Optimizing Fiducial Marker Placement for Improved Visual Localization

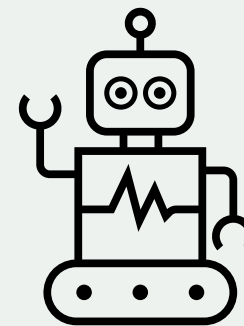Qiangqiang Huang[1], Joseph DeGol[2], Victor Fragoso[2], Sudipta Sinha[2], John Leonard[1]
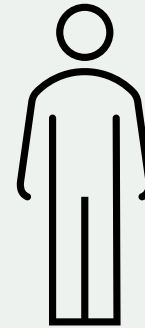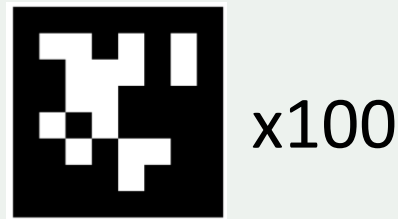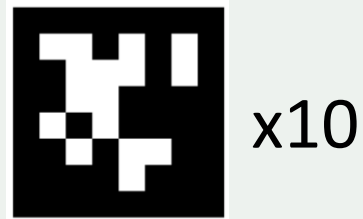
[1]MIT, [2]Microsoft

This work was transferred from IEEE RA-L.

Background

- Automatic marker placement
    - No human intervention
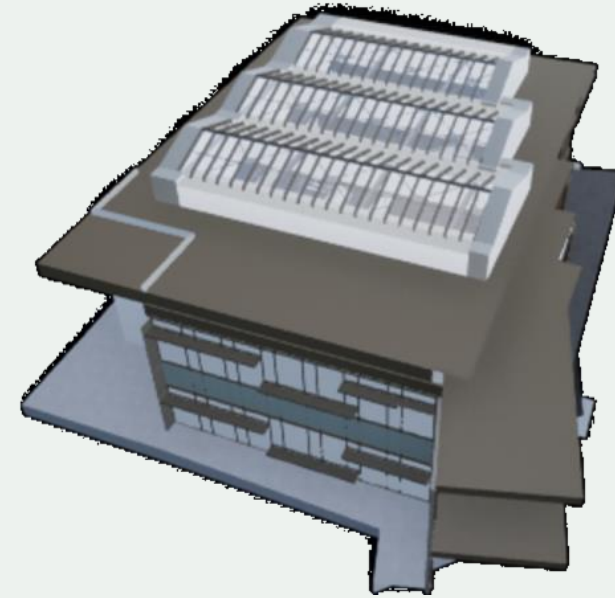   - Scalable selection of marker positions

x10

x100

Background

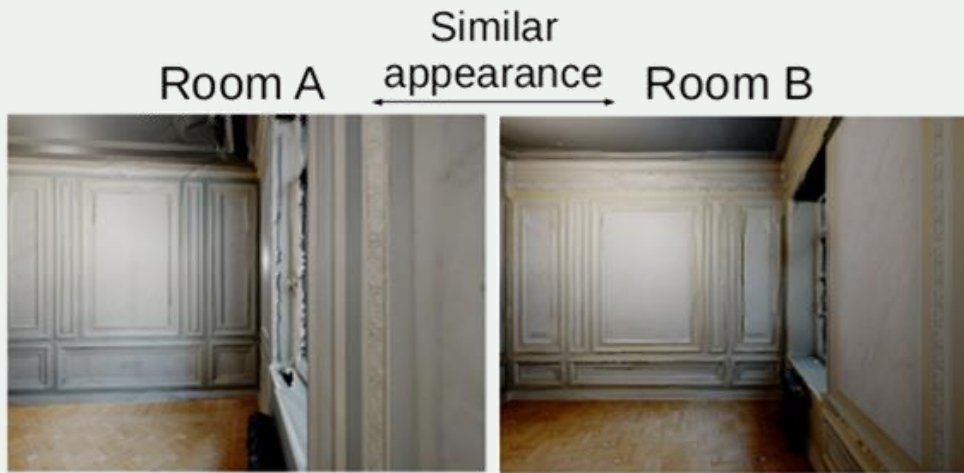- Visual localization

Image
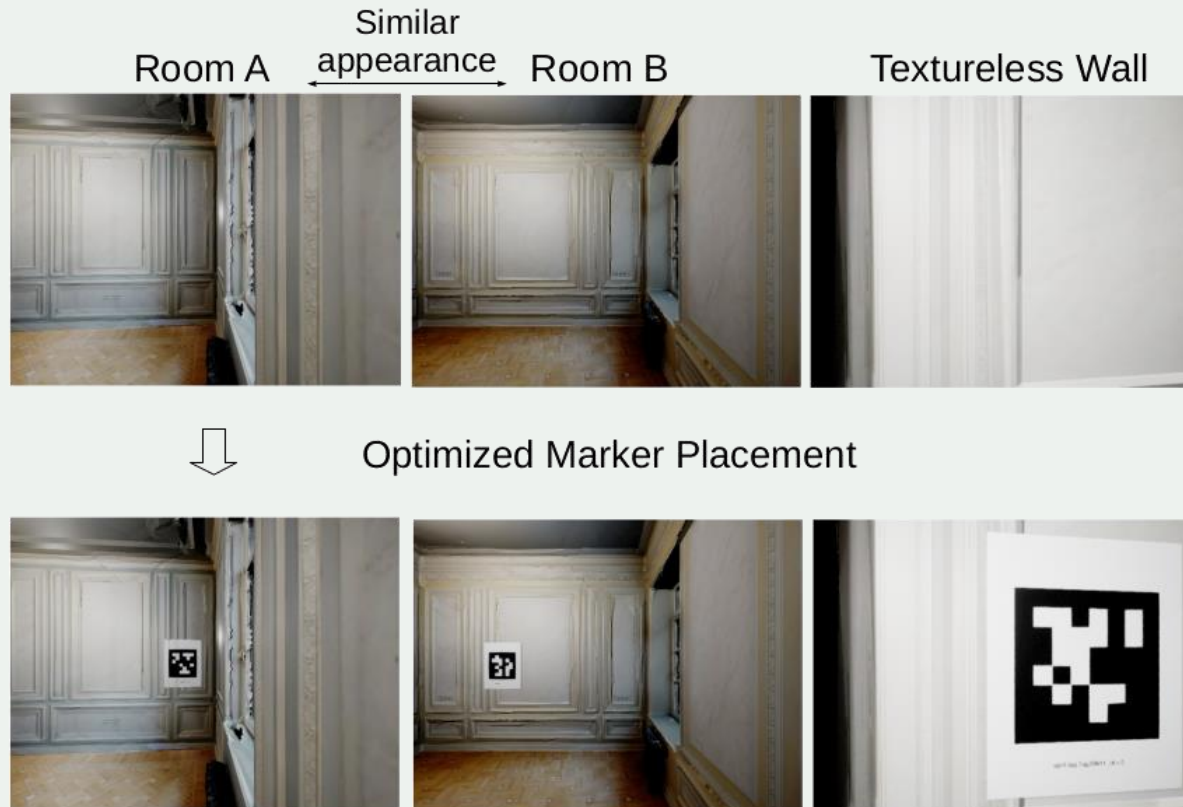
Query

Localization

Camera pose

3D model

Background

- Challenges

Similar appearance

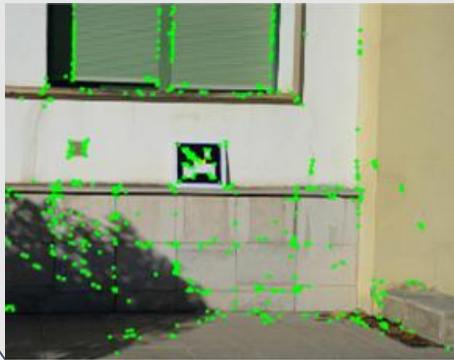Room A ← → Room B

Textureless Wall

Problem Statement

- Fiducial marker positions for improved localization accuracy?

Related Work

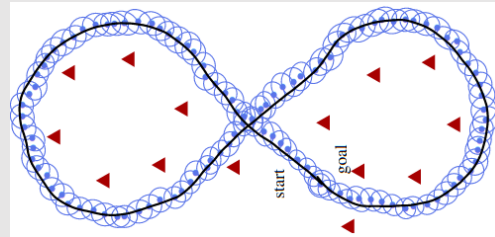**Visual SLAM**
Salinas et. al. (2020) [1]
- Features + Markers
- **No planning**

Robotic Navigation
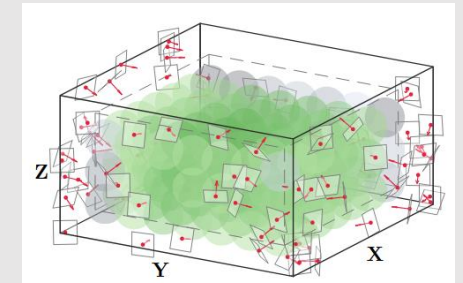Beinhofer et. al. (2013) [2]
- **Fixed trajectories**
- **2D Landmarks**

Marker placement planning
Meyer-Delius et. al. (2011) [3]
- Robot localization
- **Laser scanner**

Marker placement planning
Lei et. al. (2022) [4]
- Visual localization
- **No scene feature**
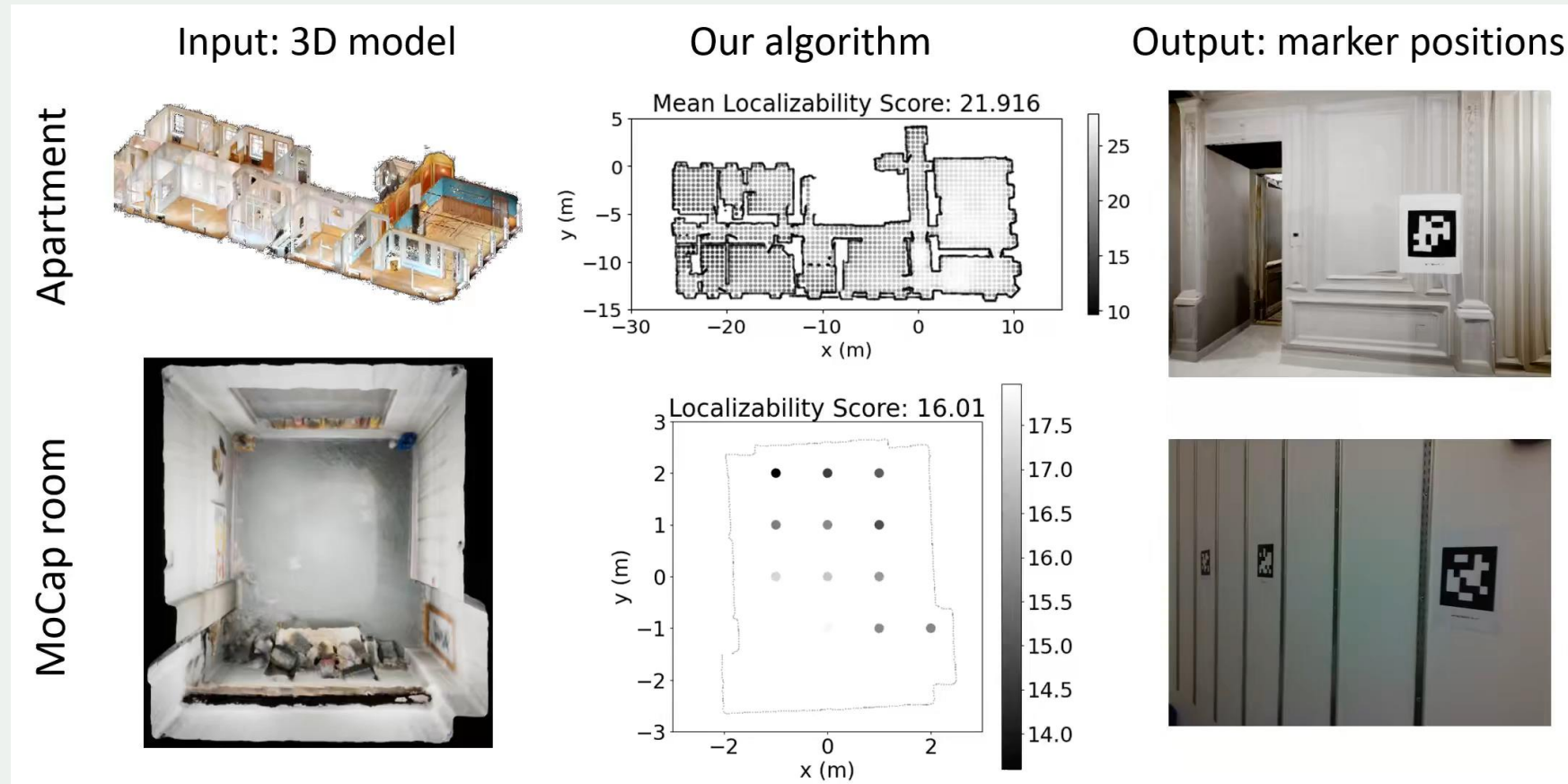- **Simple Box Space**

- We consider both natural scene features and fiducial markers when optimizing marker positions for improved visual localization.
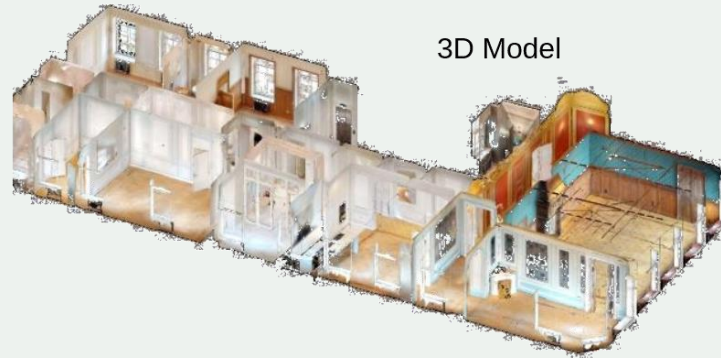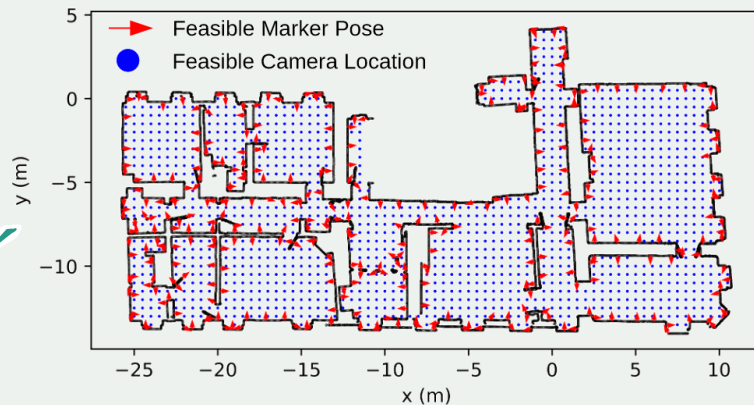
Our Approach

- Teaser video

Input: 3D model | Our algorithm | Output: marker positions

Apartment — Mean Localizability Score: 21.916
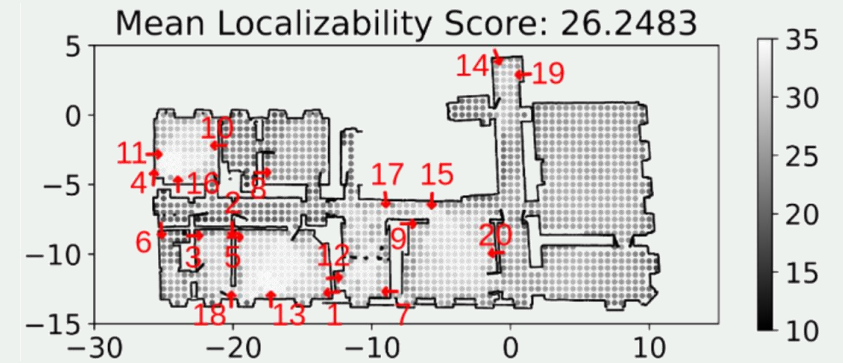
MoCap room — Localizability Score: 16.01

Our Approach

- Key elements

3D Model

Occupancy grid mapping

Camera localizability

Greedy algorithm
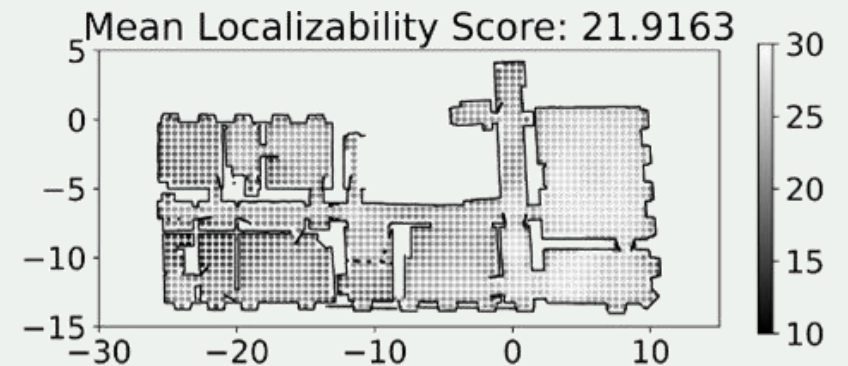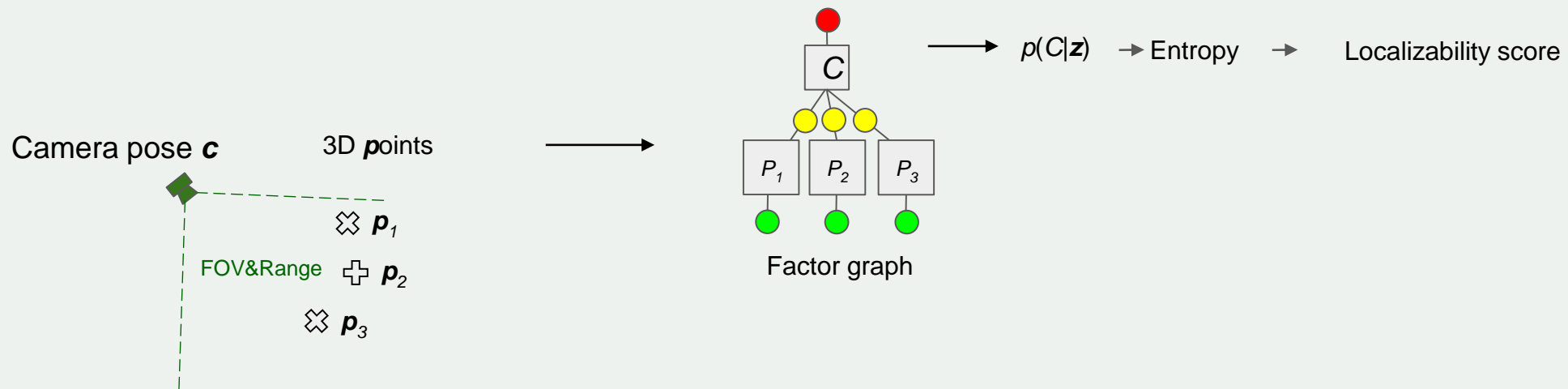
Mean Localizability Score: 26.2483

Mean Localizability Score: 21.9163

Feasible Marker Pose
Feasible Camera Location

Our Approach

- Camera localizability score

Camera pose c 3D $p$oints   → $p(C|z)$ → Entropy → Localizability score

p_1
FOV&Range p_2
p_3

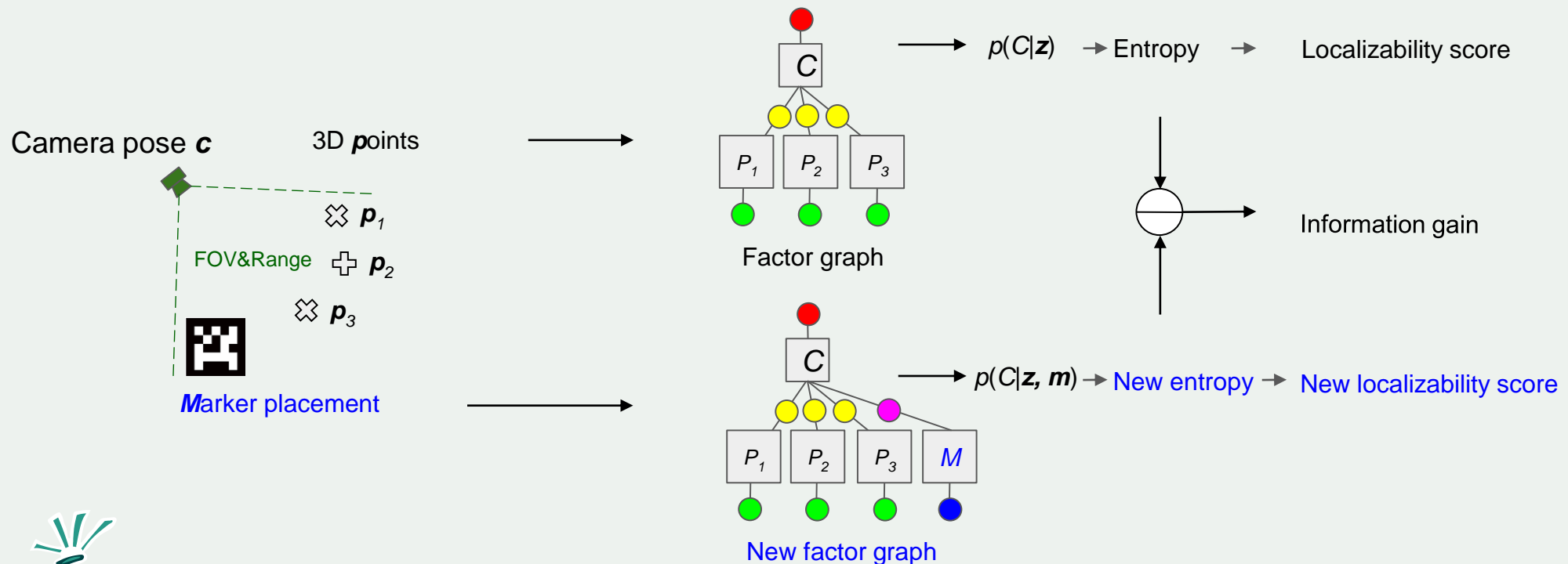Factor graph

● Camera pose factor   ● 3D point factor   ● Bearing factor   ● Marker pose factor   ● Relative pose factor

Our Approach

- Camera localizability score

Camera pose c 3D $p$oints

$p(C|z)$ → Entropy → Localizability score

Factor graph

FOV&Range p_1 p_2 p_3

Marker placement

$p(C|z, m)$ → New entropy → New localizability score

New factor graph

Information gain
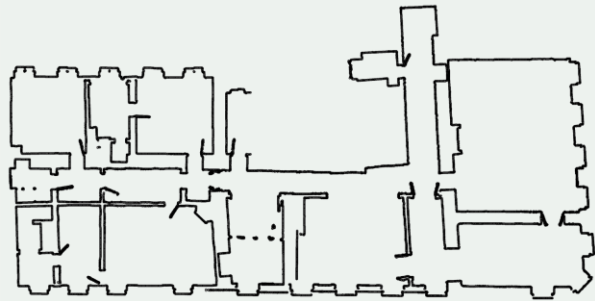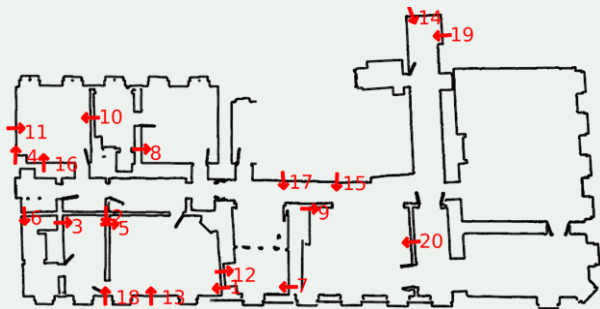
● Camera pose factor ● 3D point factor ● Bearing factor ● Marker pose factor ● Relative pose factor
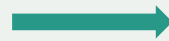
Experimental Setup

Original scene no marker

New scene with markers

Shared camera poses

Original test images
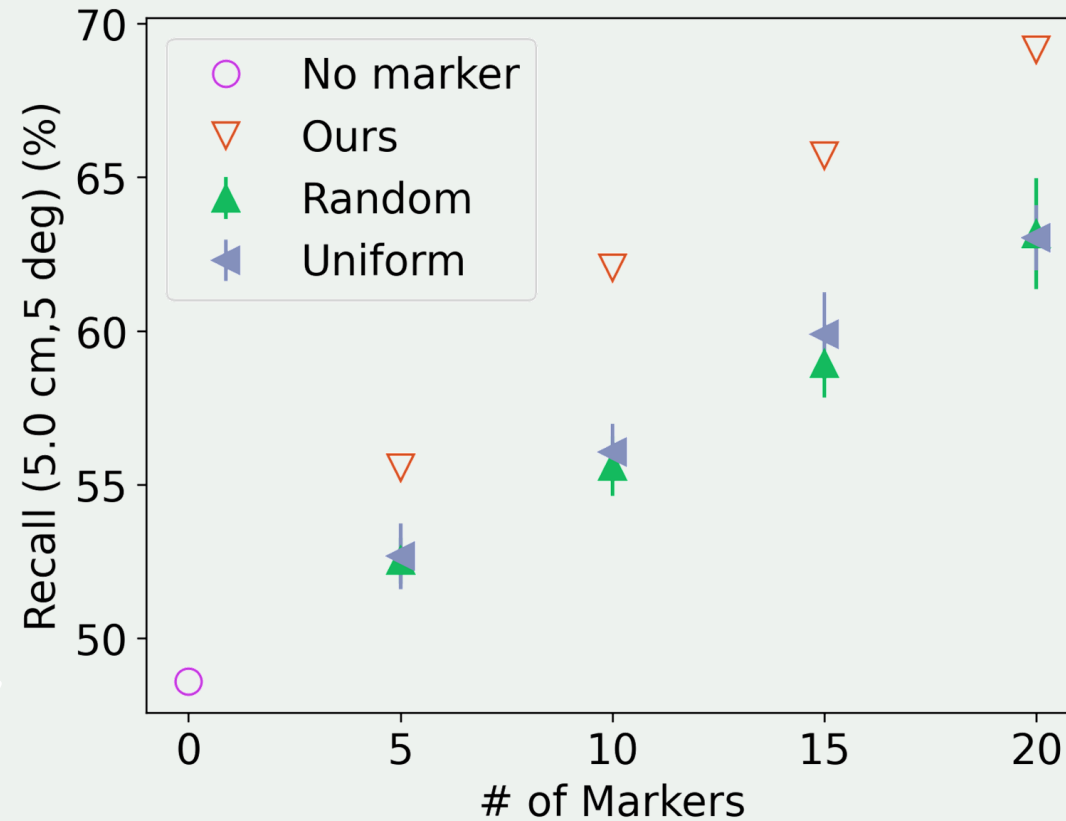
New test images

Localization systems

Original pose estimation

New pose estimation

Results

- 20 percent improvement in the localization rate of test images

Results

- Read our paper for results in more scenes.
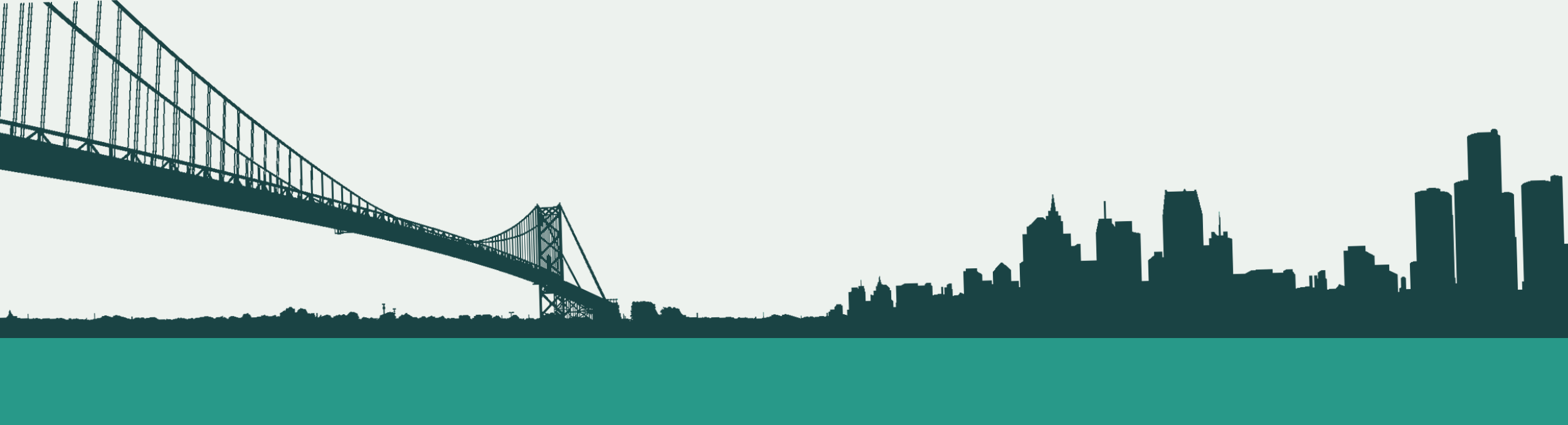

Apartment

Studio

Office

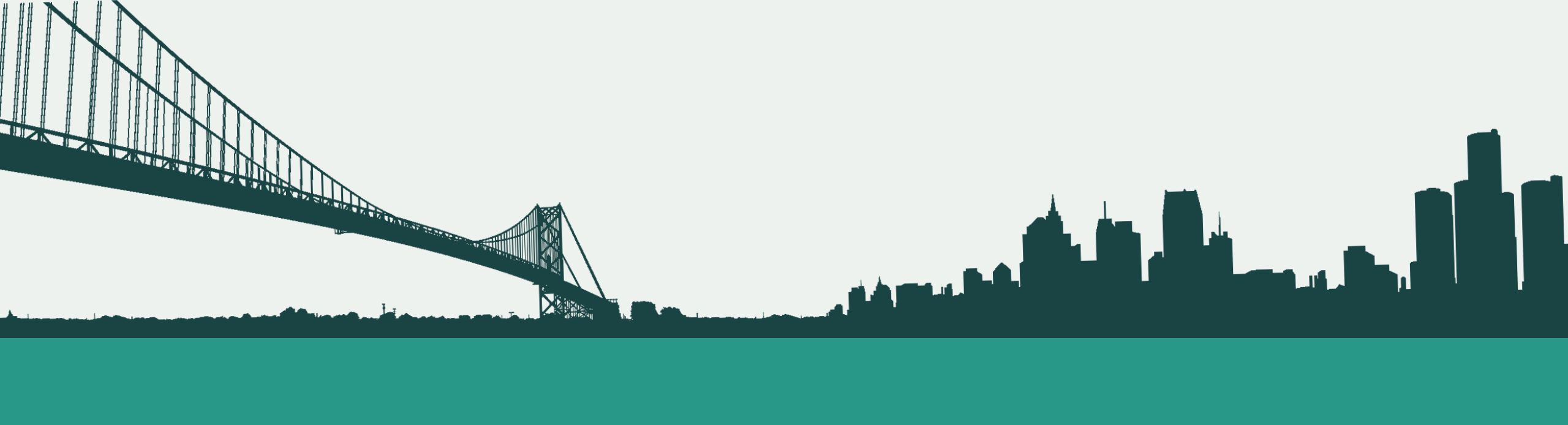MoCap room

Conclusions & Future Work

- Conclusions
  - Improving localization rates by up to 20 percent on a variety of scenes.
  - Proposing camera localizability score to identify challenge areas in a scene for visual localization.

- Future Work
  - Computing more accurate localizability scores.
  - Exploring more efficient optimization methods beyond the greedy algorithm.

Acknowledgments

Thank you.