PMSD Final Presentation

Location Recognition in Laparoscopic Surgery

Technische Universität München

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of ENGINEERING

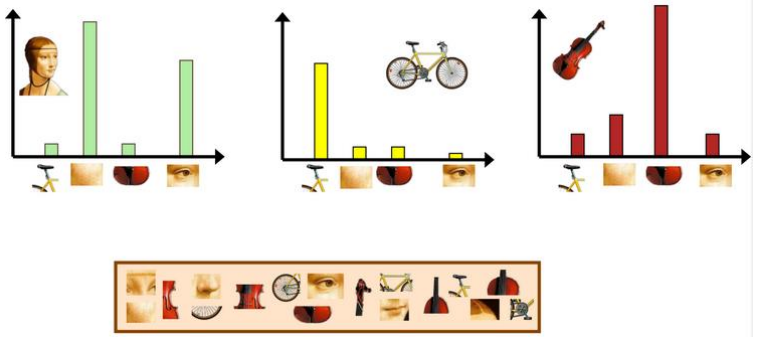
Recap: Project Requirements

- **COMPASS system:** Online construction of a **anatomical map**, based on stereo-endoscope images and IMU-sensor data using **SLAM**

- **Drift correction** by finding loop-closures (already visited locations) → **Visual Bag of Words (BoW)**

- Project requirements:
  1. **Build BoW-dictionary** for given dataset
  2. **Integrate BoW-algorithm** into existing pipeline
  3. Integrate **additional consistency checks** based on e.g. IMU-data

Source: Bokovoy, Andrey & Yakovlev, Konstantin. (2017). Original Loop-closure Detection Algorithm for Monocular vSLAM.



Source: https://kushalvyas.github.io/BOV.html

GANTT Project Plan

Oct 18 - Oct 31 **Reimplementation of Bag of Words (BoW) Algorithm**

Nov 1 - Nov 21 **Extraction of new BoW Vocabulary**
- Feature extraction for all images
- K-means Clustering
- Export of BoW Vocabulary

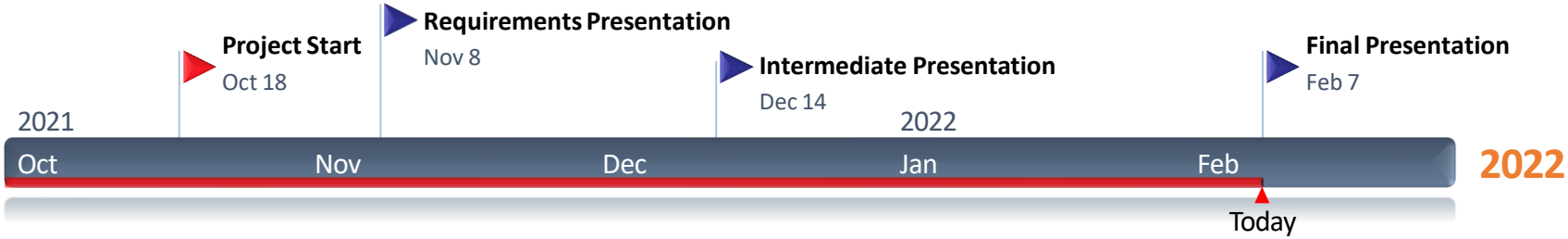
Nov 22 – Dec 12 **Testing 1**

Dec 12 – Dec 23 **Integration of BoW Algorithm in Existing Pipeline**
- Use of pre-implemented BoW algorithm

Dec 24 - Jan 9 **Christmas Holidays**

Jan 10 - Jan 23 **Integration of additional Consistency Checks**
- Based on IMU-data etc.

Jan 23 – Feb 7 **Testing 2**



Further Evaluation of BoW-Dictionaries

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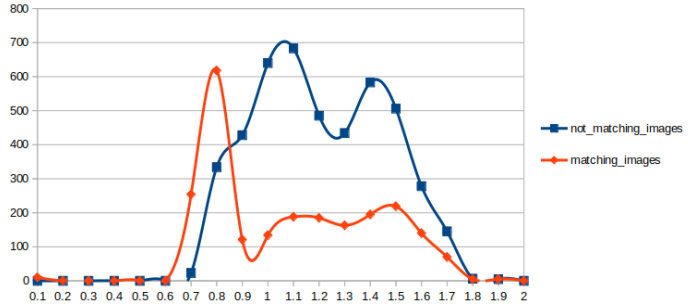
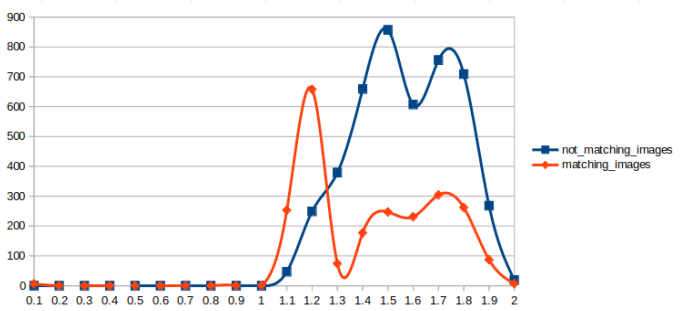
Further Evaluation BoW-Dictionaries

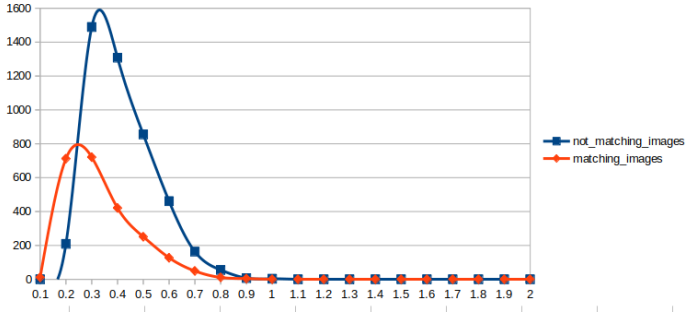
1. Evaluation of BoW-vector distances for different Dictionary parameters:



K: 10 L: 4



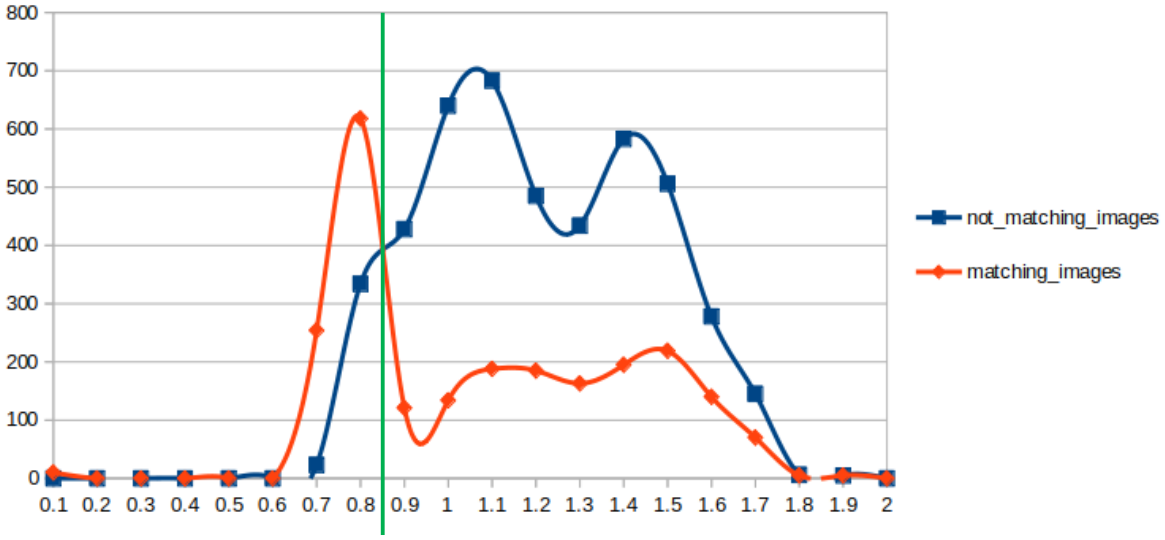
K: 15, L: 4



K: 30, L: 2

Further Evaluation BoW-Dictionaries

2. Choice of suitable matching threshold:



K: 10 L: 4

→ Improved matching precision from 0.64 to 0.74

$$Precision = \frac{TP}{TP + FP}$$

Integration into current workflow

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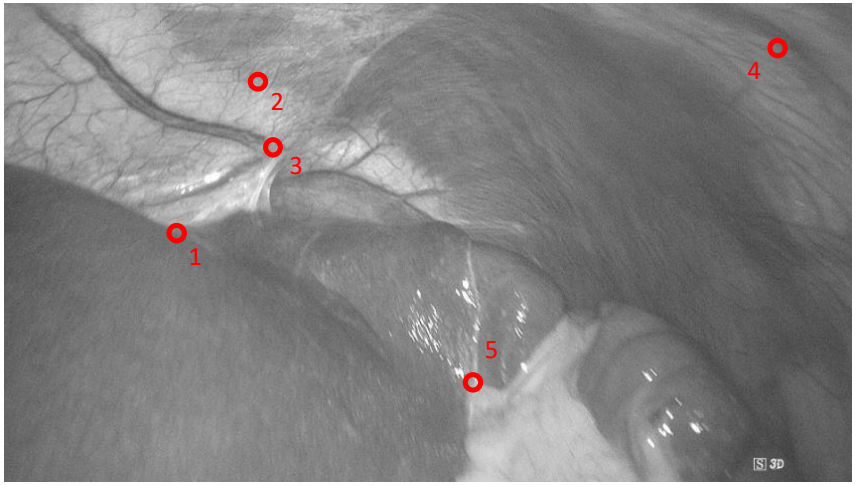
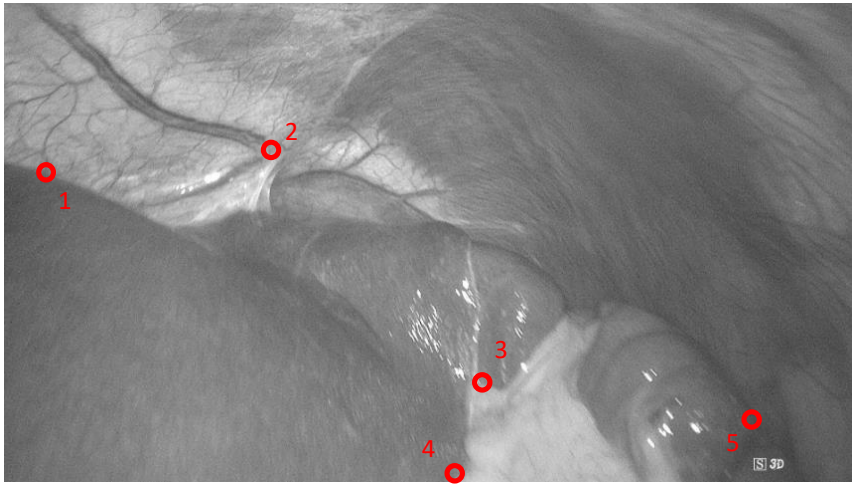
Current Workflow

1. Detection of stereo-matches (landmarks) and triangulation for 3D position:



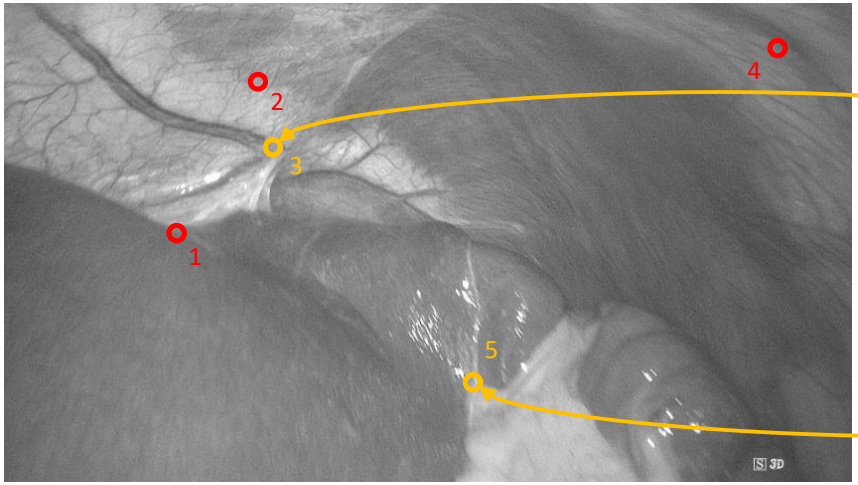
Frame A, Cam 1



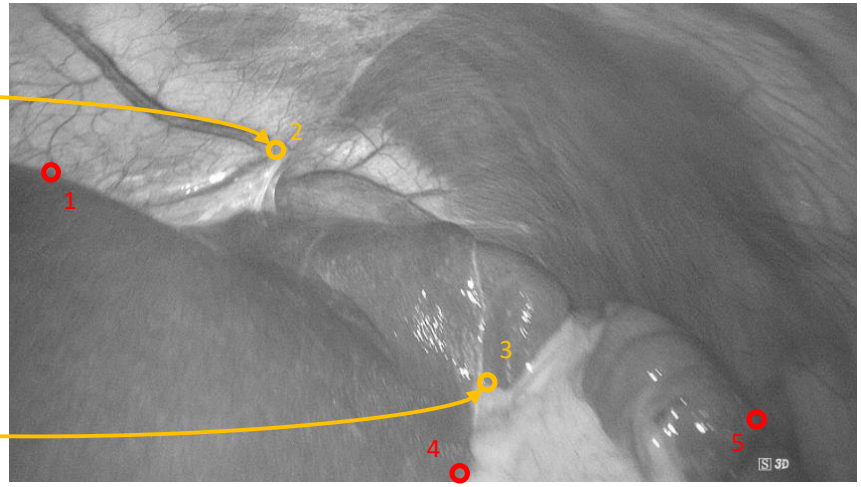
Frame A, Cam 2

Current Workflow

1. Detection of stereo-matches (landmarks) and triangulation for 3D position:



Frame A, Cam 1



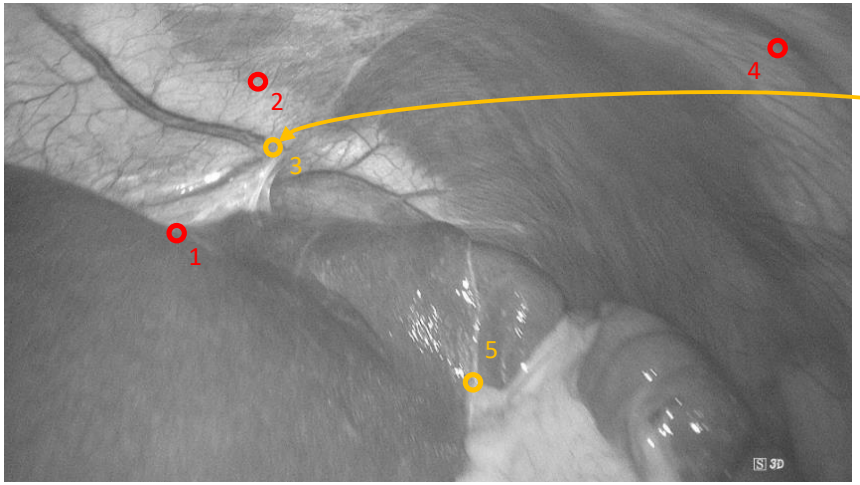
Frame A, Cam 2

Landmark_1: {{A_1, 3}; {A_2, 2}}

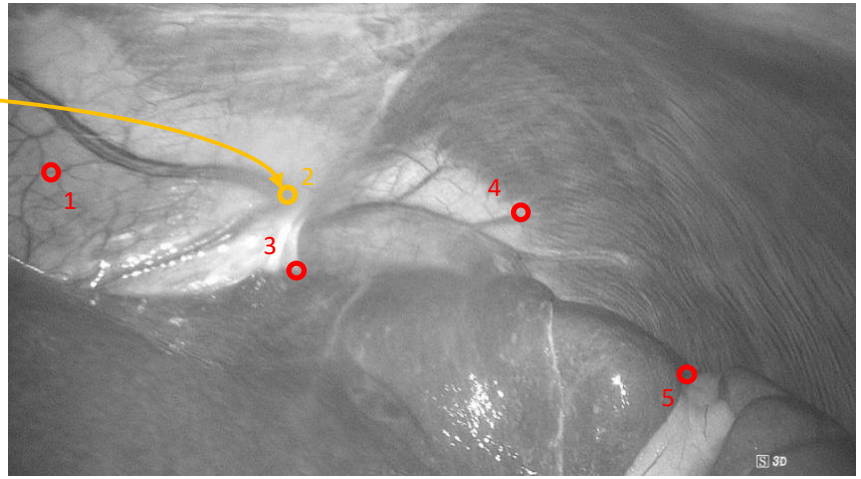
Landmark_2: {{A_1, 5}; {A_2, 3}}

Current Workflow

2. Tracking Landmarks and adding observation:



Frame A, Cam 1



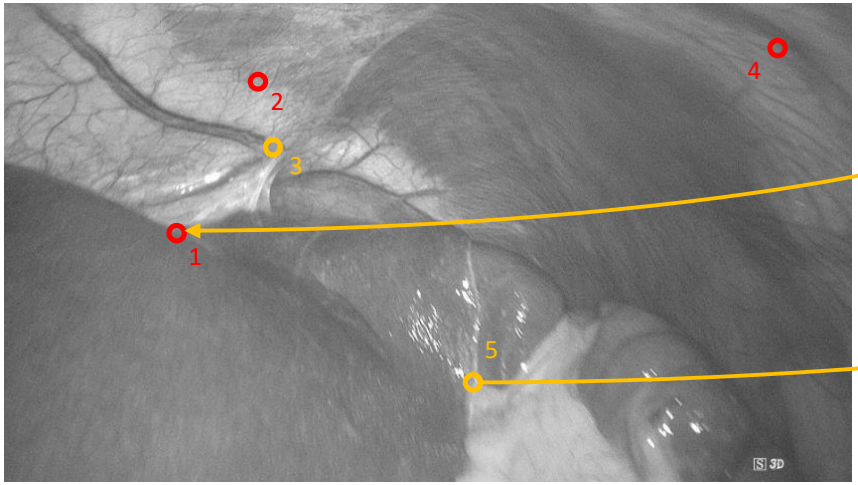
Frame B, Cam 1

Landmark_1: {{A_1, 3}; {A_2, 2}; {B_1, 2}}

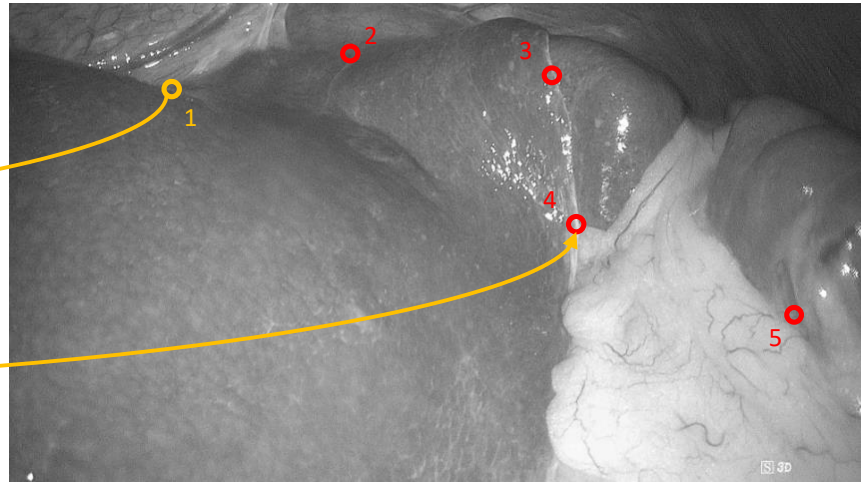
Landmark_2: {{A_1, 5}; {A_2, 3}}

Integration of BoW

For all query matches find features that match landmarks:



Frame A, Cam 1



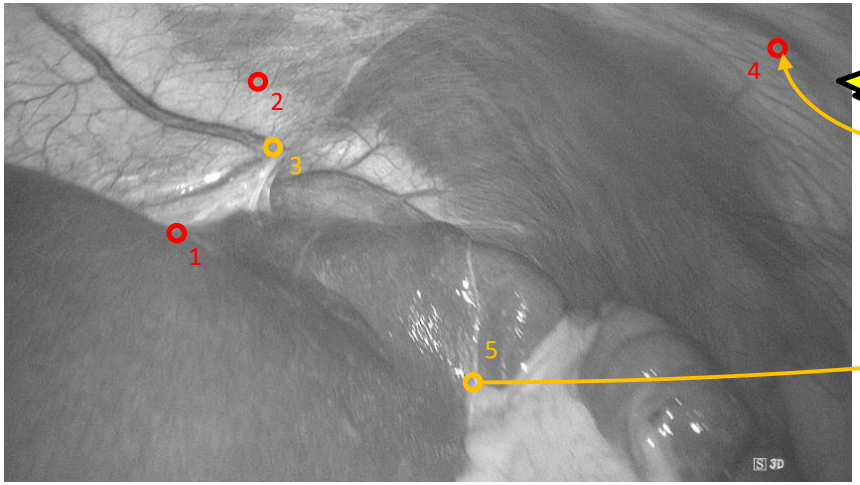
Frame Y, Cam 2

Landmark_2: {{A_1, 5}; {A_2, 3}; {Y_2, 4}}

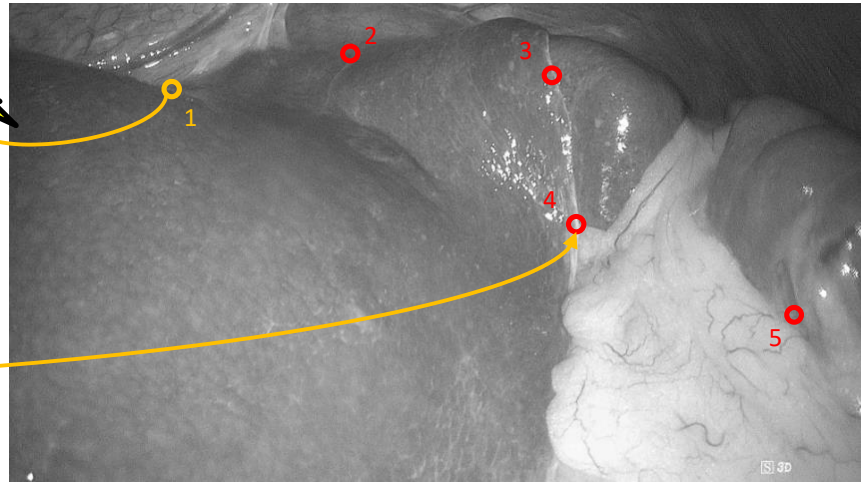
Landmark_31: {{Y_1, 2}; {Y_2, 1}; {A_1, 1}}

Motivation Consistency Checks

Problem:



Frame A, Cam 1



Frame Y, Cam 2

Landmark_2: {{A_1, 5}; {A_2, 3}; {Y_2, 4}}

Landmark_31: {{Y_1, 2}; {Y_2, 1}; {A_1, 4}}

Consistency Checks

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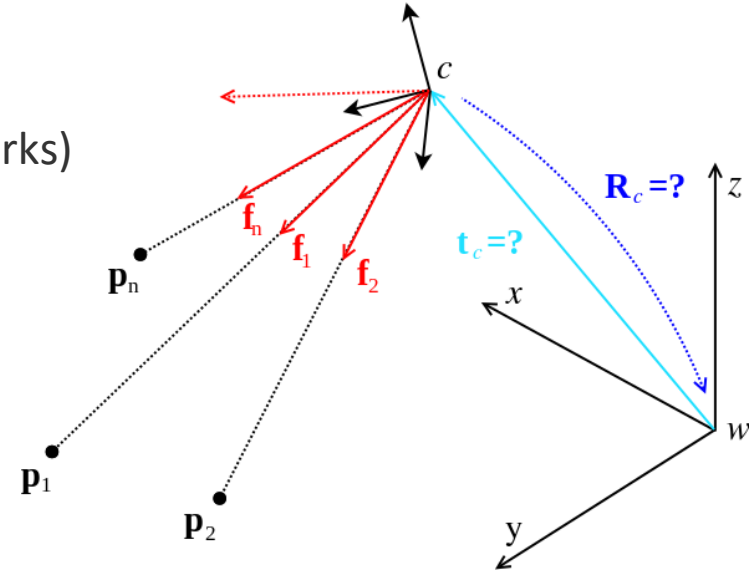
Consistency Checks

Solution: Find outliers using **RANSAC**

- find **camera pose** given a number of **2D-3D correspondences** (2D – features, 3D – landmarks)
- Try to find camera pose such that **maximum amount of correspondences** fit the transformation
- Only **inliers** get considered as observations



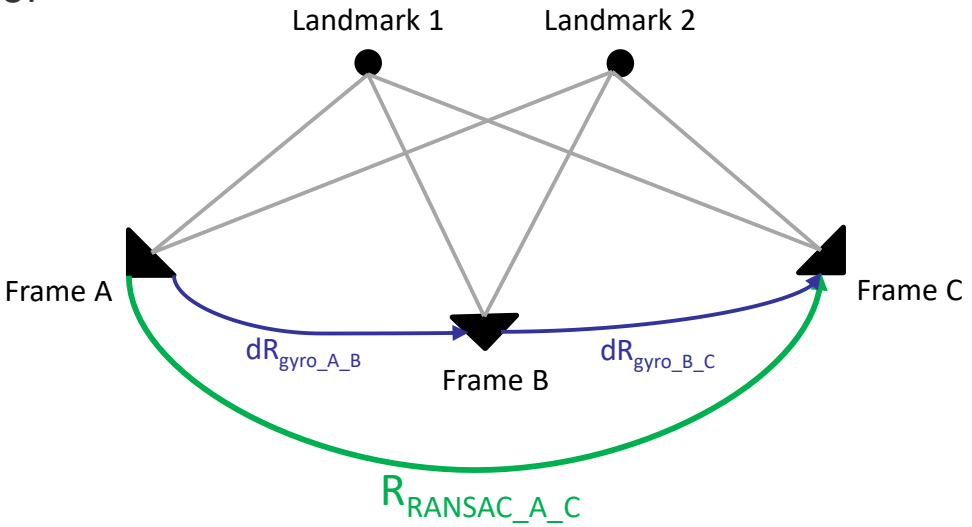
Source: https://laurentkneip.github.io/opengv/page_how_to_use.html#sec_threshold

Consistency Checks

Additional consistency check using **Gyro-data**:

- Check if **rotation R_{RANSAC} corresponds to** measured **rotation R_{gyro}** of IMU sensor
- If close enough, **add observations**

→ **Consistency check of found inliers**



Testing

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Results Testing

Project matched landmarks into current frame and **calculate** distance in 2D image coordinates

→ For **841** frames and **3923 observations** : **average error** of **1.93 pixel**

Open Problems

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Open Problems To Solve

1. Find a suiting **threshold** for **gyro-consistency** → **Compensate** for eventual **gyro-drift** over time
2. Use **more data** to extract **BoW-Dictionary**
3. Use **more data** for **testing**
4. Evaluate **online performance**

Thanks for your attention!

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