Indoor Localization of a Quadrocopter based on PTAM

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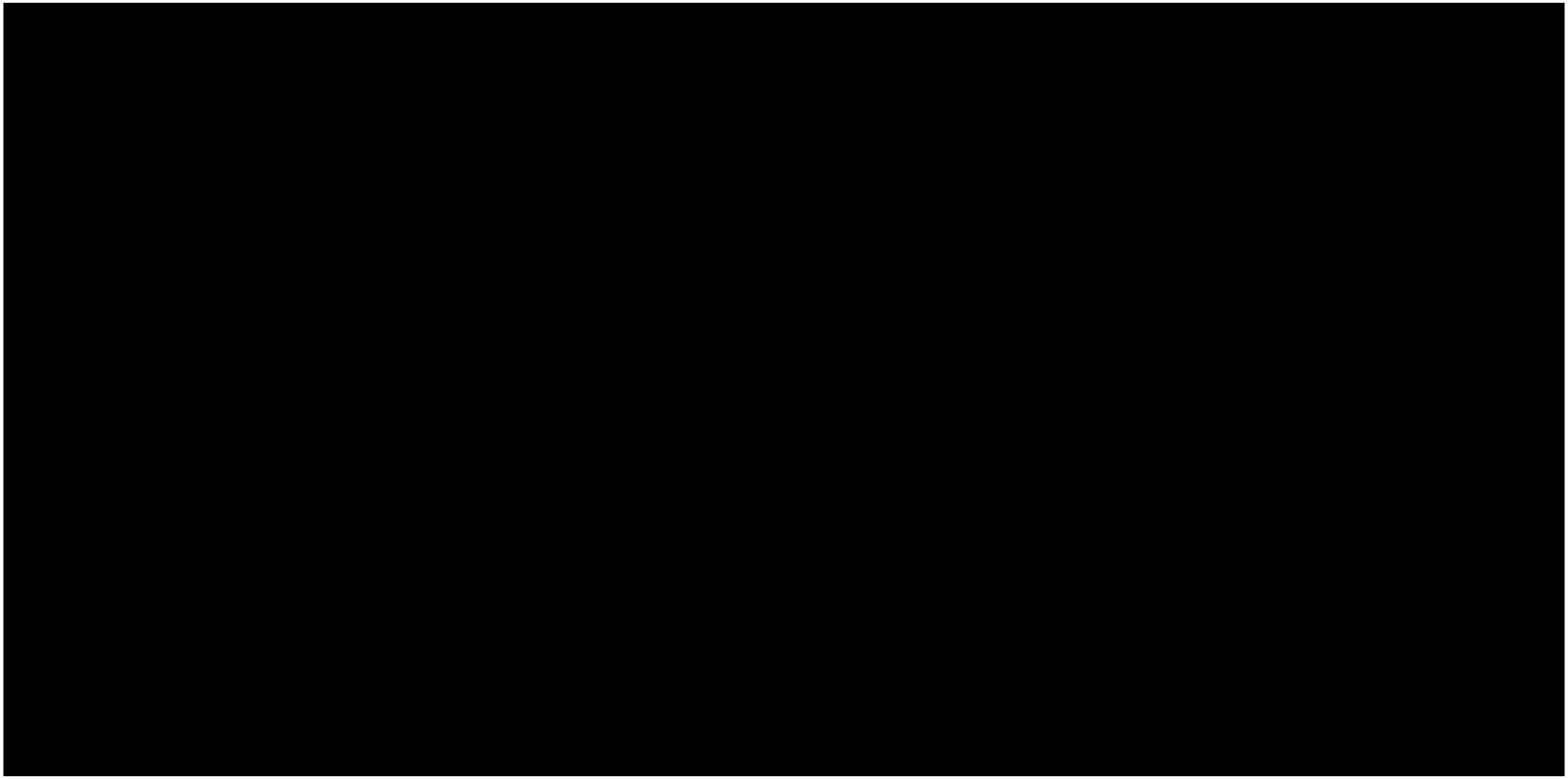
Introduction

- Indoor localization
- The principles of PTAM
  - Monocular SLAM
  - Epipolar geometry
  - Parallel threads
  - Structure from motion

Camera



General idea: keyframe-based Monocular SLAM

- INITIALIZING: Generate a 3D space (map) with several images (Five-point relative pose problem)
- TRACKING: Based on the current image to determine the current location of the camera.
- MAPPING: Based on the images with better quality to refine the map.

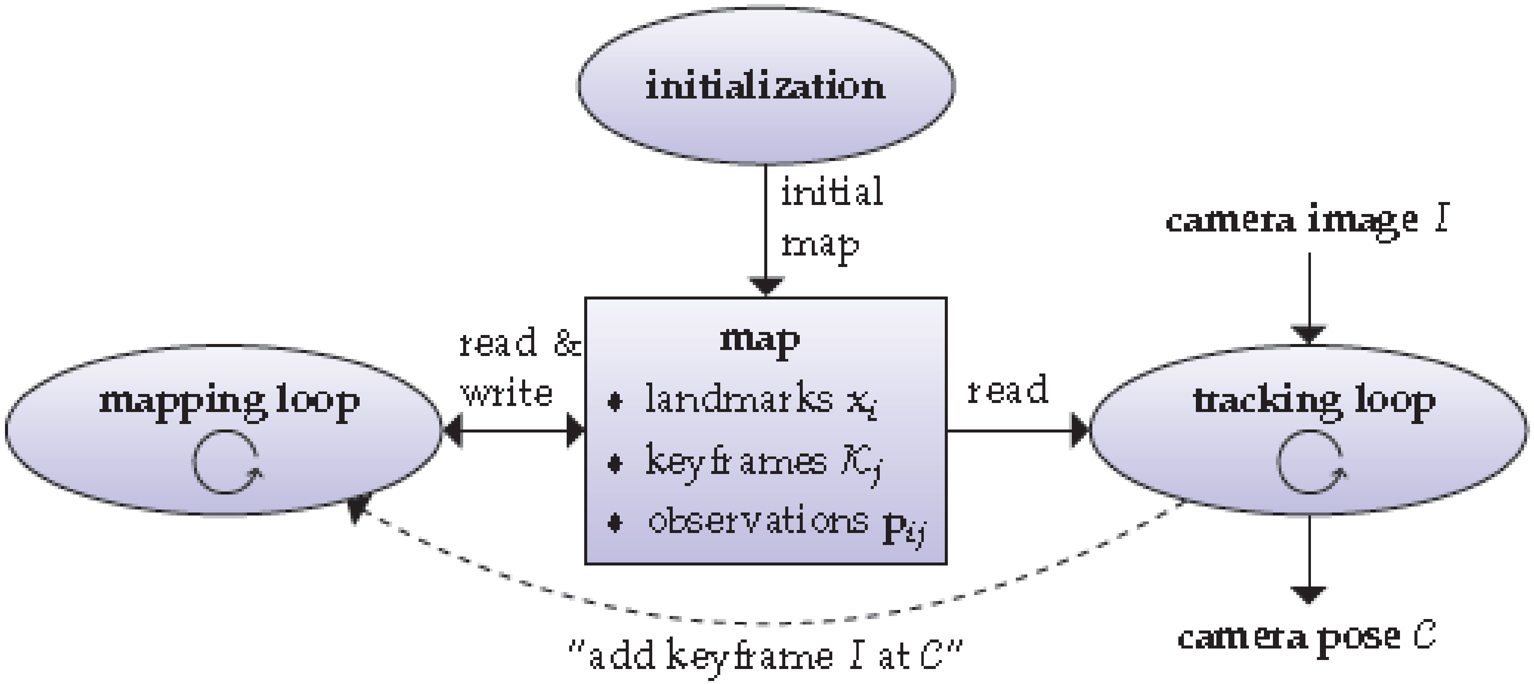


Fig 1: Schematic outline of a keyframe-based SLAM algorithm [4]

Recent researches

- Five-point relative pose problem
- FAST-16 corner detector

Five-point relative pose problem

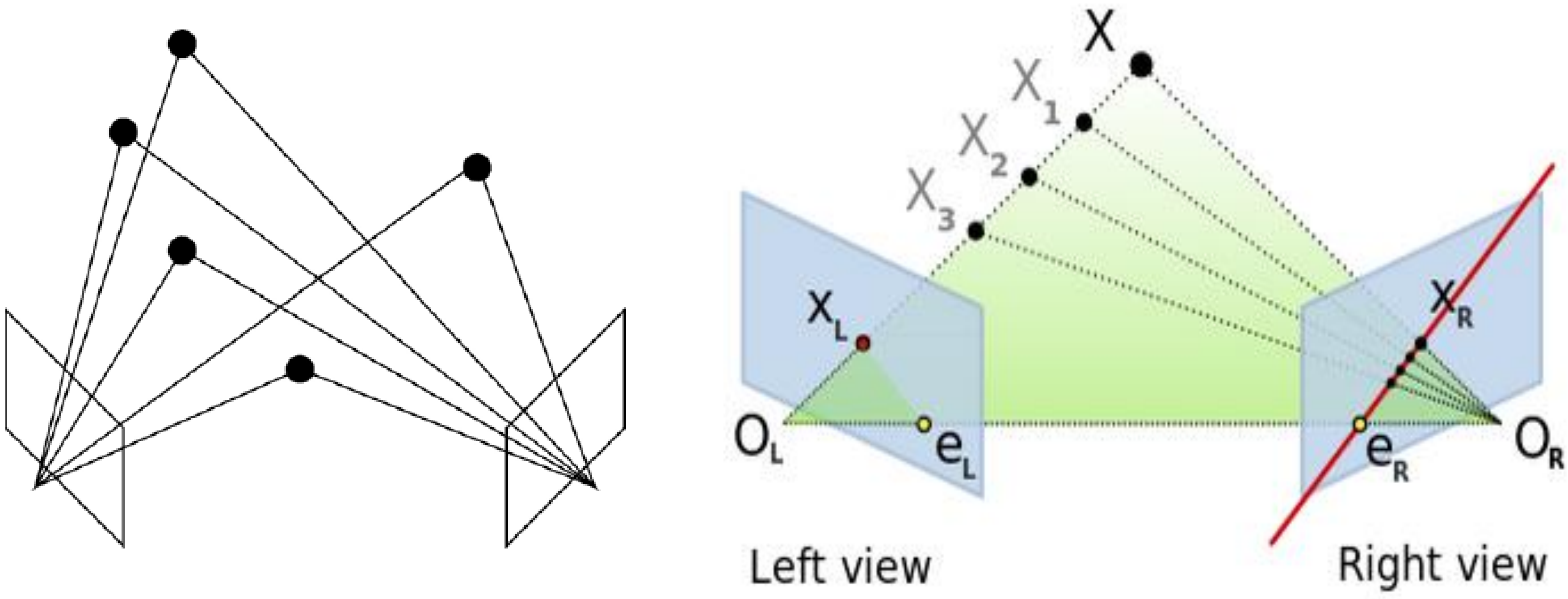


Fig 2: Five-point relative pose problem [2]

3D--2D correspondence

- The homogeneous representation of a point $\mathbf{x} \in \mathrm{R}^d$ is denoted by

$$\tilde{\mathbf{x}} := (\mathbf{x}^T, 1)^T \in \mathrm{R}^{d+1}$$

Landmark Projection

- An observation of landmark i in keyframe j is denoted by $P_{ij} \in R^2$, in normalized image coordinates. The respective pixel-coordinates are denoted by

$$\bar{P}_{ij} := \text{proj}(K_{cam} \tilde{P}_{ij})$$

The Essential Matrix

- The essential matrix is defined as:

$$E := R[t]_x \in R^{3*3}$$

- where $[t]_x \in R^{3*3}$ is the matrix corresponding to the cross-product with t.

The Essential Matrix

- For every pair of corresponding point-observations $P, P' \in R^2$, from two different viewpoints, the relation $\tilde{P'}^T E \tilde{P} = 0$ is satisfied: Let $x \in R^3$ be the threedimensional point in one camera-coordinate system, and $x' = R(x - t)$ the point in the second camera coordinate system. It follows that:

$$(x')^T E x = (x - t)^T R^T R [t]_x x = (x - t)^T [t]_x x = 0$$

Reconstruct the 3D space

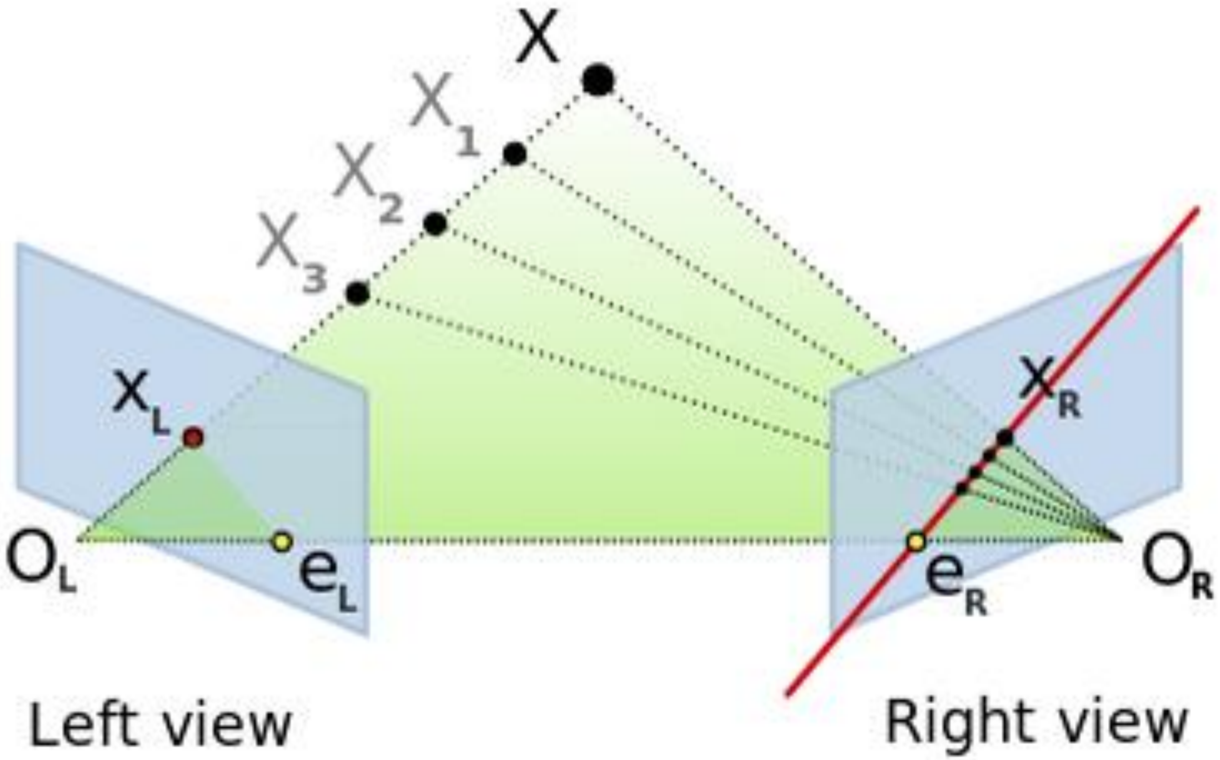


Fig 3: determin one landmarks 3D space representation

FAST-16 corner detector

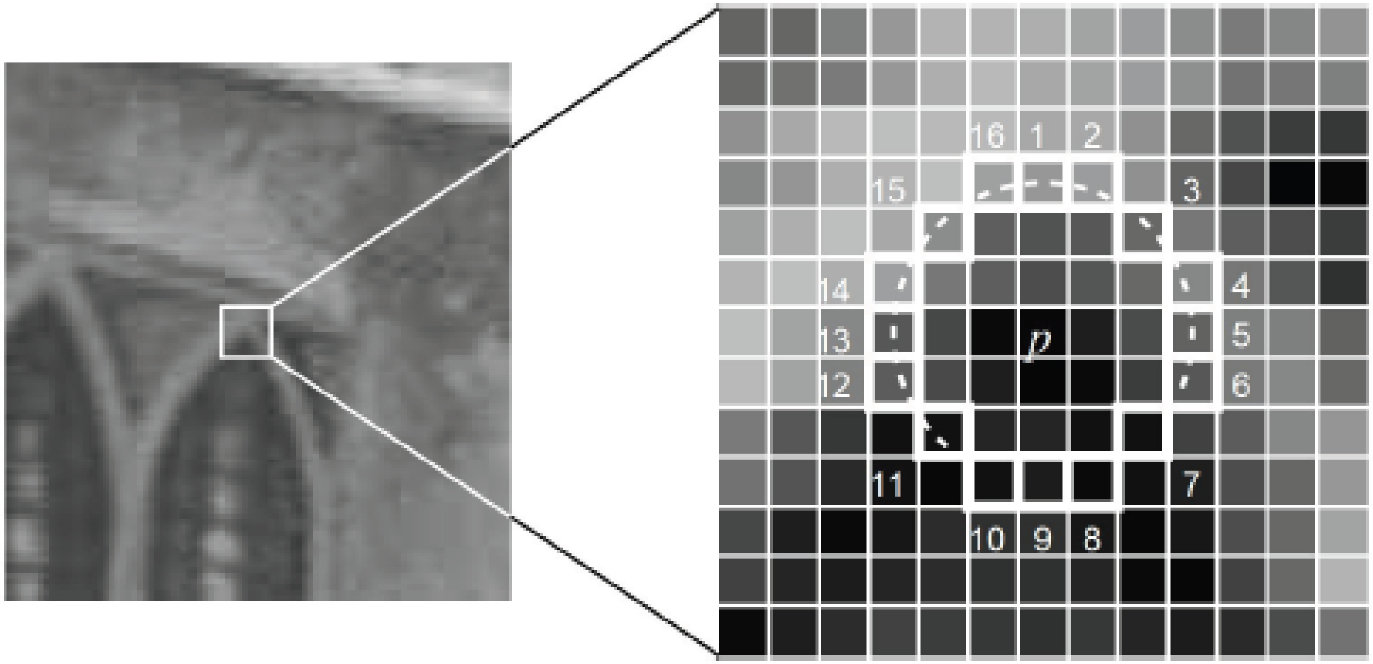


Fig 4: The FAST-16 corner detector inspects a circle of 16 pixels. As 12 continuous pixels brighter than the center are found, the patch is classified as a corner.[4]

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Localization system designed for the Quadrocopter

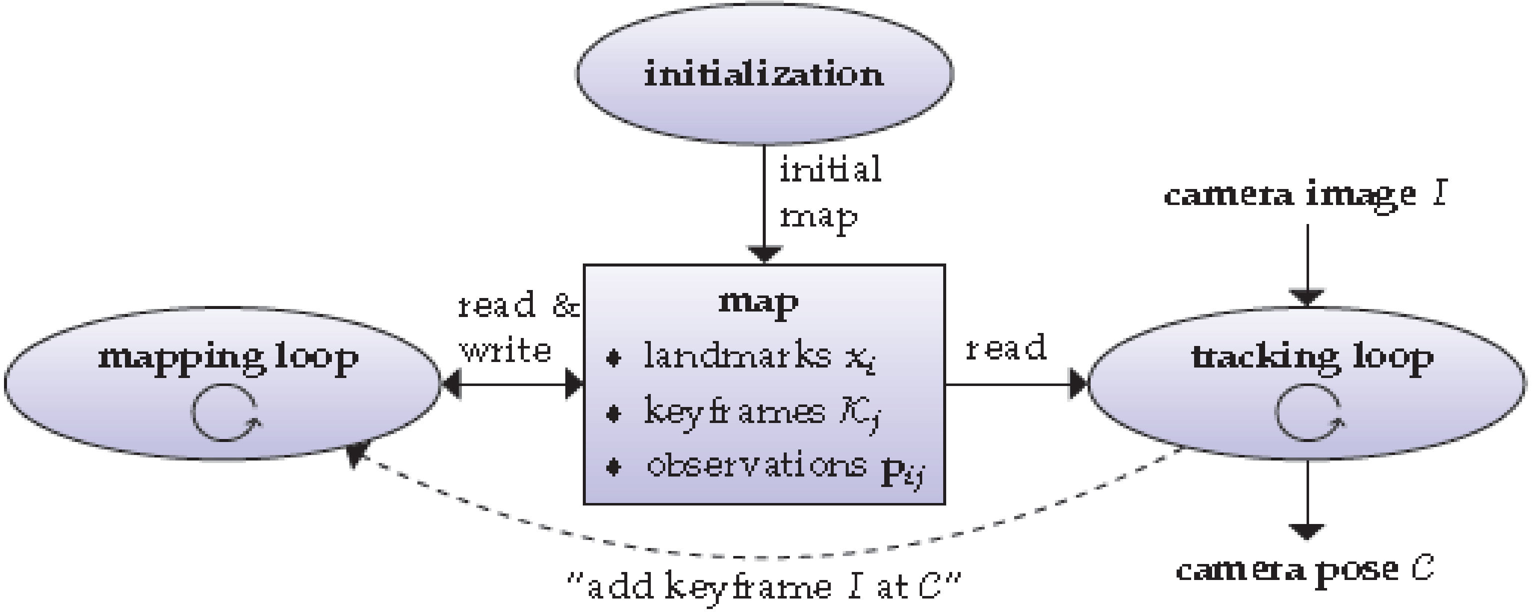

Fig 5: Schematic outline of a keyframe-based SLAM algorithm[4]

Localization System for a Quadrocopter

- Two camera frames are used to compute the essential matrix and the camera pose.
  - Observe the landmarks
  - Choose the best five points
  - Compute the essential matrix
- Reconstruct the 3D space.
- Based on the current image, and the 3D-to-2D point correspondences, the camera position is to be estimated.

RANSAC

- RANSAC (Random sample consensus) method:
  - To find the best five point pairs in two image

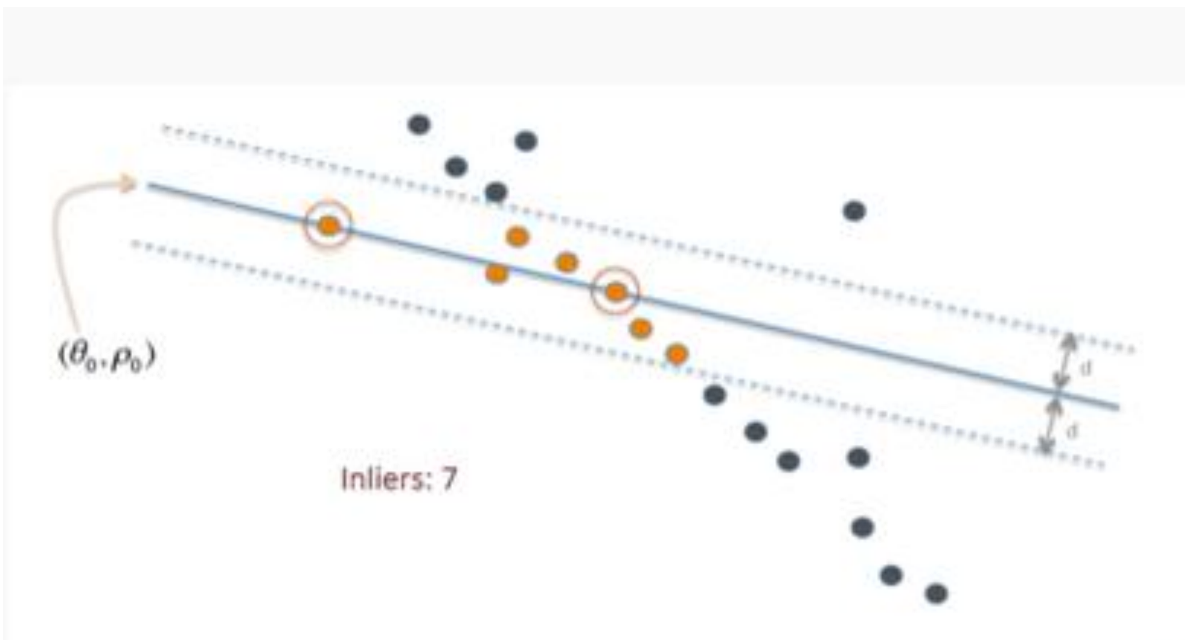

Fig 6: RANSAC: Inliers and Outliers

To Raplace RANSAC with Simulated Annealing Algorithm

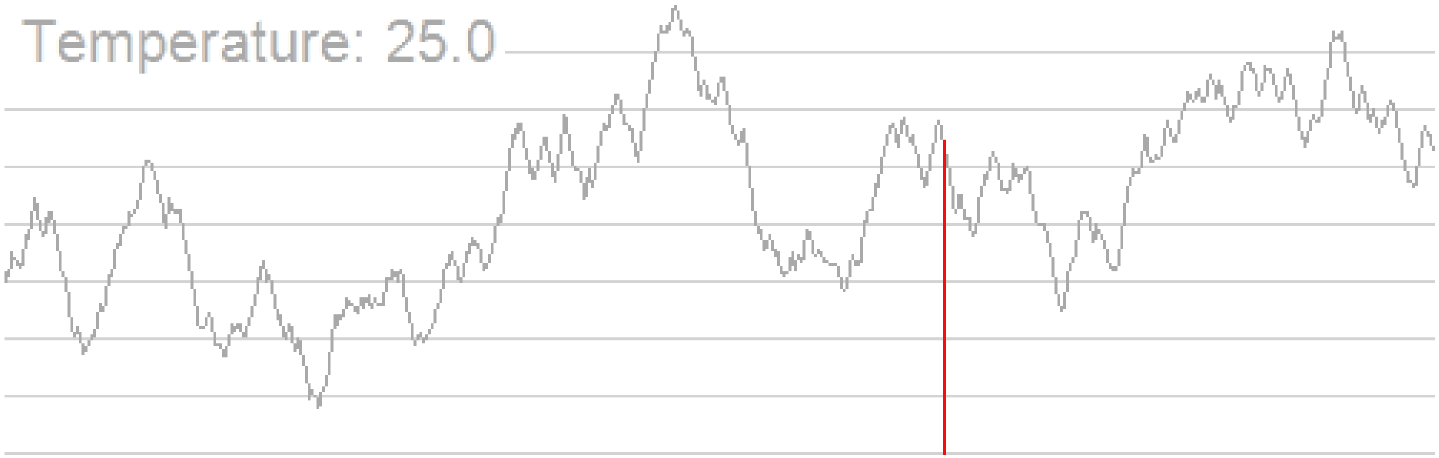

Fig 7: Simulated Annealing

Methods Could be Improved

- FAST-16 corner detector
- To replace the FAST-16 corner detector with SIFT (Scale-invariant feature transform)
  - Scale normalization
  - Accurate descriptor for each key point

Reference

- [1] G. Klein and D. Murray. Parallel tracking and mapping for small AR workspaces. In Proc. of the International Symposium on Mixed and Augmented Reality (ISMAR), 2007.
- [2] H. Stew´ enius, C. Engels, and D. Nist´ er. Recent developments on direct relative orientation. *ISPRS Journal of Photogrammetry and Remote Sensing, 60:284–294, June 2006.*

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Reference

- [3] H. Li and R. Hartley. Five-point motion estimation made easy. In Proc. of the International Conference on Pattern Recognition (ICPR), 2006.
- [4] Autonomous Camera-Based Navigation of a Quadrocopter (J. Engel), Master's thesis, Technical University Munich, 2011.