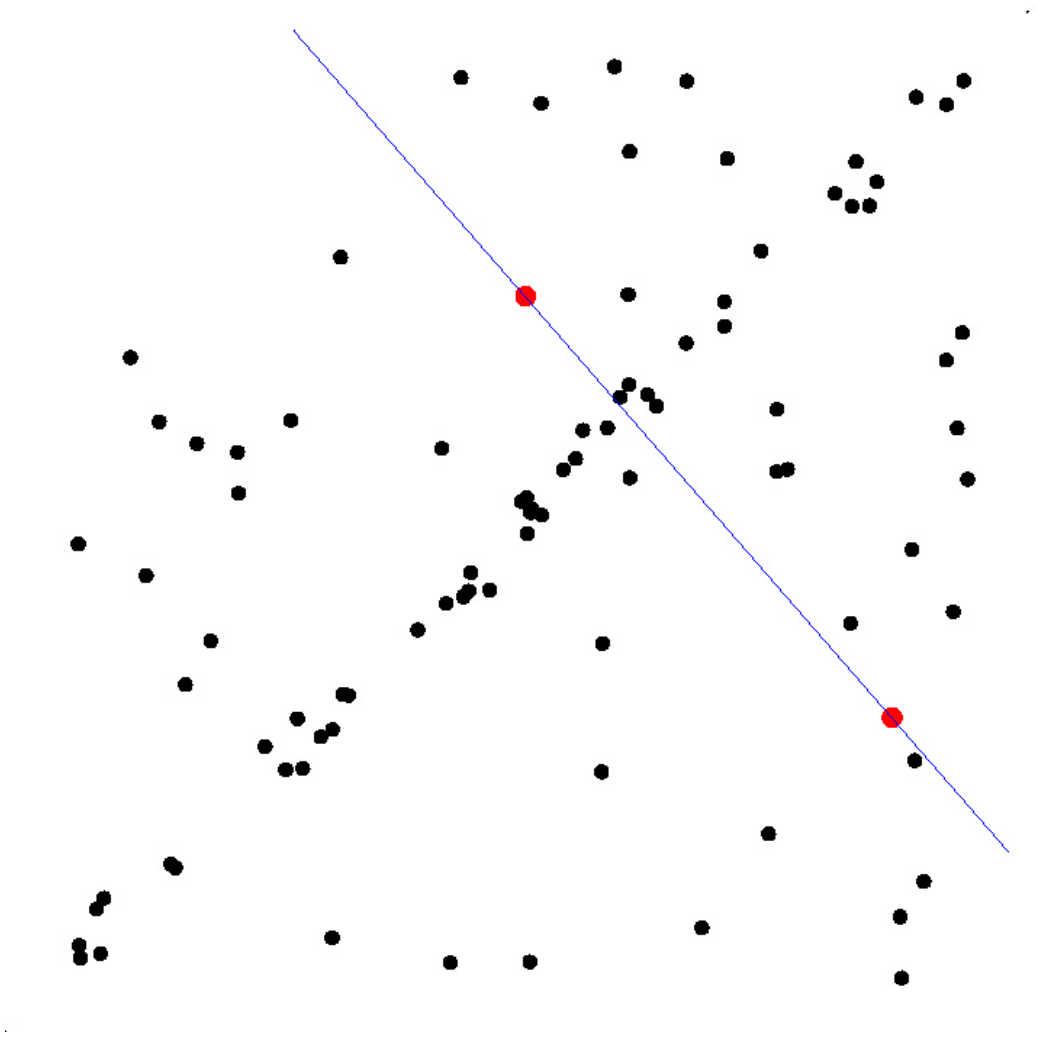
RANSAC Example: Line Extraction

Select sample of 2 points at random



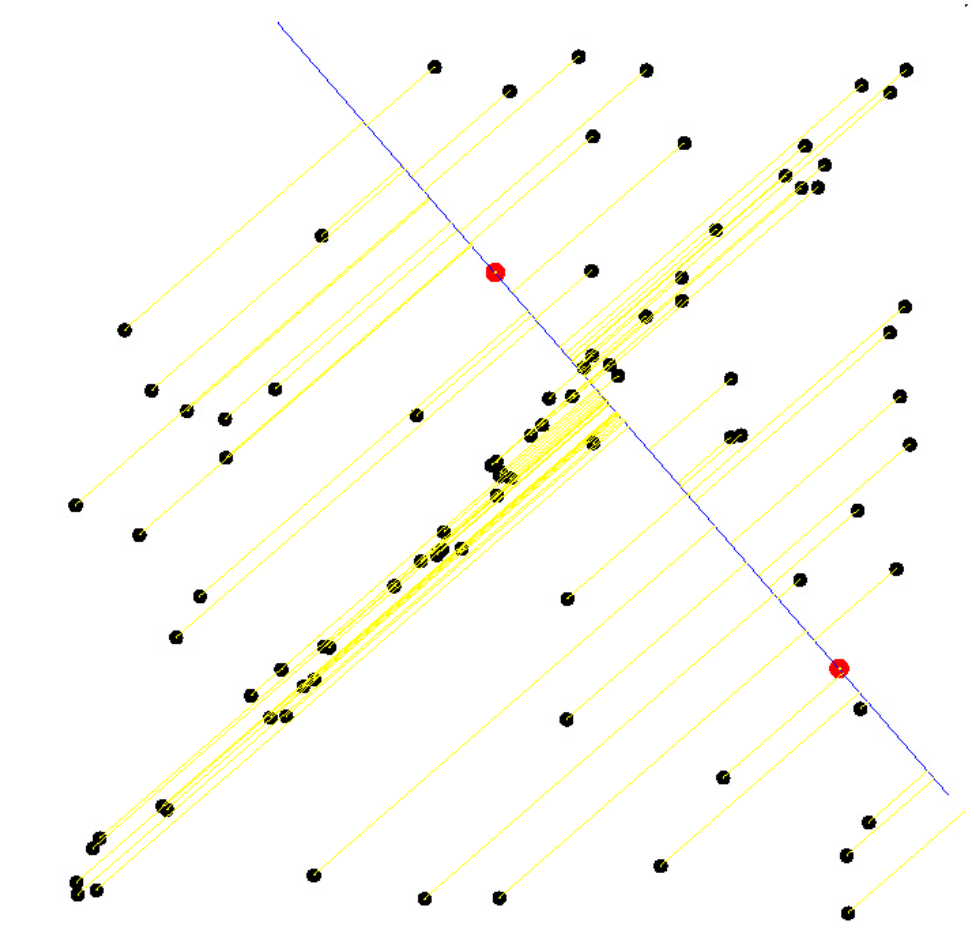
RANSAC Example: Line Extraction

Calculate model parameters that fit the data in the sample

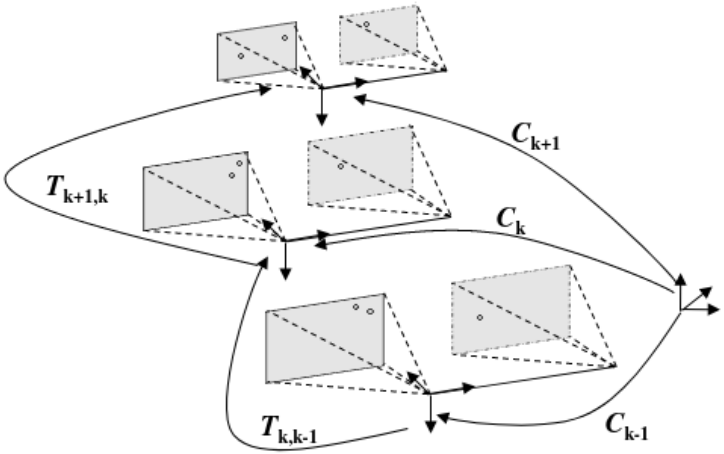


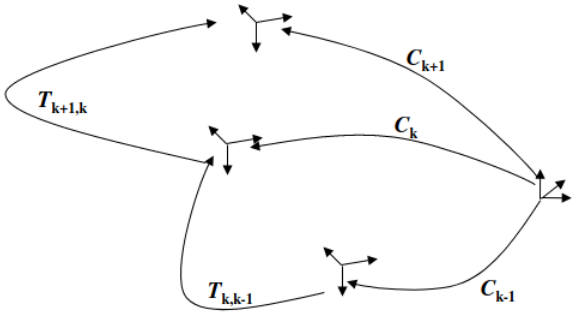
RANSAC Example: Line Extraction

Calculate error function for each data point



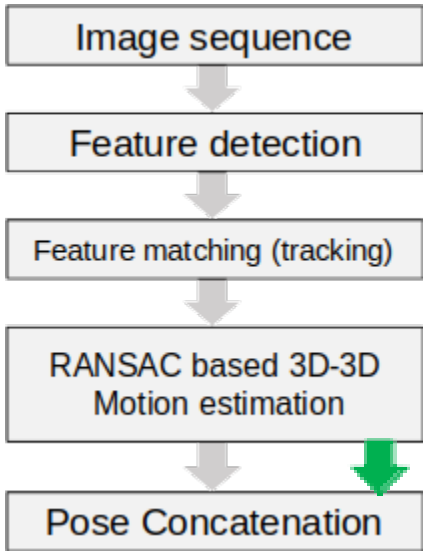
Visual Odometry Pipeline





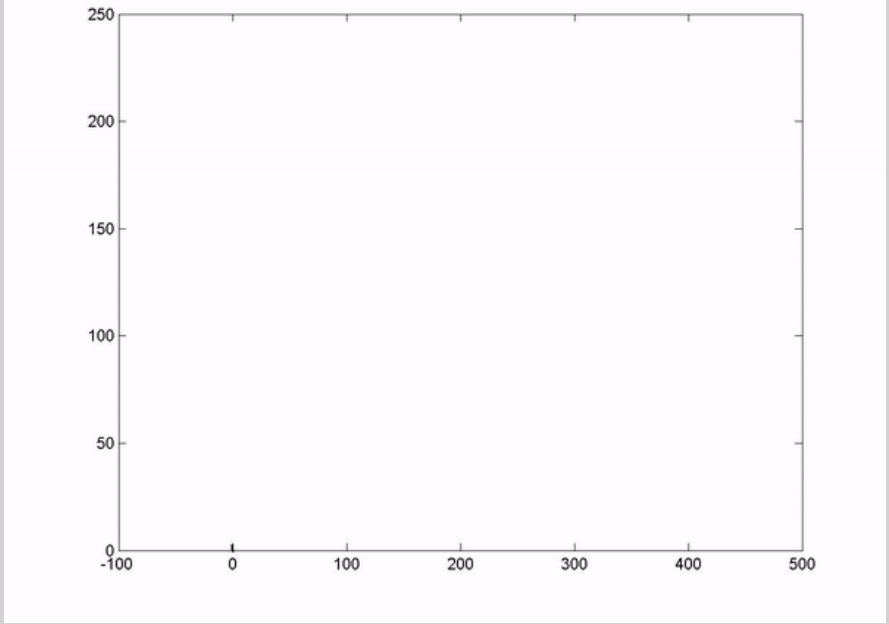
$$T_k = \begin{bmatrix} R_{k,k-1} & t_{k,k-1} \\ 0 & 1 \end{bmatrix}$$

$$C_n = C_{n-1} T_n$$



Visual Odometry Output

All the individual frame to frame transformations are added frame wise to obtain the final trajectory of the vehicle.



Descriptor Length Reduction Using Low Variance Filter for Visual Odometry

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[1] Vellore Institute of Technology, Vellore, Tamil Nadu, 632014 India
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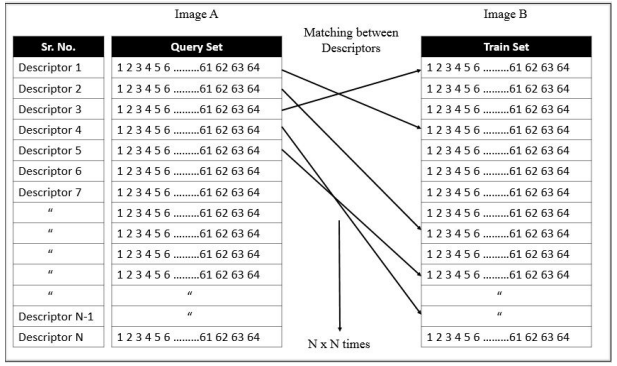
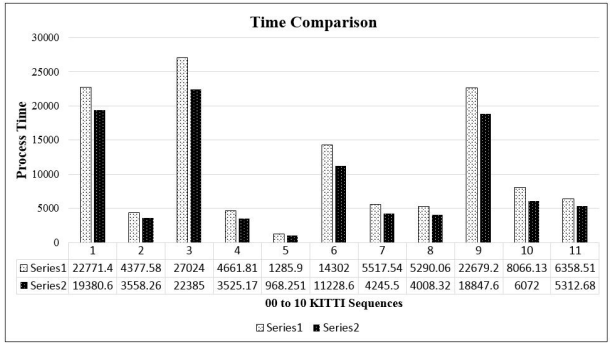
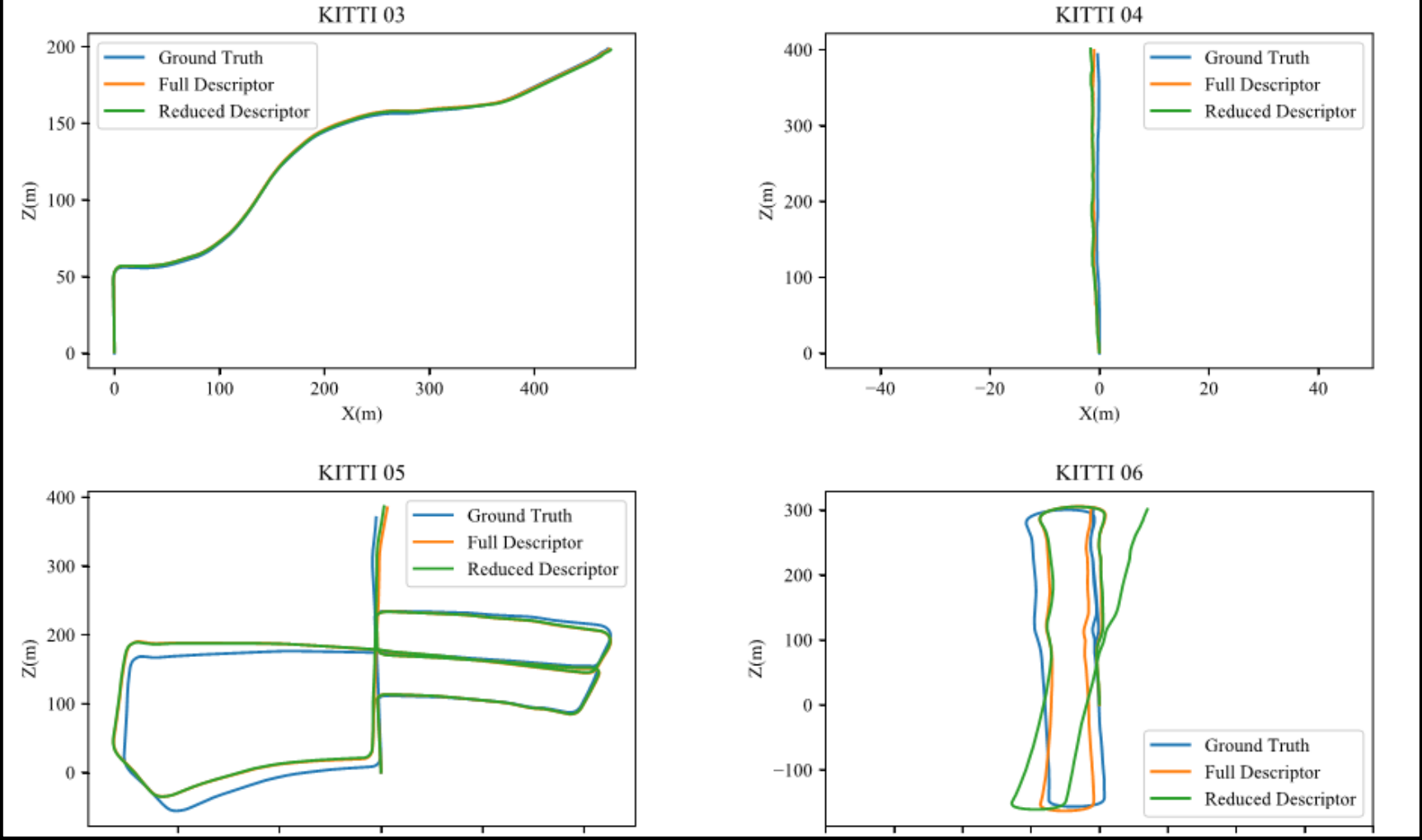
Abstract. Visual odometry is a popular technique used to estimate motion in GPS challenged environment whose accuracy depends on the features extracted from the images. In past attempts to improved feature distinctiveness, these features have become complex and lengthier, requiring more storage space and computational power for matching. In this paper, an attempt is made towards reducing the length of these feature descriptors while maintaining a similar accuracy in pose estimation. Random rejection of feature indices and elimination based on variance analysis on feature column sets are two approaches proposed and experimented in this paper. The features with reduced descriptor length is applied over the 3D-2D visual odometry pipeline and experimented on KITTI dataset for evaluating its efficacy. The proposed scheme of variance-based descriptor length reduction is found to reduce the overall time taken by the motion estimation framework while estimating the transformation with similar accuracy as that with full-length feature vector.

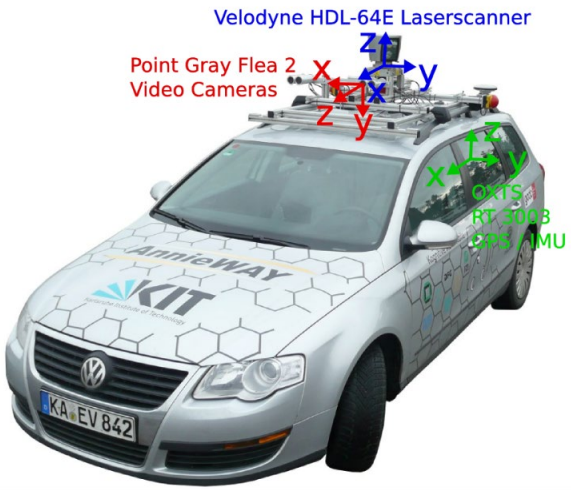


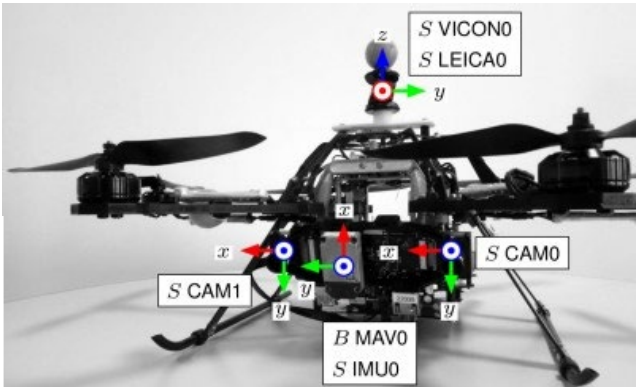


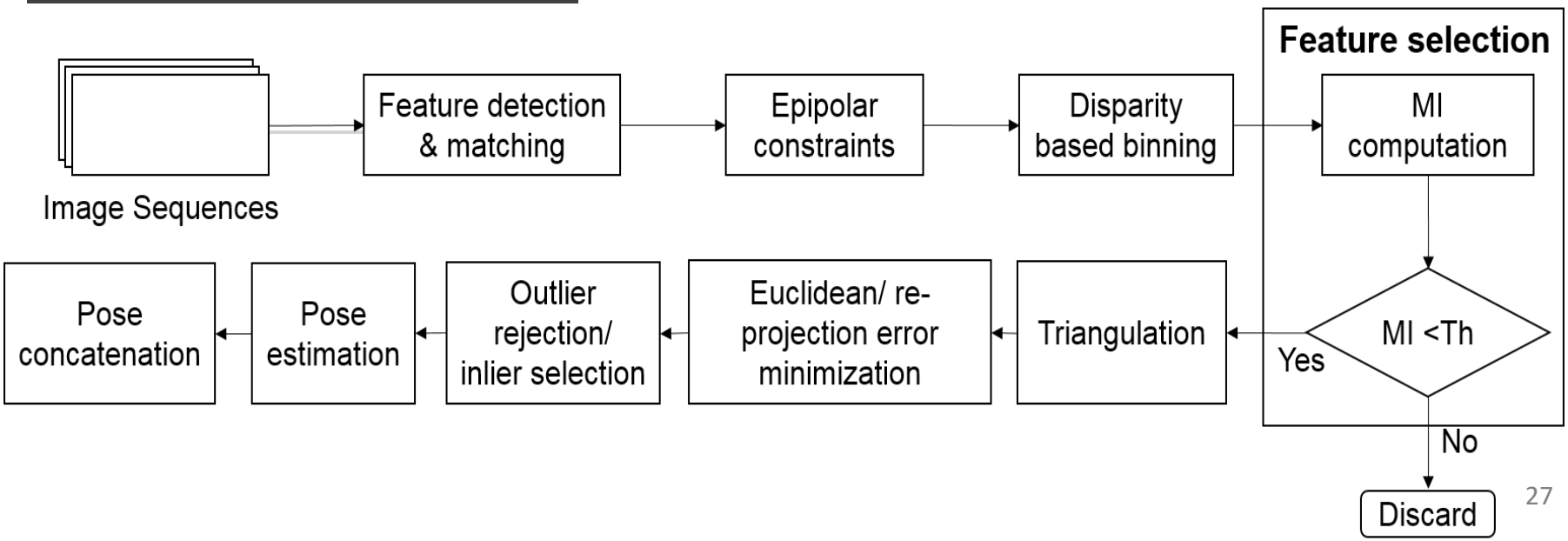


Analysis on KITTI dataset

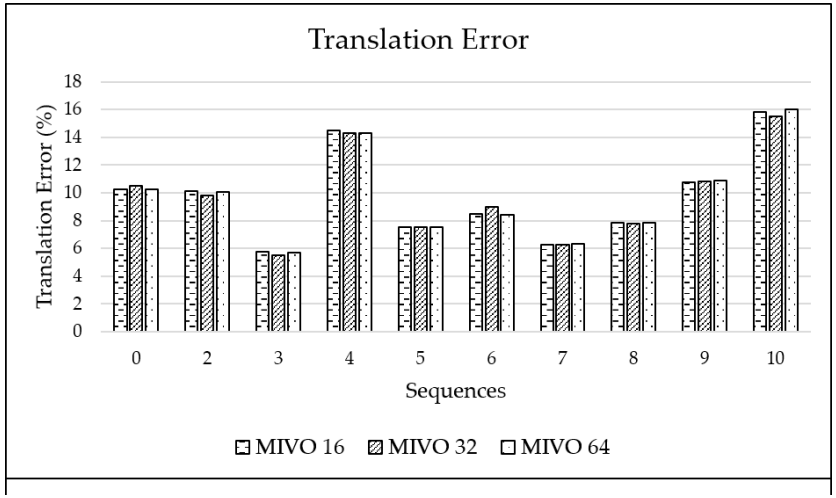
Mutual Information based Feature Selection for VO

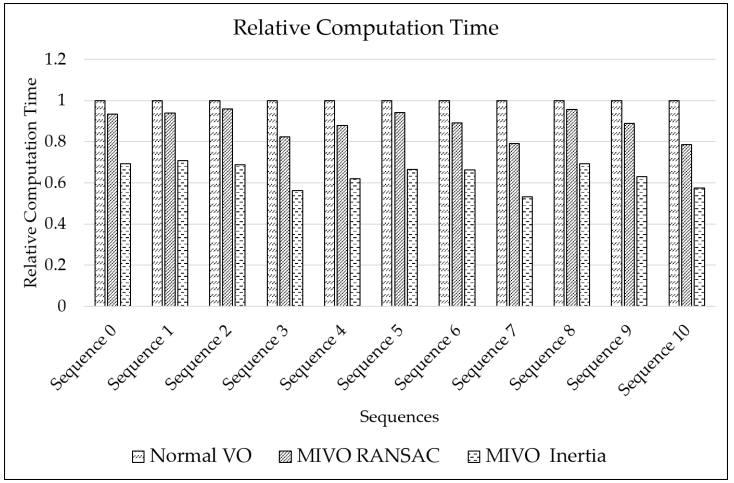


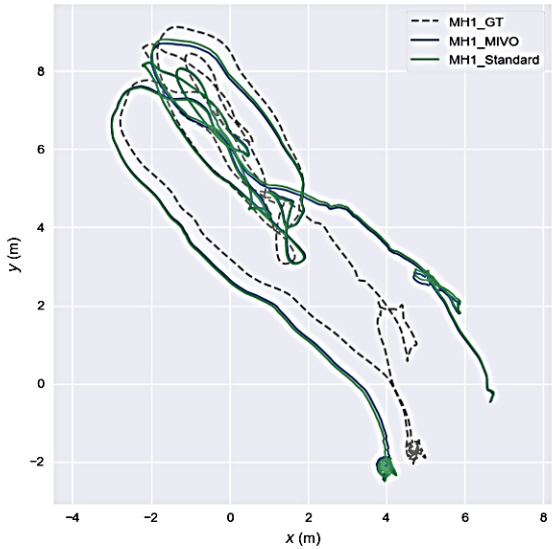


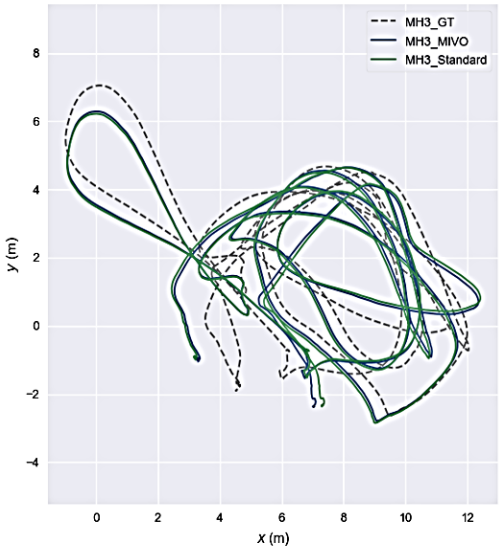


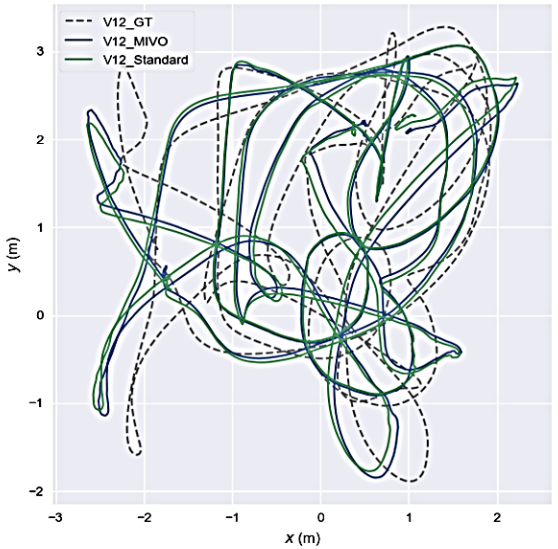
MIVO results on EuroC-MAV dataset



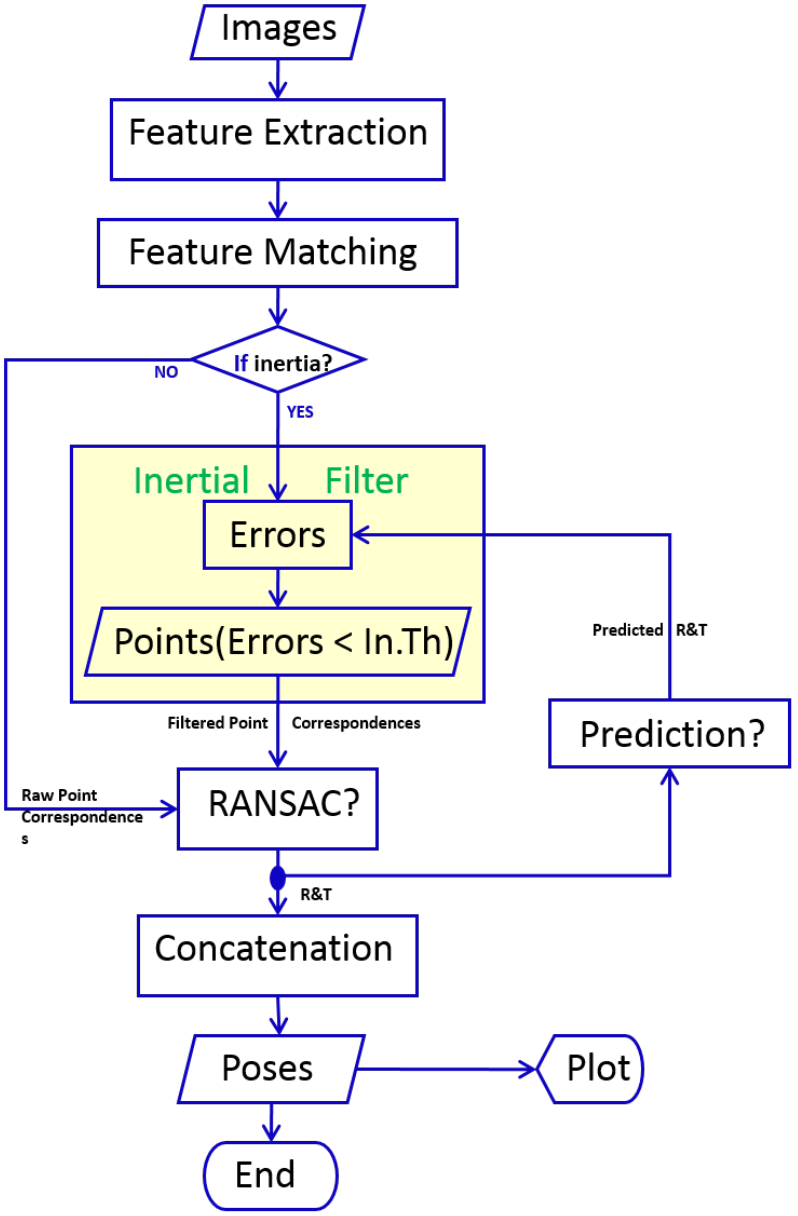




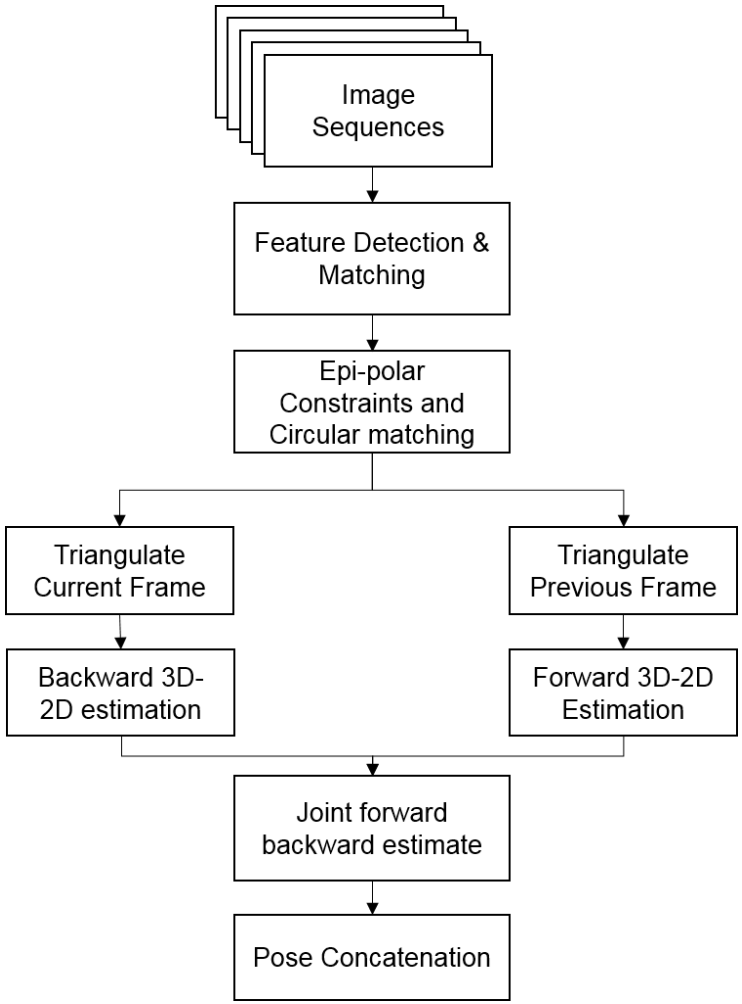


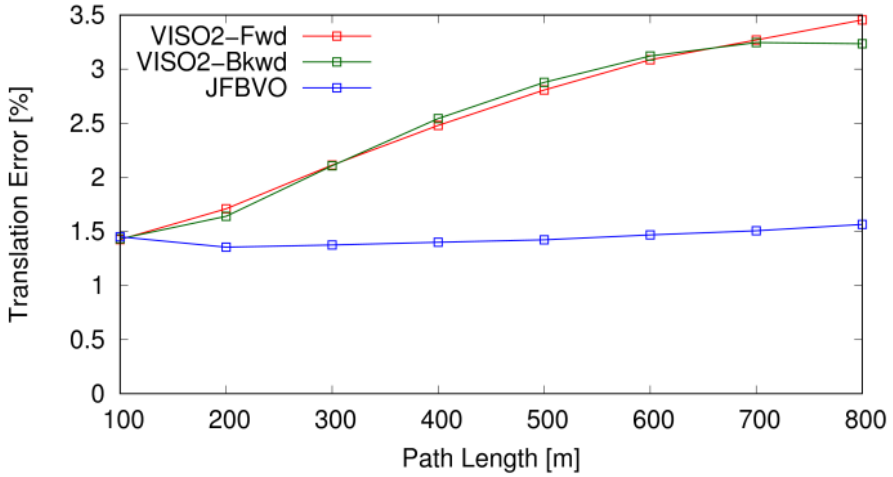


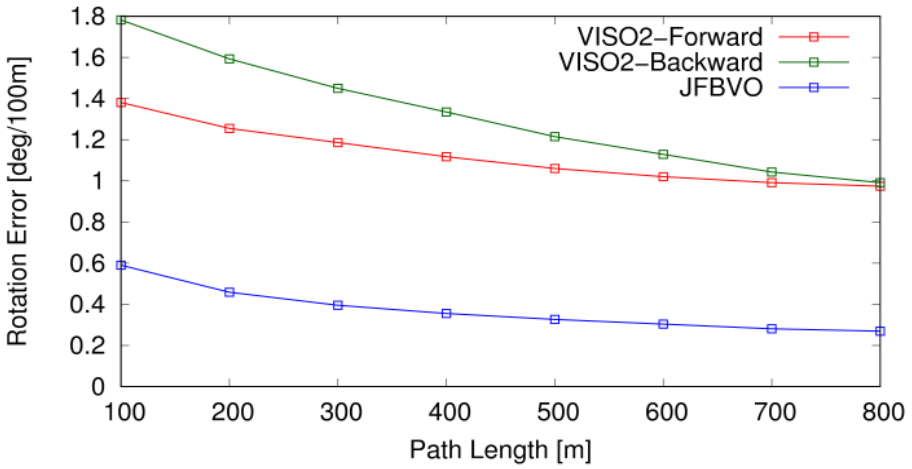
Inertia Constrained Visual Odometry

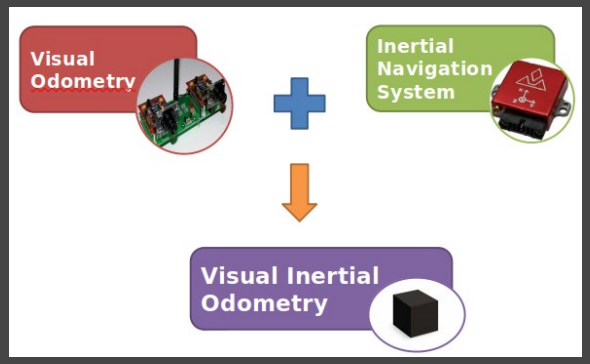


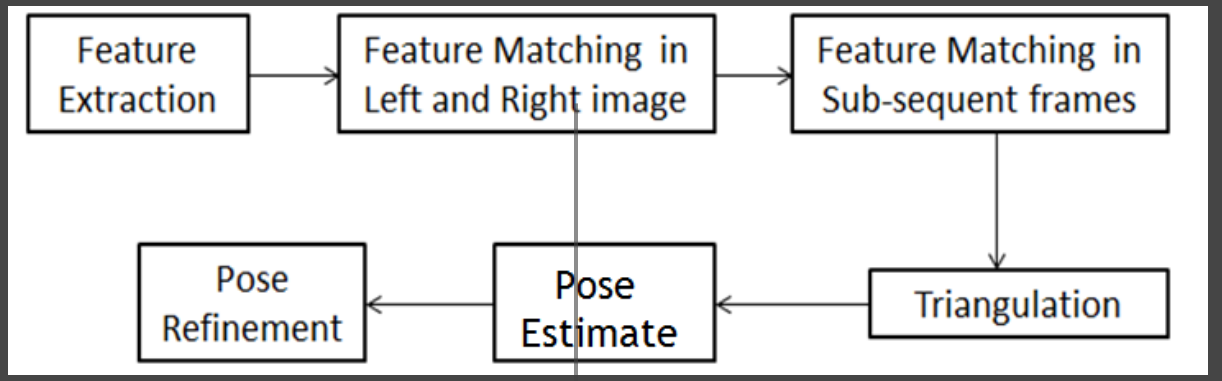
Joint forward-backward visual odometry for Stereo Camera

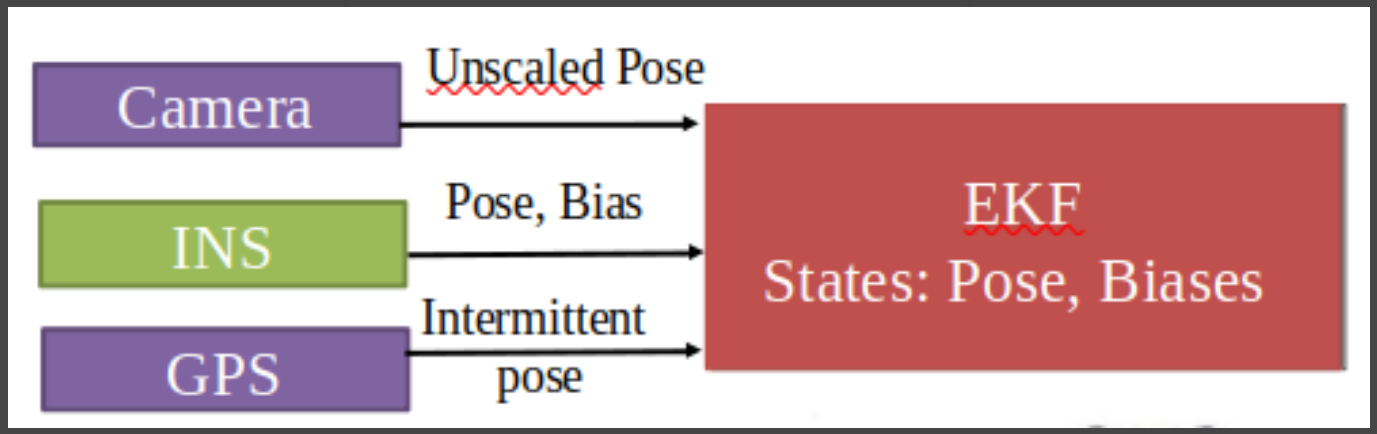












Vision aided Inertial Navigation

Applications of Vision based Navigation

Unmanned/ Autonomous Vehicle Navigation

Robotic Surgery (Endoscopic navigation)

Augmented Reality

Satellite-satellite (Aircraft) docking

GPS denied environment navigation

THANK YOU

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