CBGL: Fast Metric-based Monte Carlo Passive Global Localisation for 2D LIDAR sensors

Alexandros Filotheou

***Abstract*—**

***Index Terms*—Scan-matching, localisation, panoramic LIDAR**

I. Introduction

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum. Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum.

II. Definitions and Problem Formulation

Definition I. A conventional 2D LIDAR sensor provides a finite number of ranges, i.e. distances to objects within its range, on a horizontal cross-section of its environment, at regular angular and temporal intervals, over a defined angular range [1]. A range scan $\mathcal{S}$, consisting of N_s rays over an angular range λ, is an ordered map $\mathcal{S} : \Theta \rightarrow \mathbb{R}_{\geq 0}$, $\Theta = \{\theta_n \in [-\frac{\lambda}{2}, +\frac{\lambda}{2}) : \theta_n = -\frac{\lambda}{2} + \lambda\frac{n}{N_s},\ n = 0, 1, \ldots, N_s - 1\}$. Angles θ_n are expressed relative to the sensor's heading, in the sensor's frame of reference.

Definition II. A map-scan is a virtual scan that encapsulates the same pieces of information as a scan derived from a physical sensor. Only their underlying operating principle is different due to the fact the map-scan refers to distances to the boundaries of a point-set, referred to as the map, rather than within a real environment. A map-scan $\mathcal{S}_V^{\boldsymbol{M}}(\hat{\boldsymbol{p}})$ is derived by means of locating intersections of rays emanating from the estimate of the sensor's pose estimate $\hat{\boldsymbol{p}}$ and the boundaries of the map $\boldsymbol{M}$.

Definition III. Let $\mathcal{S}_p$ and $\mathcal{S}_q$ be two range scans, equal in angular range λ and size N_s. The value of the Cumulative Absolute Error per Ray (CAER) metric $\psi \in \mathbb{R}_{\geq 0}$ between $\mathcal{S}_p$ and $\mathcal{S}_q$ is given by

$$\psi(\mathcal{S}_p, \mathcal{S}_q) \triangleq \sum_{n=0}^{N_s-1} \Big| \mathcal{S}_p[n] - \mathcal{S}_q[n] \Big|$$

Problem P. Let the unknown pose of an immobile 2D range sensor whose angular range is λ be $\boldsymbol{p}(x, y, \theta)$ with respect to the reference frame of map $\boldsymbol{M}$. Let the range sensor measure range scan $\mathcal{S}_R$. The objective is the estimation of $\boldsymbol{p}$ given $\boldsymbol{M}$, λ, and $\mathcal{S}_R$.

III. Prior Work

IV. Approach

Hypothesis H. Let the unknown pose of a 2D range sensor measuring range scan $\mathcal{S}_R$ (def. I) be $\boldsymbol{p}(x, y, \theta)$ with respect to the reference frame of map $\boldsymbol{M}$. Let $\mathcal{H}$ be a set of pose hypotheses within the free (i.e. traversable) space of $\boldsymbol{M}$: $\mathcal{H} = \{\hat{\boldsymbol{p}}_i(\hat{x}_i, \hat{y}_i, \hat{\theta}_i)\} \subseteq \texttt{free}(\boldsymbol{M})$, $i = 0, 1, \ldots, |\mathcal{H}| - 1$; $\mathbb{S}$ be the set of map-scans (def. II) of $\boldsymbol{M}$ from pose hypotheses $\mathcal{H}$: $\mathbb{S} = \{\mathcal{S}_V^{\boldsymbol{M}}(\hat{\boldsymbol{p}}_i)\}$; and Ψ be the set of CAERs (def. III) between $\mathcal{S}_R$ and the elements of $\mathbb{S}$: $\Psi = \{\psi(\mathcal{S}_R, \mathcal{S}_V^{\boldsymbol{M}}(\hat{\boldsymbol{p}}_i))\}$. Then there exist $\delta_0, \psi_0 \in \mathbb{R}_{>0}$ which define a set of pose estimates $\mathcal{V} \subseteq \mathcal{H}$ such that

$$\|\boldsymbol{p} - \hat{\boldsymbol{p}}_\mathcal{V}\|_2 < \delta_0 \text{ and}$$
$$\psi(\mathcal{S}_R, \mathcal{S}_V^{\boldsymbol{M}}(\hat{\boldsymbol{p}}_\mathcal{V})) < \psi_0$$

for all $\hat{\boldsymbol{p}}_\mathcal{V} \in \mathcal{V}$, for which

$$\psi(\boldsymbol{p}, \hat{\boldsymbol{p}}_\mathcal{V}) < \psi(\boldsymbol{p}, \hat{\boldsymbol{p}}_{\mathcal{H}\setminus\mathcal{V}}) \quad \Rightarrow$$
$$\|\boldsymbol{p} - \hat{\boldsymbol{p}}_\mathcal{V}\|_2 < \|\boldsymbol{p} - \hat{\boldsymbol{p}}_{\mathcal{H}\setminus\mathcal{V}}\|_2$$

for any $\hat{\boldsymbol{p}}_{\mathcal{H}\setminus\mathcal{V}} \in \mathcal{H}\setminus\mathcal{V} : \|\boldsymbol{p} - \hat{\boldsymbol{p}}_{\mathcal{H}\setminus\mathcal{V}}\|_2 \geq \delta_0$.

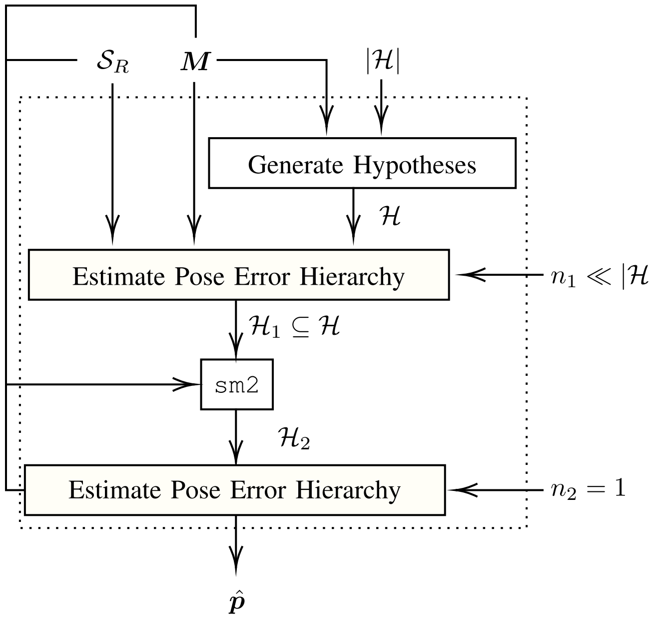

Fig. 1:

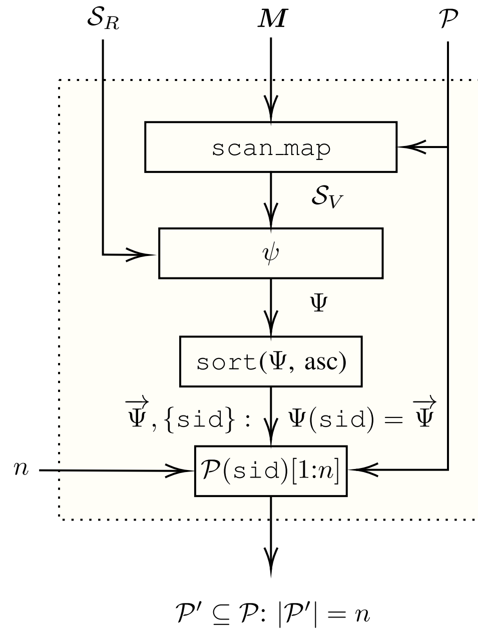

Fig. 2:

V. Results

VI. Characterisation

VII. Conclusions and Future Steps

References

[1] M. Cooper, J. Raquet, and R. Patton, "Range Information Characterization of the Hokuyo UST-20LX LIDAR Sensor," *Photonics*, 2018.