Optimizing Fiducial Marker Placement for Improved Visual Localization

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Github page

Problem Statement

Fiducial markers improve localization and mapping

- But selecting marker positions require human intervention and
- we don't know the optimal positions for improved localization

Challenges in visual localization

- Repetitive structures
- Textureles areas

We pursue optimal marker positions for visual localization

- given a 3D model of a scene and a set of fiducial markers.
- The algorithm is also promising for improved tracking

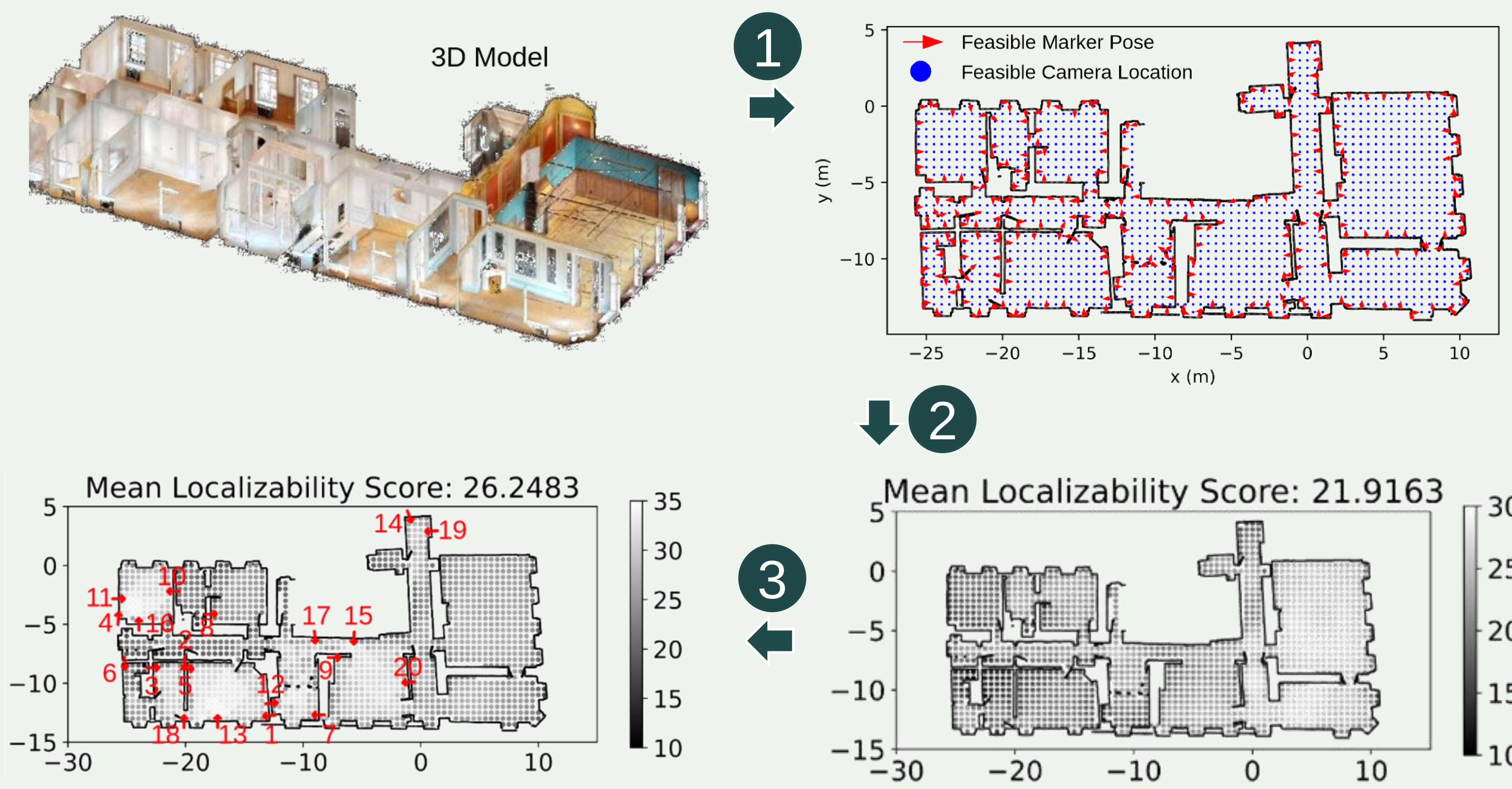
Optimized marker placement

Optimized Marker Placement

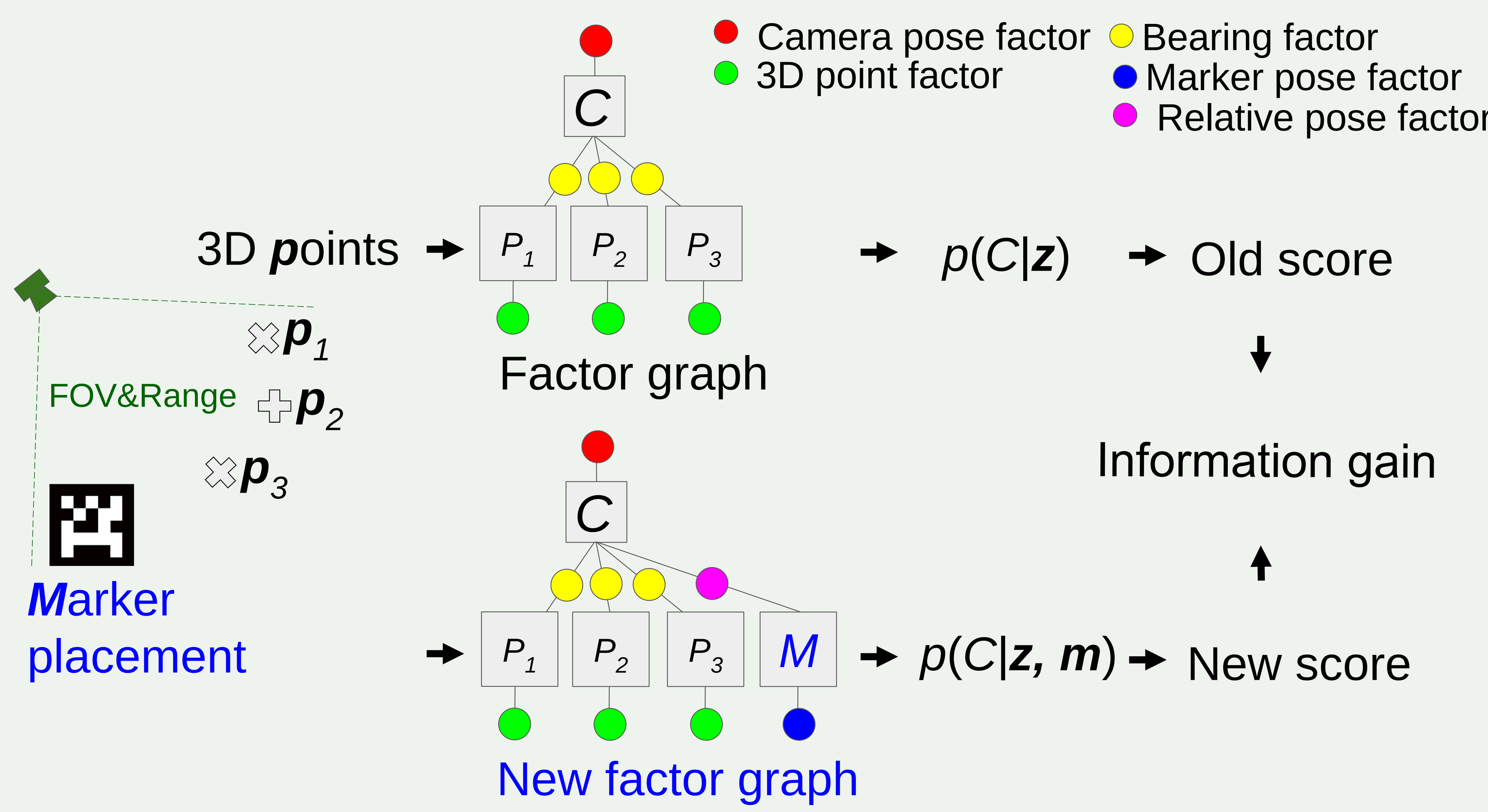
Assumptions: 3D model and plane at the eye level

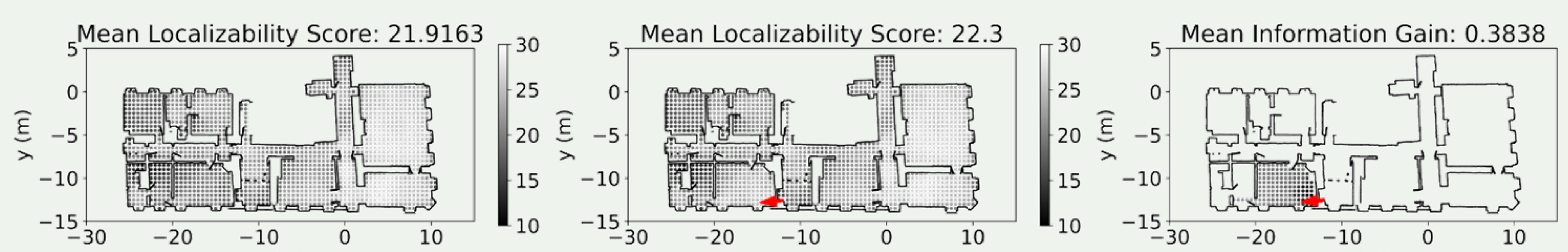
Three key elements:

- 1. Discretization via occupancy grid mapping.
- 2. Camera localizability score $l(\mathbf{c}) = -H(p(C|\mathbf{z})) = \mathbb{E}[\ln p(C|\mathbf{z})]$
- 3. Greedy algorithm that seeks one marker placement each time



Camera localizability score and information gain

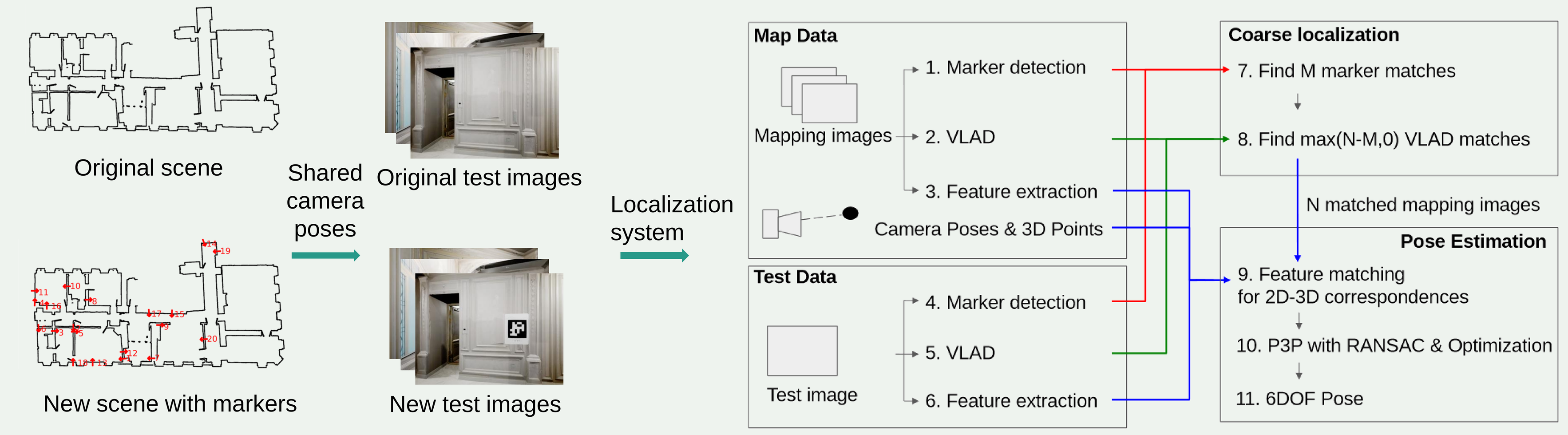




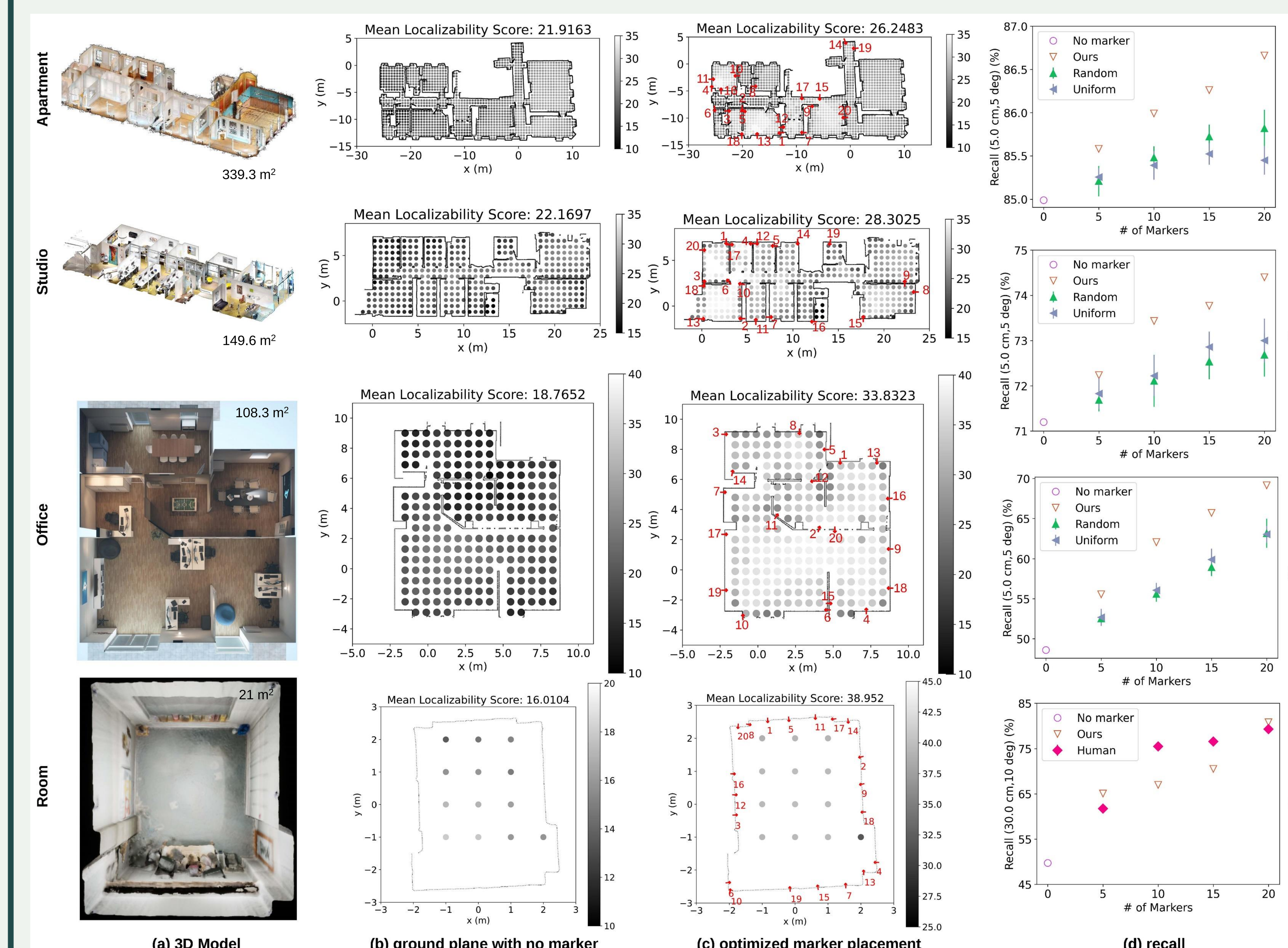
Localizability scores before adding a marker | Localizability scores after adding a marker | Difference between the scores

Results

Experimental Setup



Improving localization rate by up to 20 percent on four different scenes



(a) 3D Model (b) ground plane with no marker (c) optimized marker placement (d) recall

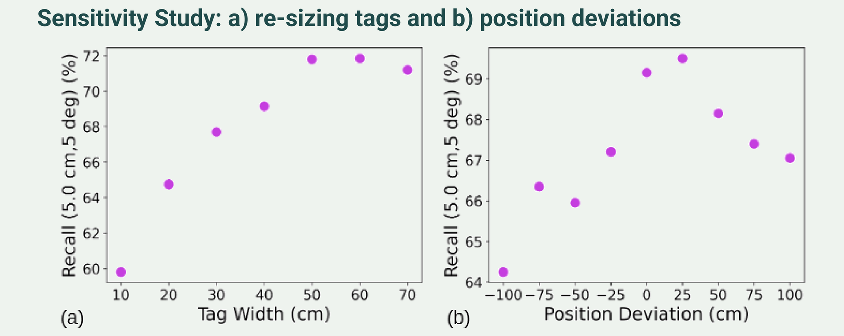
Parameter study about the hyperparameter *v*, the test data enabling/disabling marker detection, and enabling/disabling the similarity analysis.

Experiment group	Recall of test images with k markers (%)				
	$k=0$	5	10	15	20
$v = 90$ (df.)	**48.6**	**55.5**	**62.1**	**65.7**	**69.2**
$v = 99$	48.6	55.5	60.4	64.5	67.4
$v = 70$	48.6	54.8	61.1	63.2	66.6
$v = 50$	48.6	54.3	57.6	63.9	66.8
Marker detect. on (df.)	**48.6**	**55.5**	**62.1**	**65.7**	**69.2**
Marker detect. off	48.6	55.2	60.7	64.2	67.5
Low-scoring data (df.)	48.6	55.5	62.1	65.7	69.2
Unif. test data	**57.4**	**63.7**	**68.4**	**72.1**	**74.8**
Similarity analysis (df.)	**48.6**	**55.5**	**62.1**	**65.7**	**69.2**
Sim. analysis disabled	48.6	55.4	61.8	65.0	67.8

Specifics of scenes

Model	Area (m^2)	# of map images	# of test images
Apartment	339.3	10856	10000
Studio	149.6	2832	3000
Office	108.3	1768	2000
Room	21.0	250	200

Sensitivity Study: a) re-sizing tags and b) position deviations



Key Findings:

- Too large or small values of hyperparameter *v* incur lower improvements of the recall.
- The localizability score can be a good indicator of localization errors.
- Both the visual appearance and decoded label of markers are helpful for localization.
- Deactivating the analysis of feature similarity decreases the recall.

Reference:

S. K. Ramakrishnan et al., "Habitat-matterport 3D dataset (HM3D): 1000 large scale 3D environments for embodied AI," in Proc. Conf. Neural Inform. Process. Syst. Dataset. Benchmark. Track (Round 2), 2021.