Lab #3. Visual SLAM: Camera Tracking

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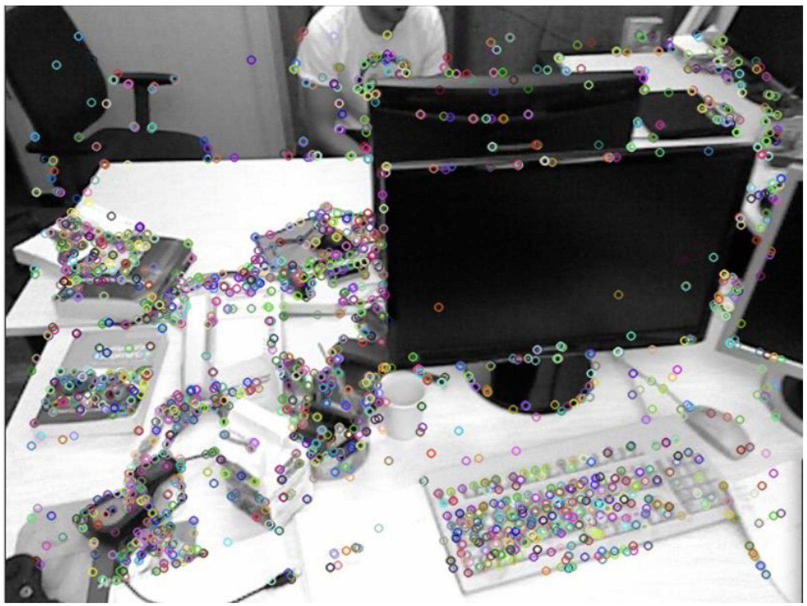
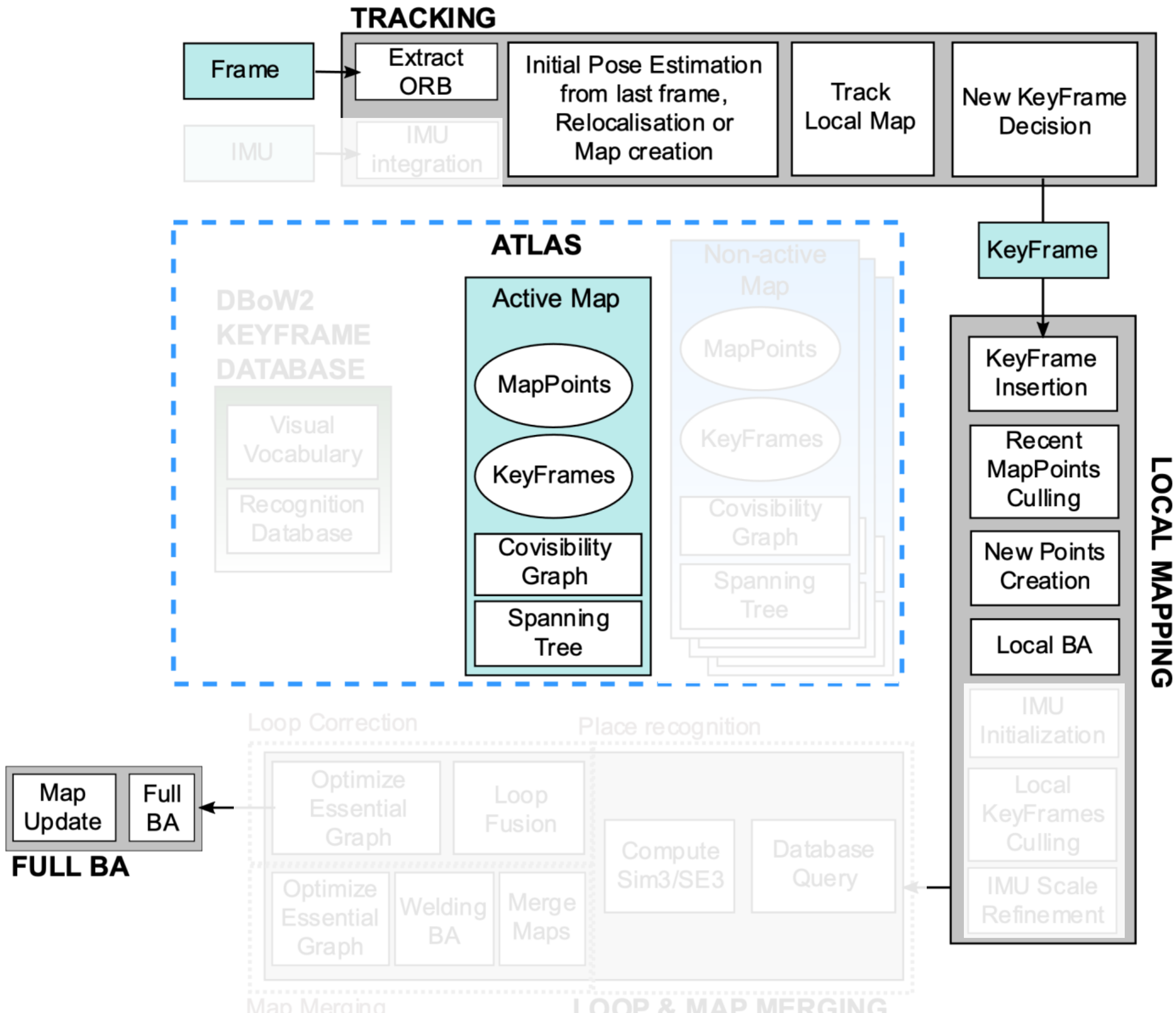
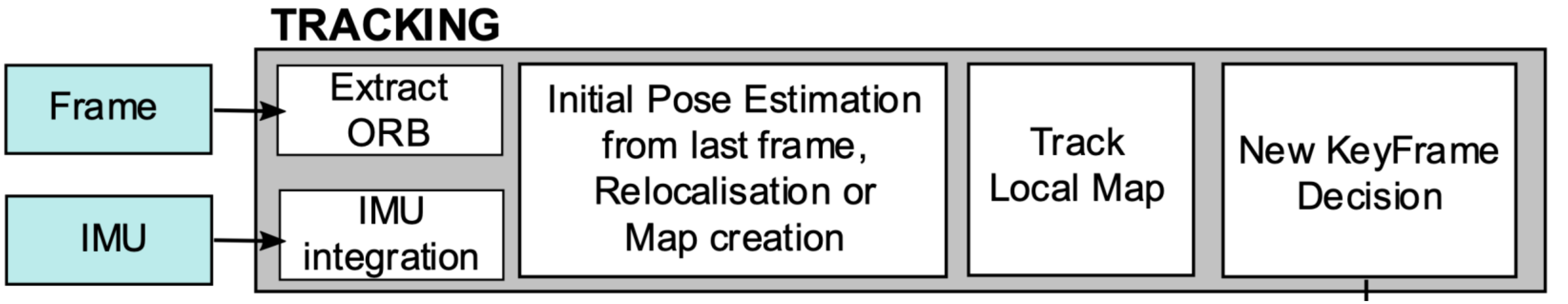
robots.unizar.es/SLAMLAB



Mini-SLAM vs ORB-SLAM3

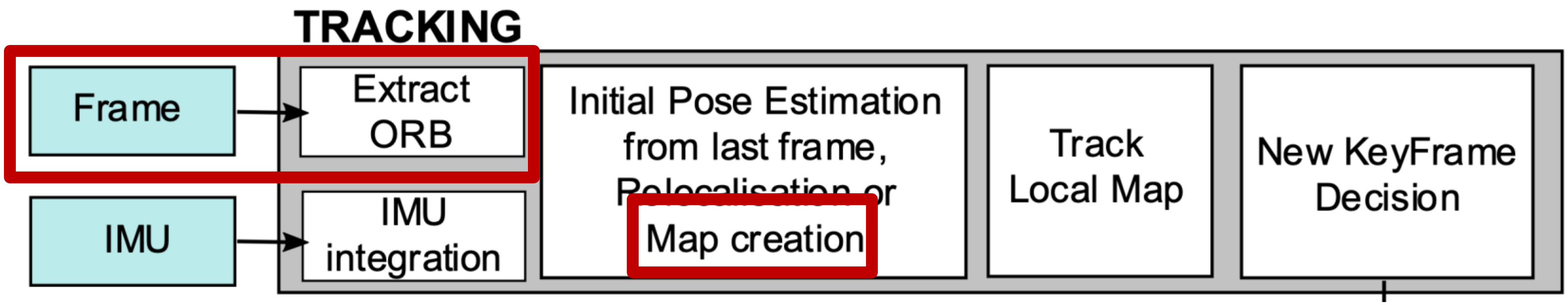


Camera Tracking



- Task 0 – Download the dataset
- Task 1 – Monocular Map Initialization
- Task 2 – Pinhole camera model
- Task 3 – Reprojection error
- Task 4 – Tracking the local map
- Task 5 – Fish-eye camera model

Task 1 — Monocular Map Initialization



2D Feature Matching → 3D Points and Motion

- Compare descriptors to get putative matchings
  - ORB: Hamming distance
  - Improves using ratio to second neighbor (NNR)
- Brute force or guided matching
- Draw the matches to check they are correct

Task 2 — Pinhole camera model

- Projection of point j on camera i

$$\mathbf{X}_c = \mathbf{x}_{ij} = \mathbf{R}_{iw}\mathbf{x}_{wj} + \mathbf{t}_{iw} \qquad \mathbf{T}_{iw} \begin{cases} \mathbf{R}_{iw} \in \mathrm{SO}(3) \\ \mathbf{t}_{iw} \in \mathbb{R}^3 \end{cases}$$

- Monocular pin-hole camera model
  - Projection

$$\mathbf{x} = \pi_m(\mathbf{X}_c) = \begin{bmatrix} f_x \frac{X}{Z} + c_x \\ f_y \frac{Y}{Z} + c_y \end{bmatrix}, \quad \mathbf{X}_c = [X, Y, Z]^T, \quad \mathbf{x} = [u, v]^T$$

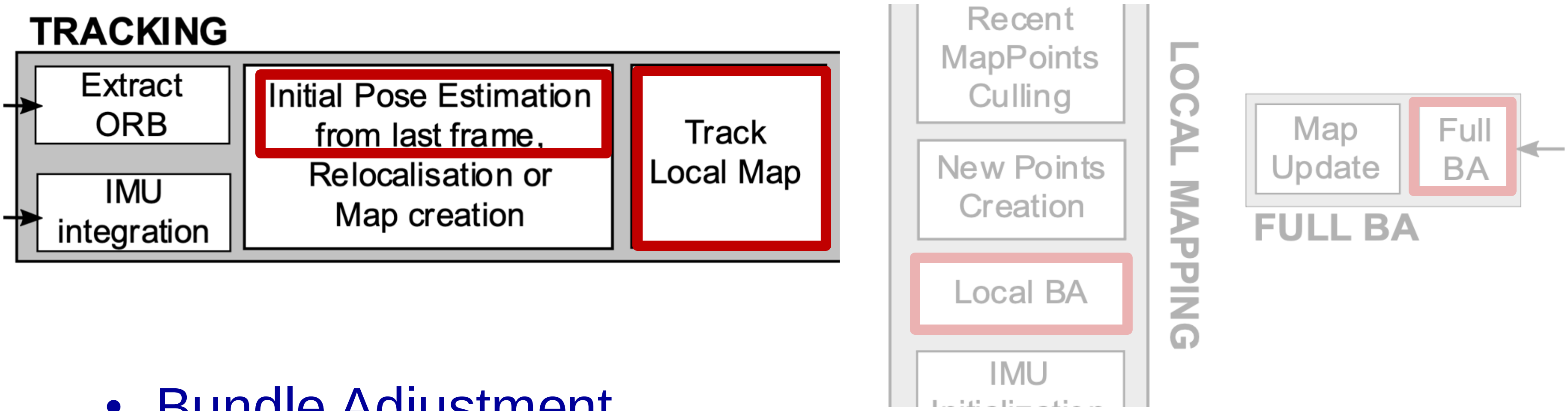
  - Unprojection

$$\mathbf{X}_c = \pi_m^{-1}(\mathbf{x}) = ?$$

  - Jacobian

$$J_\pi = \begin{pmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} & \frac{\partial u}{\partial z} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} & \frac{\partial v}{\partial z} \end{pmatrix} = ?$$

Task 3 — Reprojection error



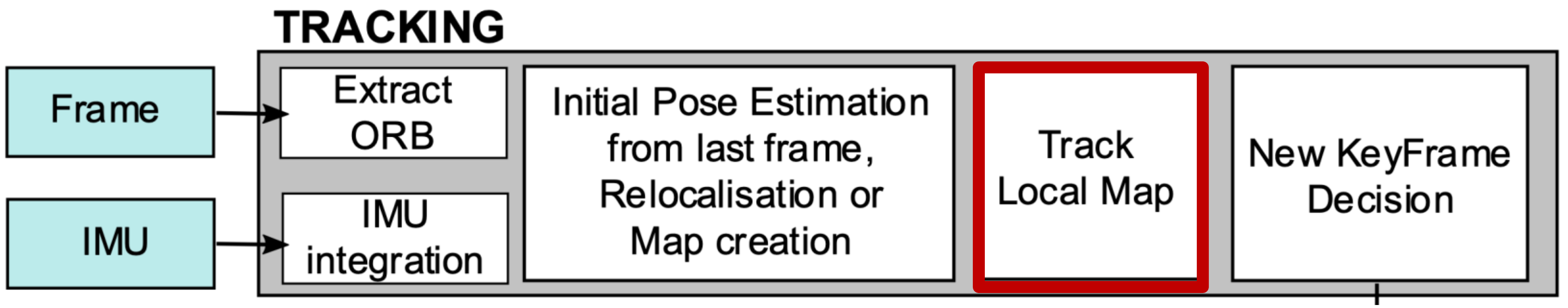
- Bundle Adjustment

$$\{\mathbf{R}_{iw}, \mathbf{t}_{iw}, \mathbf{x}_{wj} \,|\, i \in \mathcal{C}, j \in \mathcal{P}\}^* = \underset{\mathbf{R}_{iw},\mathbf{t}_{iw},\mathbf{x}_{wj}}{\operatorname{argmin}} \sum_{i,j} \rho\left(\left\|\boxed{\mathbf{u}_{ij} - \pi_i\left(\mathbf{R}_{iw}\mathbf{x}_{wj} + \mathbf{t}_{iw}\right)}\right\|^2_{\Sigma_{ij}}\right)$$

- Pose-only optimization

$$\{\mathbf{R}_{iw}, \mathbf{t}_{iw}\}^* = \underset{\mathbf{R}_{iw},\mathbf{t}_{iw}}{\operatorname{argmin}} \sum_{j} \rho\left(\left\|\boxed{\mathbf{u}_{ij} - \pi_i\left(\mathbf{R}_{iw}\mathbf{x}_{wj} + \mathbf{t}_{iw}\right)}\right\|^2_{\Sigma_{ij}}\right)$$

Task 4 — Tracking the local map



- Project MapPoints and match them to features
  - MapPoints that should be visible in the current frame.
  - Features not already matched with a MapPoint.
- Hamming distance, guided matching…
- Check ATE before and after this task

Task 5 — Fish-eye camera model

- Kannala-Brandt projection:

$$r = \sqrt{x^2 + y^2}, \quad \theta = \arctan\left(\frac{r}{z}\right)$$

$$d(\theta) = \theta + k_1\theta^3 + k_2\theta^5 + k_3\theta^7 + k_4\theta^9$$

$$u = f_x d(\theta)\frac{x}{r} + c_x, \quad v = f_y d(\theta)\frac{y}{r} + c_y$$

$$J_\pi = \begin{pmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} & \frac{\partial u}{\partial z} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} & \frac{\partial v}{\partial z} \end{pmatrix} = \boxed{?}$$

- Kannala-Brandt backprojection:

$$m_x = \frac{u - c_x}{f_x}, \quad m_y = \frac{v - c_y}{f_y}, \quad r' = \sqrt{m_x^2 + m_y^2}$$

$$\boxed{\theta = d^{-1}(r')}$$

$$\mathbf{d} = \left(\sin\theta\frac{m_x}{r'}, \sin\theta\frac{m_y}{r'}, \cos\theta\right)$$

- Lookup table
- Inverse polynomial
- Newton's method

Results

- What?
  - Short report (discussion, figures…)
    Answer the questions for each task
  - Code (clean and with some comments)
    Include <u>only</u> *Modules* and *Apps* folders

- When?
  - Submission @ 23:59 on Monday after Lab 3.2 session