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Lidar2BIM: Global Lidar Registration on BIM Leveraging Pose Hough Transform

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Background

Indoor relocalization based on maps is crucial for robots to carry out tasks such as navigation and construction. Utilizing Building Information Models (BIM) is increasingly recognized as a promising alternative to time-consuming and costly pre-built global maps. However, the integration of BIM for robot relocalization presents several significant challenges:

Ambiguity. BIM primarily employs planar elements to represent indoor environments, which often lacks salient and distinctive features. This results in repeated patterns throughout the space, leading to perceptual aliasing where different areas appear indistinguishable to sensors

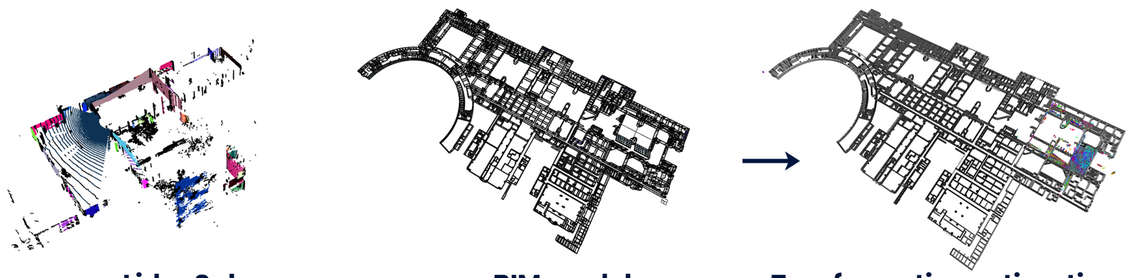
Unbalanced Point Cloud Registration. While BIM provides comprehensive structural details of a building, robot sensors capture limited field of view. This discrepancy often results in false data associations and expands the search space required for accurate pose estimation.

Lack of Public Datasets. The absence of publicly available datasets specifically designed for BIM-based relocalization hinders researchers to conduct in-depth studies and perform standardized evaluations.

Objective

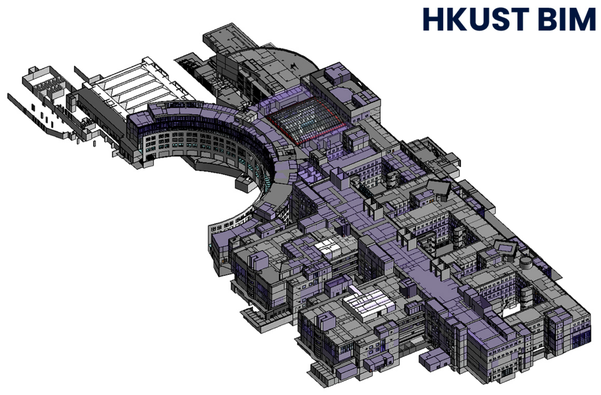
Submap pointcloud registration to BIM

The objective is to estimate the robot's pose by aligning local 3D submaps built from the robot's Lidar against the prior BIM.

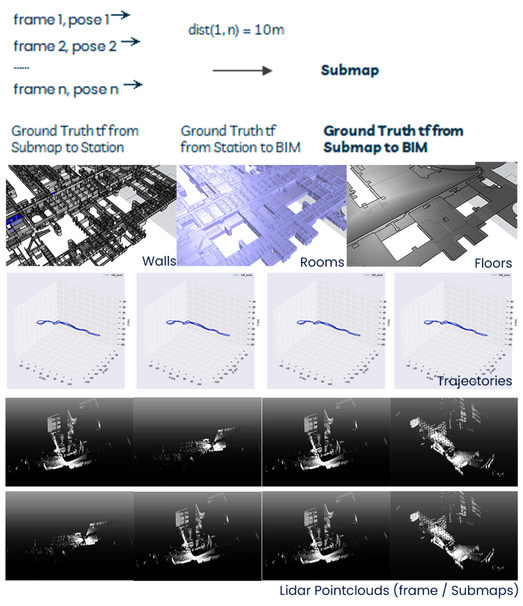


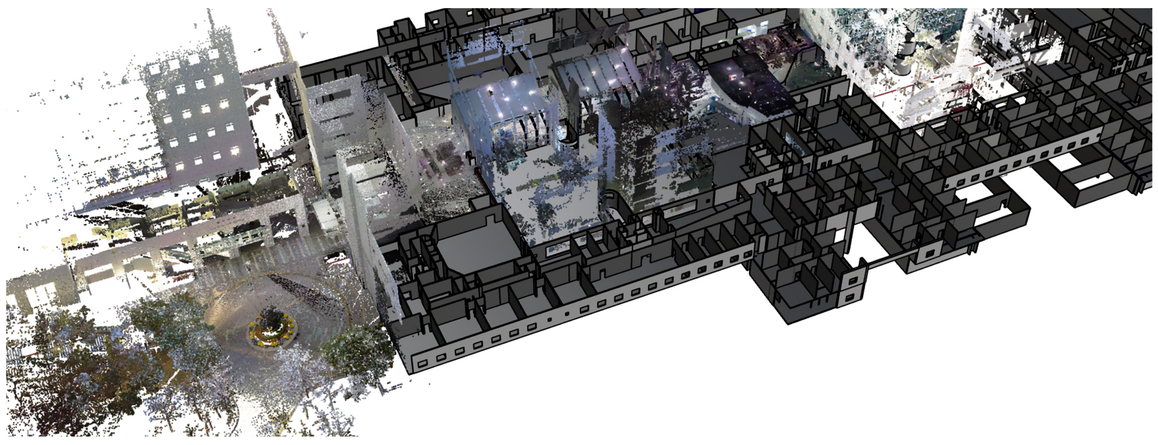
Dataset

HKUST BIM



The groundtruth transformation of each frame was obtained by positing a manual initial guess, subsequently refined through ICP

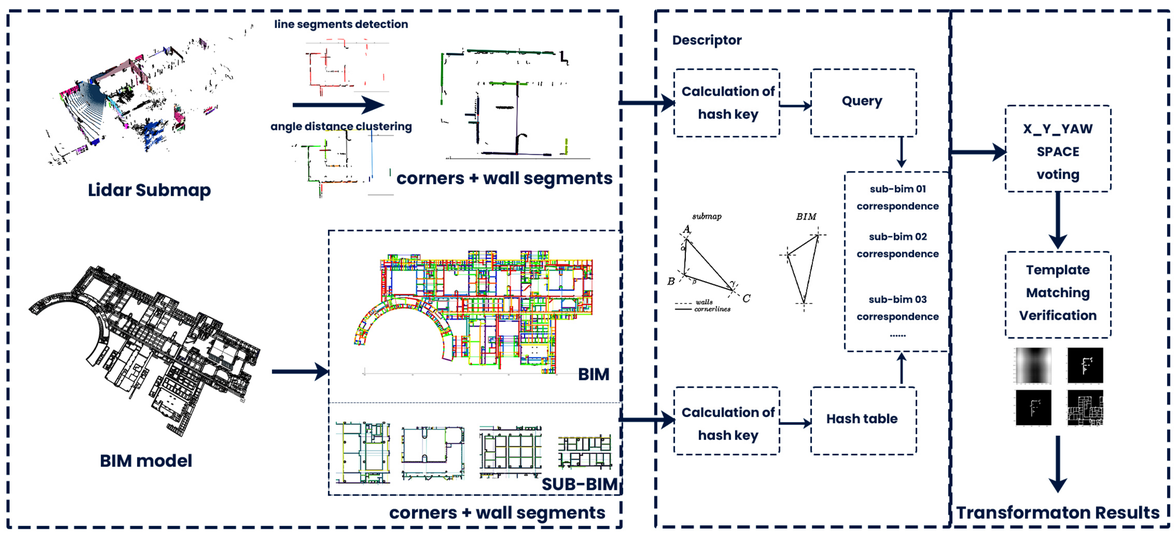




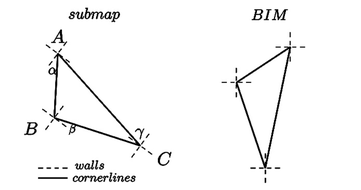
The **FusionBIM** combines BIM and Lidar pointclouds, providing the transformations for each individual frame or submap in relation to the reference frame of BIM.

Pipeline

Lidar Submap was first projected onto the ground plane. Extracted the corners and wall segments. Decomposed BIM into Sub-BIMs. Corners and walls are processed as descriptors and stored in Hash tables. Correspondences were obtained after query and were used for voting in X_Y_Yaw space. Template Matching verified the pose candidates.



Descriptor

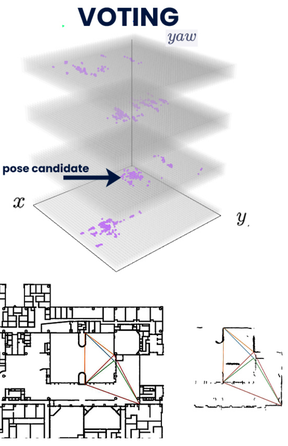


$$d^6 = \begin{bmatrix} \|AB\| \\ \|BC\| \\ \|AC\| \\ \alpha \\ \beta \\ \gamma \end{bmatrix} \quad \|AB\| < \|BC\| < \|AC\|$$

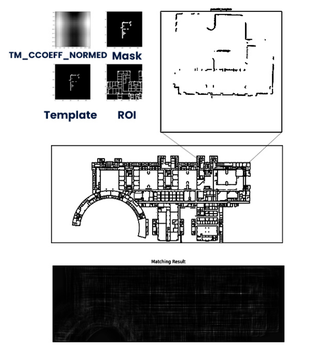
A, B, C are corners, and alpha, beta, gamma are the orientation angles of AB, BC,CA with respect to the nearest wall segments

→ Hash Table

X_Y_YAW SPACE VOTING



Template Matching Verification



$$R(x,y) = \frac{\sum_{x',y'}(T'(x',y')\cdot I'(x+x',y+y'))}{\sqrt{\sum_{x',y'}T'(x',y')^2\cdot\sum_{x',y'}I'(x+x',y+y')^2}}$$

TM_CCOEFF_NORMED

Experiments

Setup

sampling consecutive frames as submaps, the length from the start of the trajectory to the end of the trajectory is $L = 10, 15, 30$ m

Metrics of success:

given the estimated transformation $(\mathbf{R}_{est}, t_{est})$, the registration is classified as successful if

$$\arccos\left(\frac{\mathrm{tr}(\mathbf{R}_{est}^T\mathbf{R}_{gt})-1}{2}\right) < thd_{rot}$$

$$\left\|\mathbf{R}_{est}^T(t_{gt}-t_{est})\right\|_2 < thd_{trans}$$

Data collection platform:

Metacam

Benchmark

Comprehensive evaluation of success rate and time of proposed methods compared with FPFH+TEASER
success rate $\mathbf{success(\%)}$, rotation threshold thd_{rot}, translation threshold thd_{trans}, average time $\mathbf{time}$, Interval L

Metric		Method	sequences						
			building_day	2f_office_01		2f_office_02		2f_office_03	
			L = 10m	L = 15m	L = 30m	L = 15m	L = 30m	L = 15m	L = 30m
success(%)	$\mathrm{thd}_{rot} = 10°, thd_{trans} = 5m$	FPFH + TEASER	0	NA	NA	NA	NA	NA	NA
	$\mathrm{thd}_{rot} = 5°, thd_{trans} = 3m$	FPFH + TEASER	0	NA	NA	NA	NA	NA	NA
	$\mathrm{thd}_{rot} = 3°, thd_{trans} = 1.5m$	FPFH + TEASER	0	NA	NA	NA	NA	NA	NA
	$\mathrm{thd}_{rot} = 10°, thd_{trans} = 5m$	Ours(Top5)	86.11	70.00	100.00	54.55	50.00	31.58	75.00
		Ours(Top1)	83.33	30.00	100.00	45.45	25.00	15.79	50.00
	$\mathrm{thd}_{rot} = 5°, thd_{trans} = 3m$	Ours(Top5)	86.11	70.00	100.00	54.55	50.00	31.58	75.00
		Ours(Top1)	83.33	30.00	100.00	45.45	25.00	15.79	50.00
	$\mathrm{thd}_{rot} = 3°, thd_{trans} = 1.5m$	Ours(Top5)	72.22	70.00	100.00	54.55	50.00	31.58	75.00
		Ours(Top1)	72.22	30.00	100.00	45.45	25.00	15.79	50.00
time(s)		FPFH + TEASER	80.49	46.55	60.98	47.71	65.84	47.44	75.37
		Ours(Top5)	8.87	39.27	314.4	66.66	61.15	9.92	86.20
		Ours(Top1)	7.99	40.86	317.9	68.61	61.50	9.53	83.73

Qualitative registration results

Different Lidar Submaps registered to the BIM.