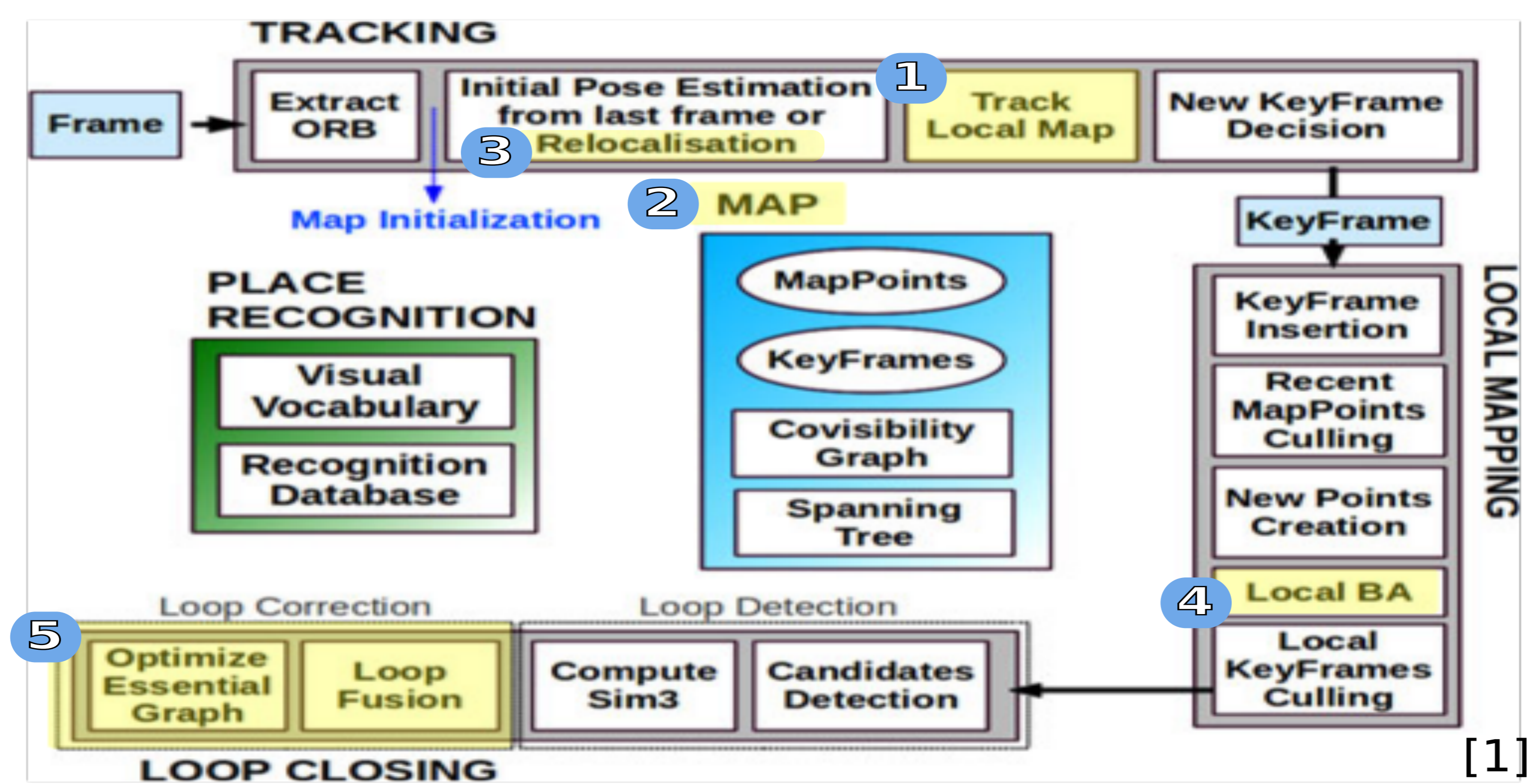


Abstract

Visual simultaneous localization and mapping is a well-known problem for rigid environments. Our proposal is a novel pipeline that allows to fully extend these algorithms to medical environments. We have conceived a pipeline able to work in deformable environments.

Key ideas:

- Shape-from-Template (SfT) techniques to track the camera pose w.r.t. the deformable map in real-time.
- Non-Rigid-Structure-from-Motion (NRSfM) techniques to estimate the deformable maps.
- Upgrading the state-of-the-art rigid VSLAM (ORB-SLAM [1]) pipeline to deformable.



- 1 Tracking -> Shape-From-Template
- 2 Deformable Map -> Template (Surface)
- 3 Deformable Relocalisation -> RANSAC + NR-PnP
- 4 Map Estimation -> Local NRSfM method
- 5 Loop Closing -> Global NRSfM method

Method

1 Camera pose tracking

From the matches between the current frame and the deformable map we estimate the deformation and the camera pose in real-time in a dedicated thread.

The optimization includes a data term and several regularizers that code the deformation model

$$\arg \min_{T_i, V_k^i \in \mathcal{L}_i} \frac{1}{N} \sum_j \rho \left(\left\| \pi_i \left(T_i, \varphi(b_j, V_{f_j}^i) \right) - x_j^i \right\|^2 \right) \quad \text{Data term}$$

$$+ \frac{\lambda_d}{N} \sum_k \sum_{l \in \mathcal{N}_k} \left(\frac{\|V_k^i - V_l^i\| - \|V_k^0 - V_l^0\|}{\|V_j^0 - V_l^0\|} \right)^2 \quad \text{Stretching constraint}$$

$$+ \frac{\lambda_b}{N} \sum_k (\|\delta_k^i\| - \|\delta_k^0\|)^2 \sum_{l \in \mathcal{N}_k} \frac{1}{\|V_j^0 - V_l^0\|^2} \quad \text{Bending constraint}$$

$$+ \frac{\lambda_T}{SN} \sum_k \|V_k^i - V_k^{i-1}\| \quad \text{Temporal smoothness}$$

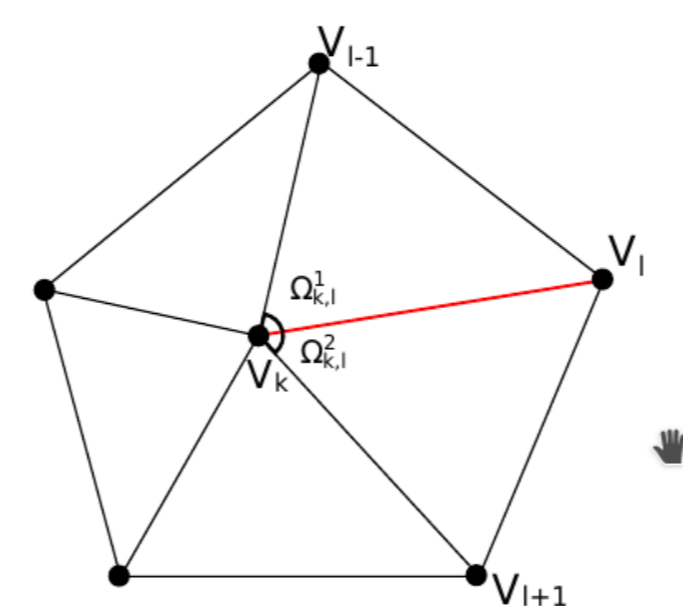
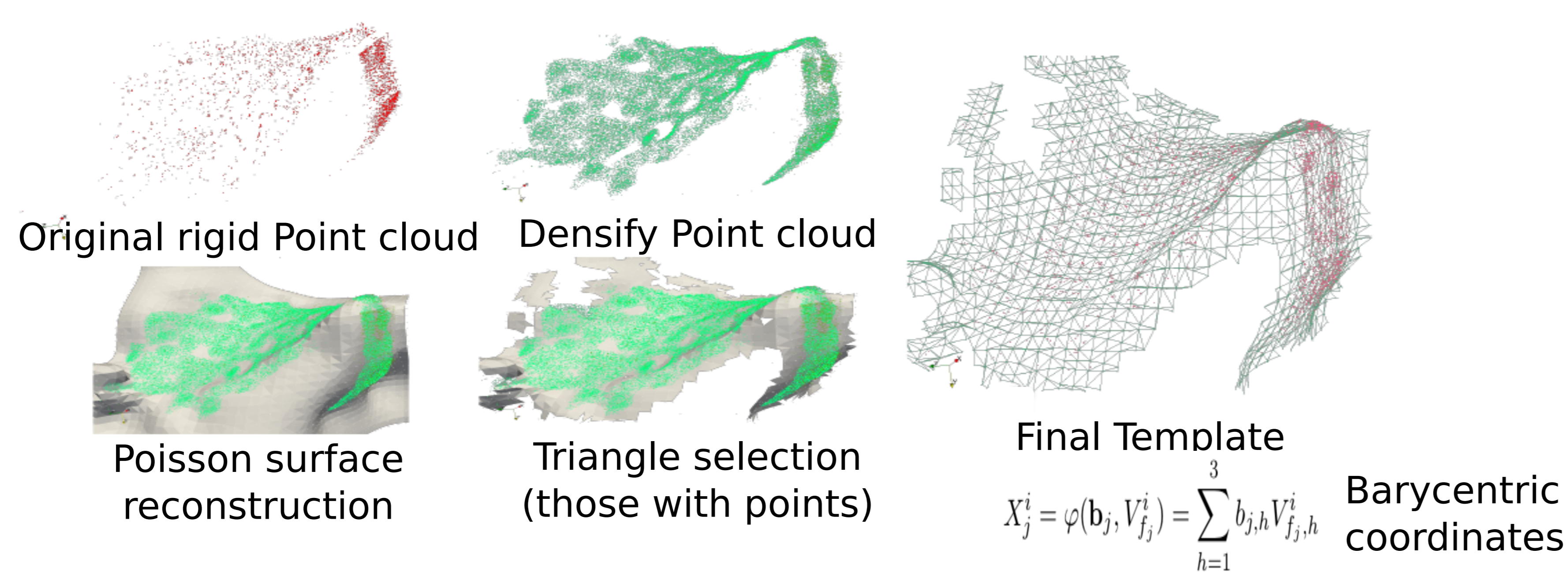


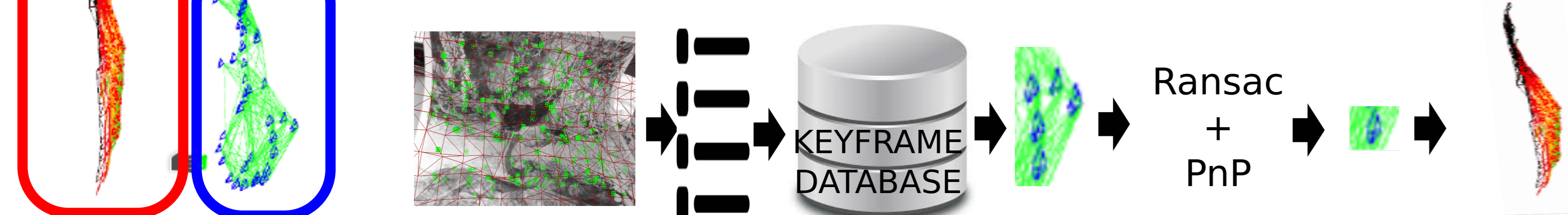
Fig. 2. Ring of neighbours \mathcal{N}_k of the node K . [3]

2 Deformable Map: Template estimation

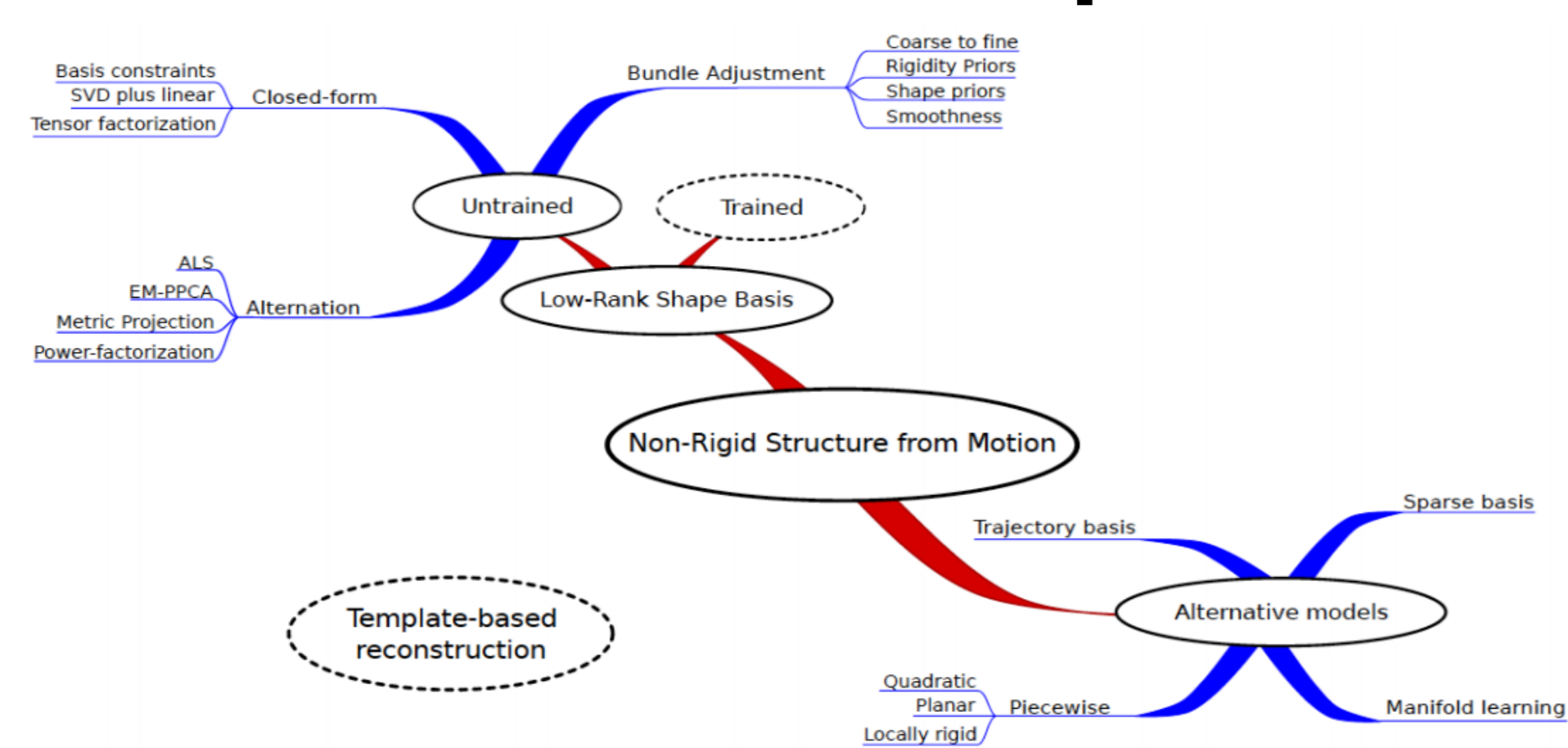


3 Deformable Relocalisation

Binary BoW to recover a close keyframe and 20 putative matches. Relaxed PnP guided search reaches more than 50 matches. Purely rigid PnP achieves a 25% recall while the relaxed one reaches 49%



4 Deformation model (map) estimated with NRSfM

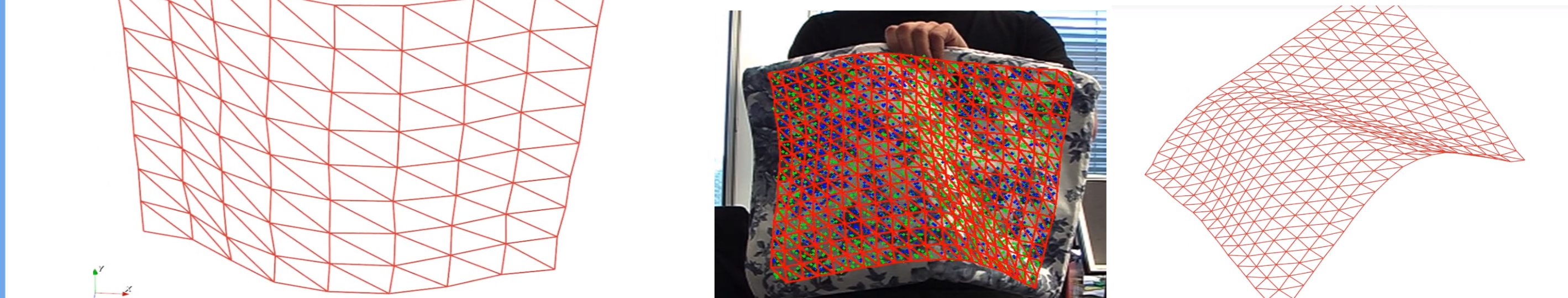
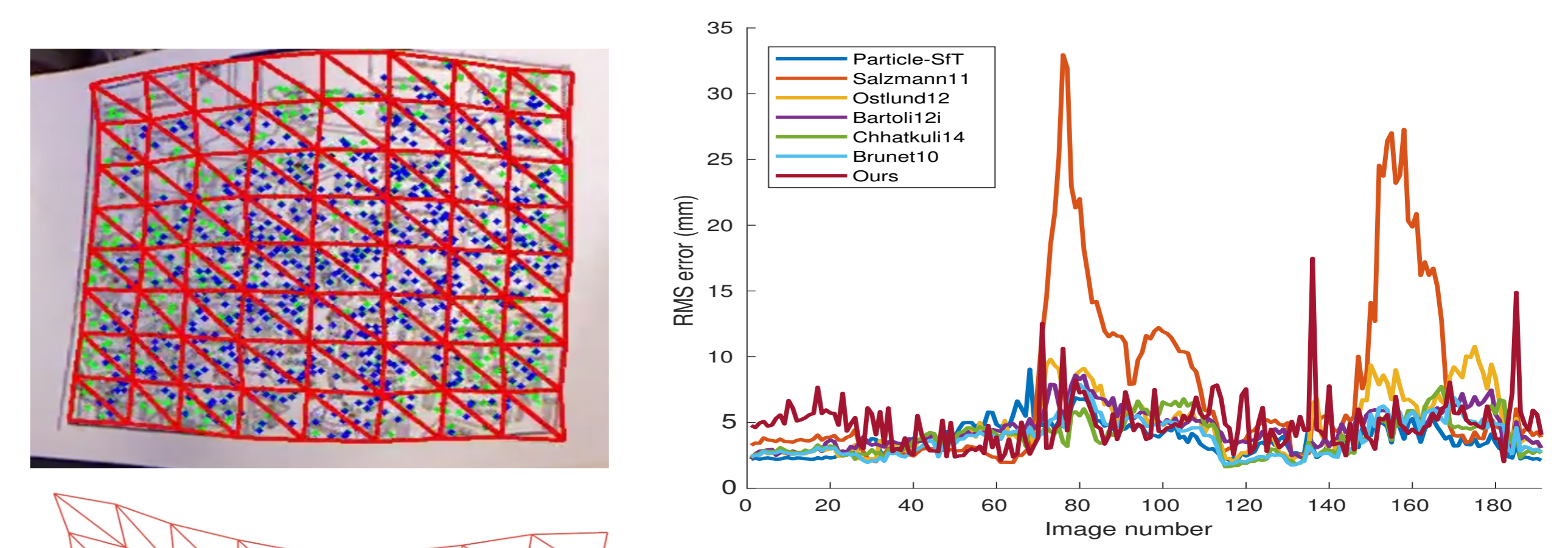


The challenge is estimating the deformation model live from a sequence of monocular images of the deforming scene

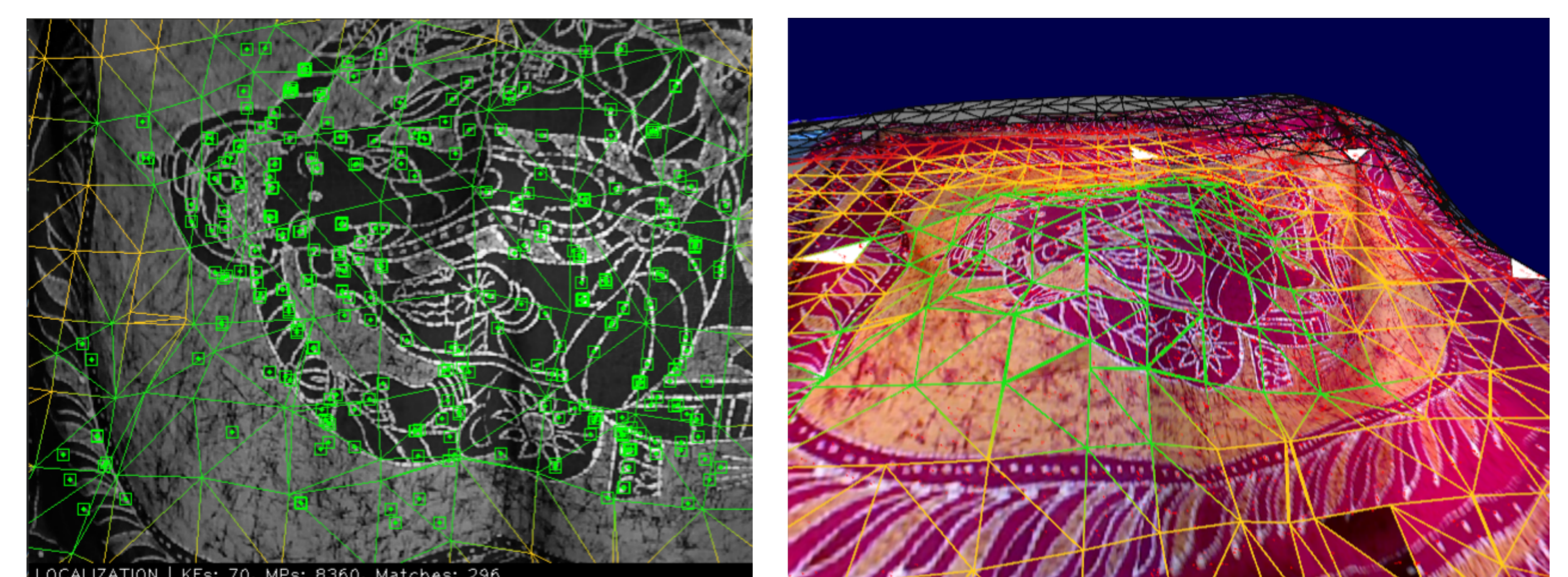
FUTURE WORK

Evaluation & Conclusions

We achieve a robust real-time at 8Hz. system for 1, 2 and 3. We evaluate our SfT constraints in public dataset.



We evaluate the performance in our Mandala dataset that mimics our goal: deformable SLAM of an environment bigger than the camera field of view.



• QR CODE TO OUR PAPER AND VIDEO!

Related Work

- [1] Mur-Artal, R., Montiel, J. M. M., & Tardos, J. D. (2015). ORB-SLAM: a versatile and accurate monocular SLAM system. *IEEE Transactions on Robotics*, 31(5), 1147-1163.
- [2] Lepetit, V., Moreno-Noguer, F., & Fua, P. (2009). Epnp: An accurate o(n) solution to the pnp problem. *International journal of computer vision*, 81(2), 155.
- [3] Lamarca J., Montiel, J.M.M. (2018) "...". (Paper submitted to ECCV18 (Double blind))