Incremental Visual-Inertial 3D Mesh Generation with Structural Regularities

Introduce

deal map represent：

- lightweight to compute and store
- describes the topology of the environment
- couples state estimation and mapping, improve each other

So proposed a method use 3D mesh represent

Framework

consider a stereo visual-inertial system and adopt a keyframe-based approach

Front-end

- 3D Mesh Generation

  it is difficult to create a 3D mesh

  - 3D positions of the landmarks are noisy
  - the density of the point cloud is highly irregular
  - points are being removed (marginalized) and added

  perform a 2D Delaunay triangulation only over the tracked keypoints in the latest frame

  > Delaunay triangulation maximizes the minimum angle of all the angles of the triangles in the triangulation

- 3D Mesh Propagation

> maintain a mesh over the receding horizon of the fixed-lag smoothing optimization problem

  - Temporal

    we re-compute a 2D Delaunay triangulation from scratch over the keypoints of the current frame

  - Spatial

    add: merging new local 3D mesh, ensuring no duplicated 3D faces

    remove: remove any face in the 3D mesh that has the landmark as a vertex

- Regularity Detection

  extract the geometry in the scene in a non-iterative way (unlike RANSAC approaches).

  interested in co-planarity regularities between landmarks(ground and wall)

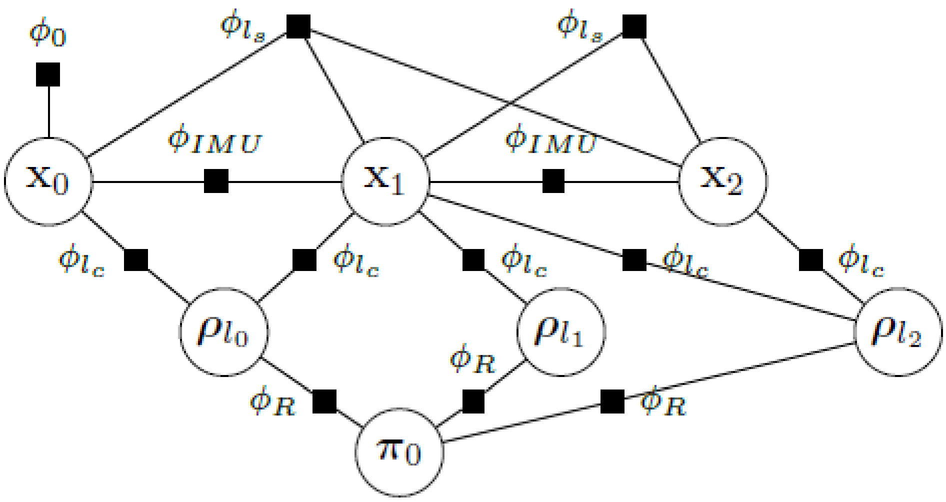
  - detect planes that are horizontal (i.e. floor, tables)
  - cluster the faces of the mesh with vertical normals
  - build a 1D histogram of the height of the vertices
  - smoothing the histogram with a Gaussian filter
  - take the candidates with the most inliers (above 20 faces).

Back-end

- Factor Graph Formulation

  estimate the posterior probability

$$p(\mathcal{X}_t|\mathcal{Z}_t) \overset{(a)}{\propto} p(\mathcal{X}_t)p(\mathcal{Z}_t|\mathcal{X}_t)$$



- MAP Estimation

  calculate the maximum a posteriori (MAP) estimator

- Regularity Constraints

  $$\boldsymbol{n} \cdot \boldsymbol{\rho}_{l_c} - d.$$

  will lead to a singular information matrix

  To avoid this problem, we optimize in the tangent space

  $$\mathrm{S}^2 \doteq \{\mathbf{n} = (n_x, n_y, n_z)^T \,|\, \|\mathbf{n}\| = 1\}$$

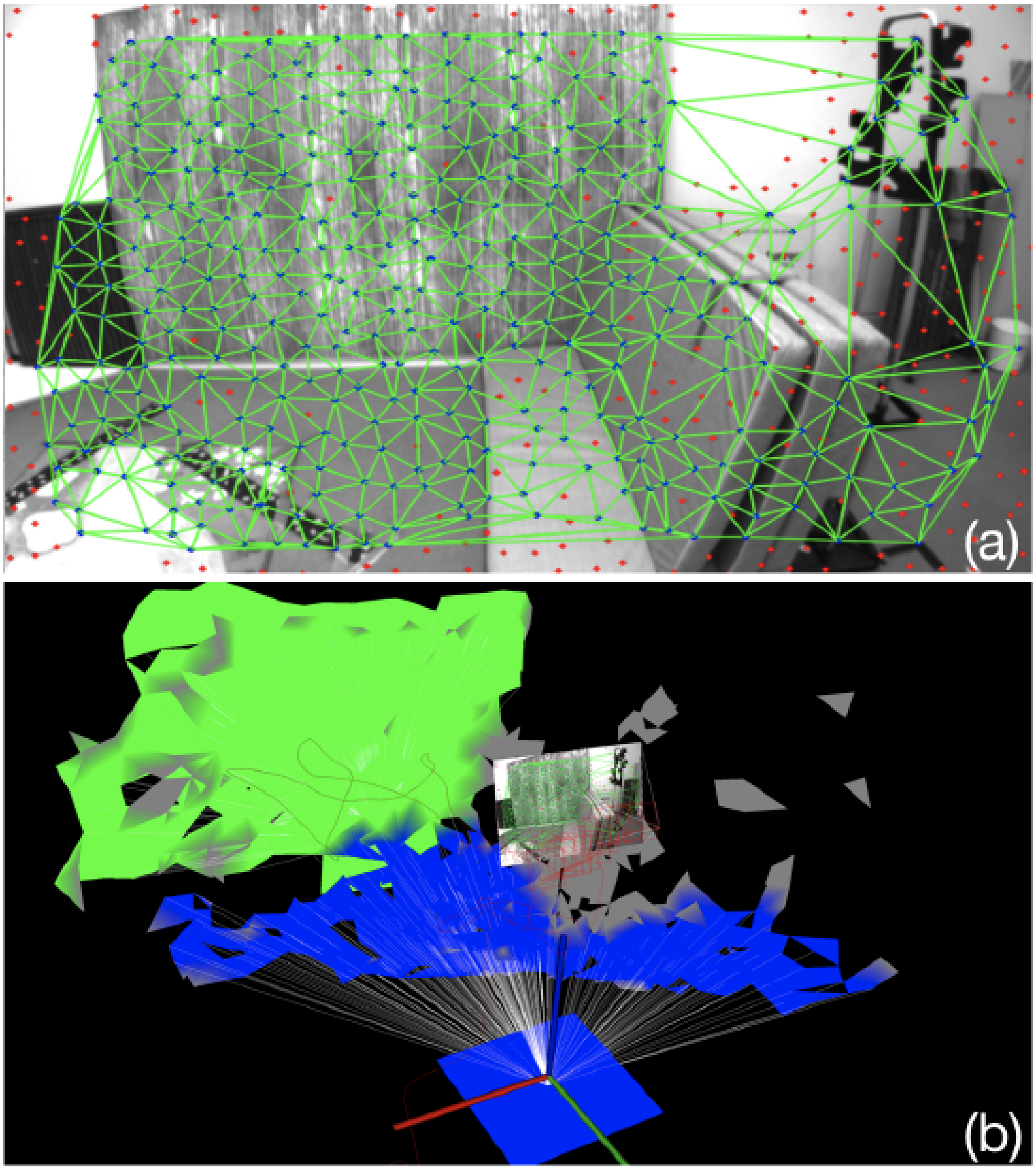
  $$\mathcal{R}_{\boldsymbol{n}}(\boldsymbol{v}) : T_{\boldsymbol{n}} S^2 \in \mathbb{R}^2$$

  $$\mathbf{r}_R(\boldsymbol{v}, d) = \mathcal{R}_{\boldsymbol{n}}(\boldsymbol{v})^\mathsf{T} \cdot \boldsymbol{\rho} - d$$

Result

a(2D Delaunay triangulation), b(3D Mesh)

green(wall), blue(ground)


(a)
(b)