Adaptive Visual Perception for Robotic Construction Process: A Multi-Robot Coordination Framework

XIC Lab

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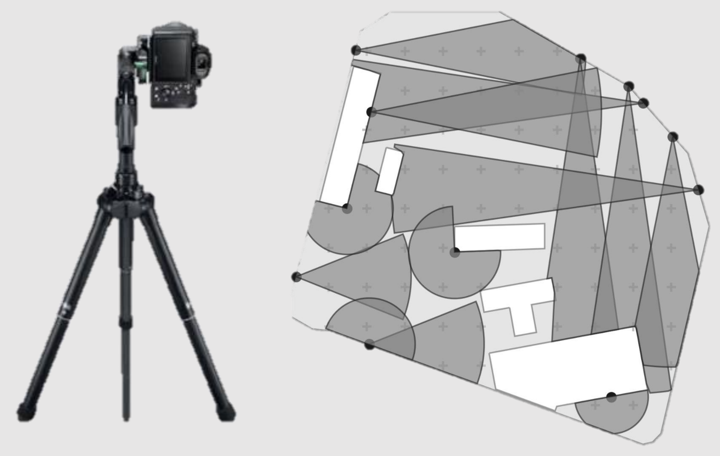
Video

BACKGROUND & MOTIVATION

Limitations of available visual feedback for construction robots

Camera in hand

Occlusion caused by large construction elements under handling



Environmental cameras

Large amount needed for covering large task space

Occlusion caused by the evolving construction site and the construction robot itself

RESEARCH QUESTIONS

How can we effectively provide visual feedback for a construction robot that

- adapts to large task spaces?
- adapts to the upcoming construction robot motion?
- ensures high-quality data capture?

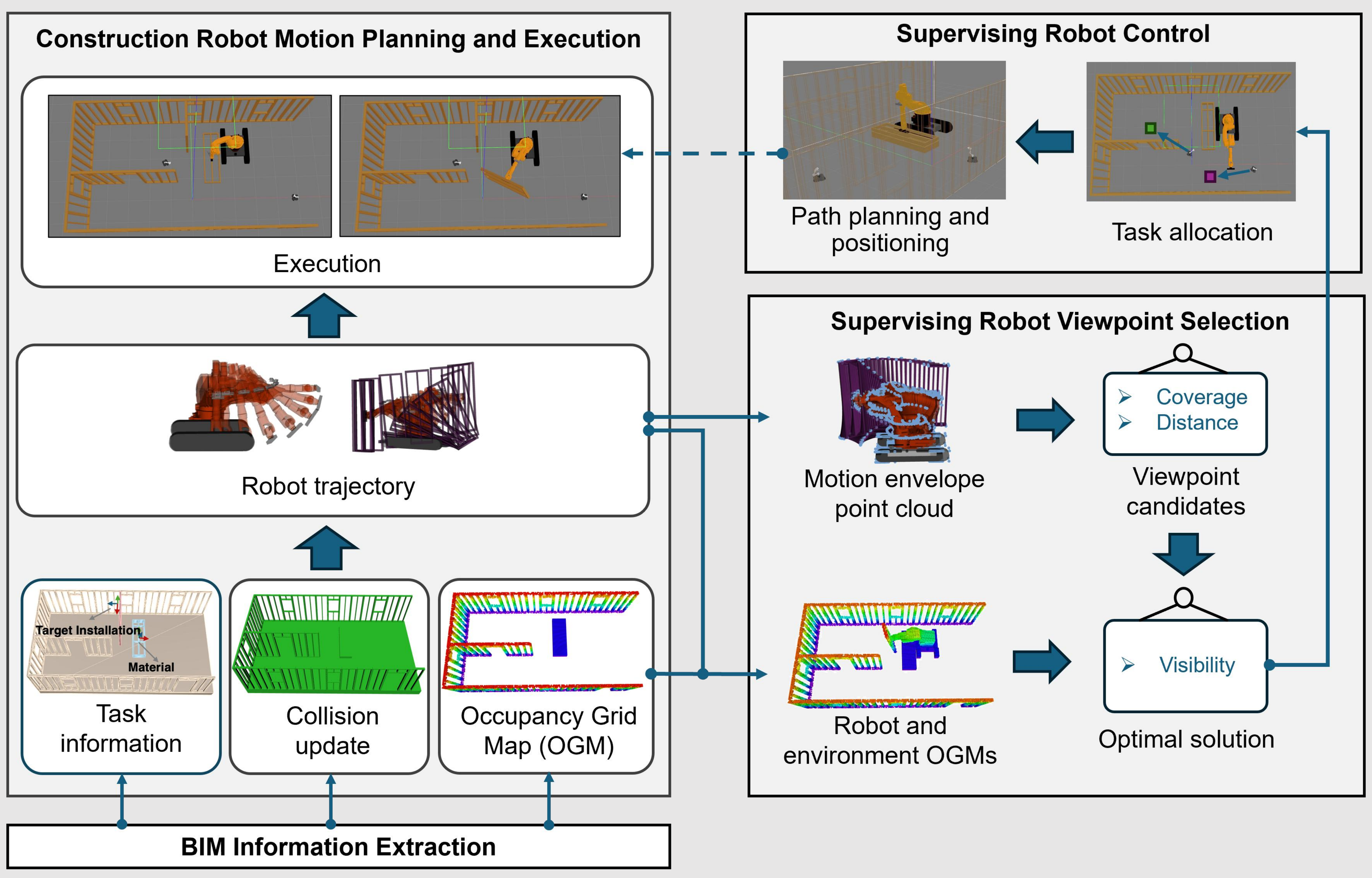
RESEARCH OBJECTIVES

1. A **multi-robot coordination framework** that coordinates supervising robots with the construction robot to achieve adaptive visual perception for upcoming robotic construction processes

2. An **adaptive viewpoint selection method** for supervising robots that adapt to:

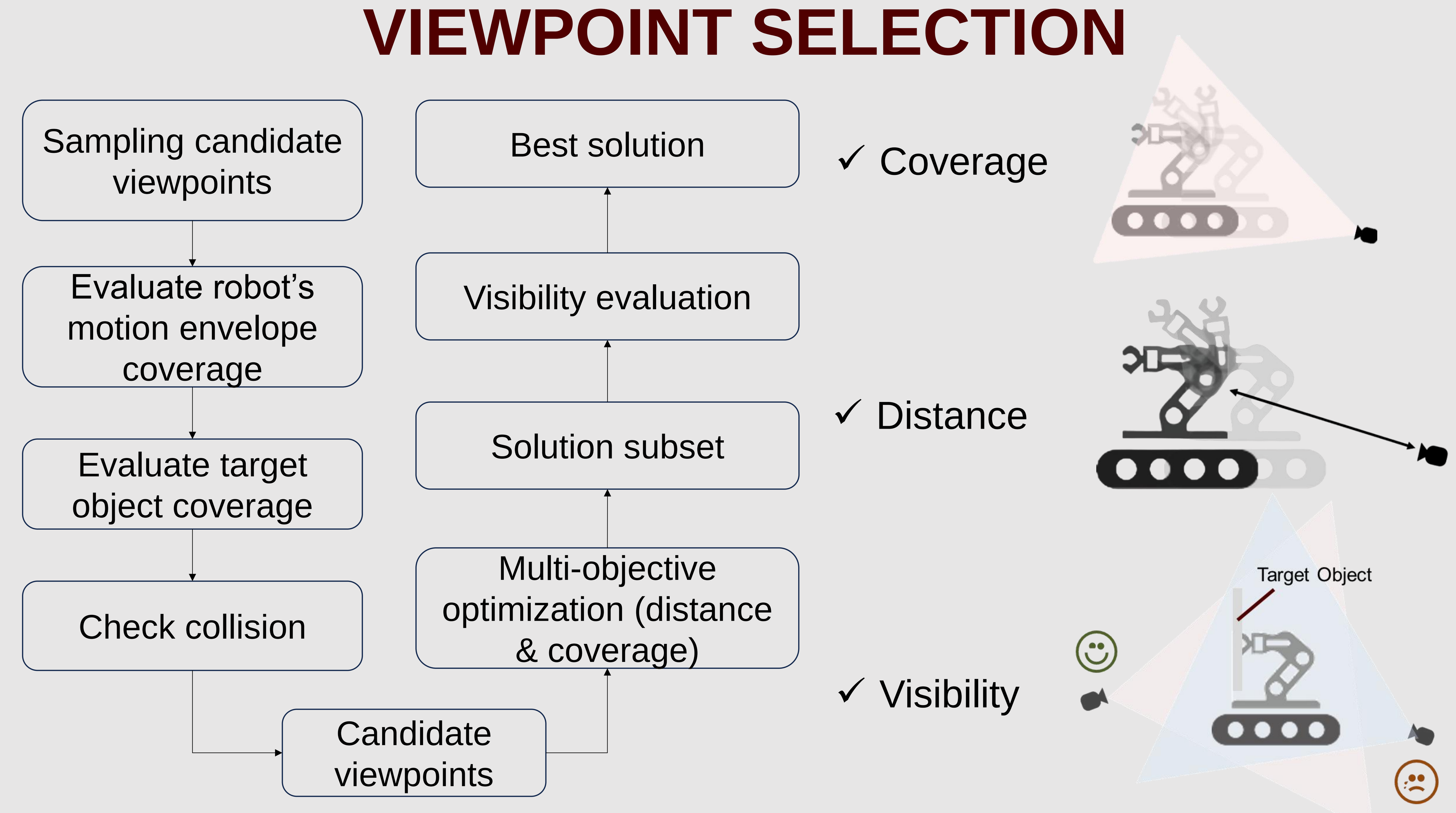
- large task spaces
- upcoming movements of the construction robot
- different objects of interest

MULTI-ROBOT COLLABORATION FRAMEWORK

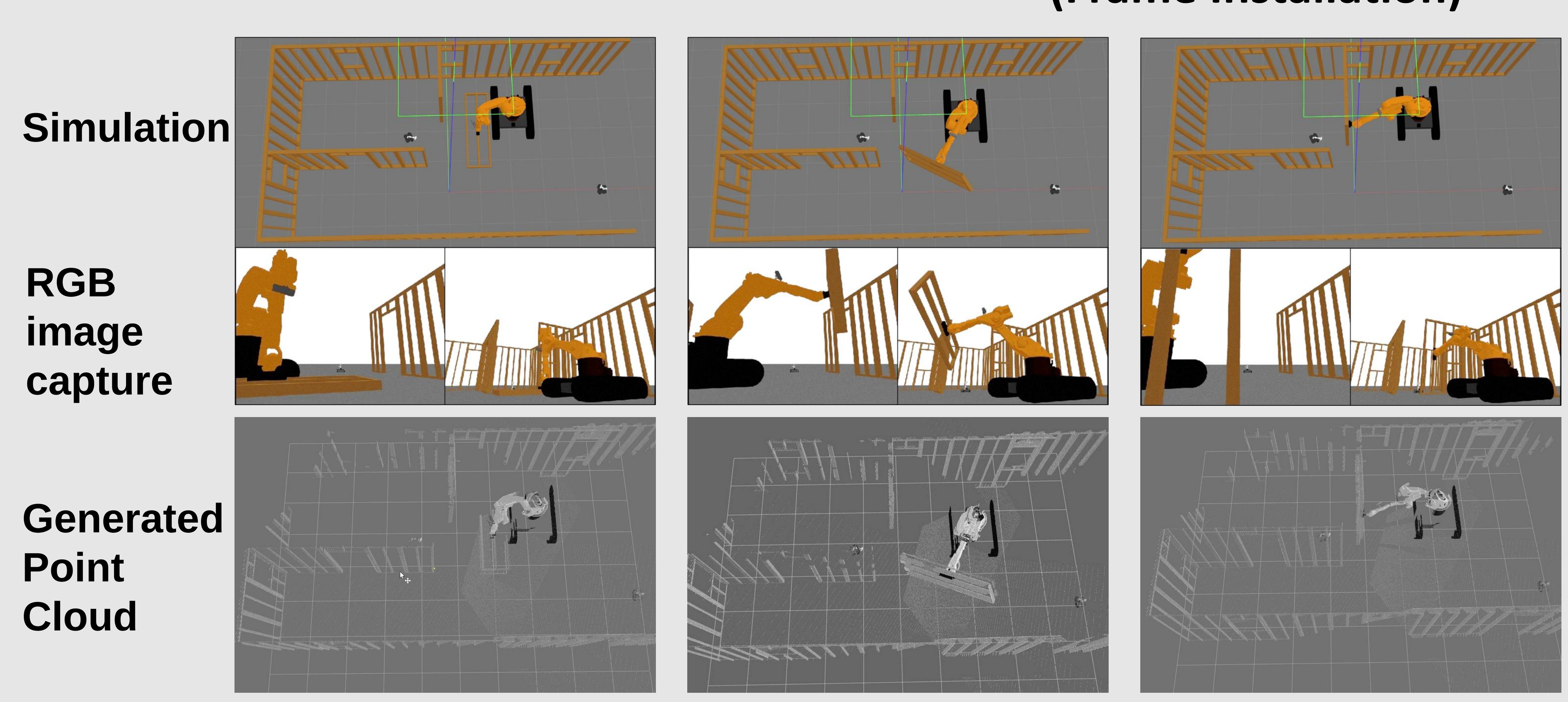


- Next motion plan of construction robot is generated based on extracted BIM data
- Viewpoints for supervising robots are selected based on the motion plan.
- Supervising robots adjust cameras to assigned viewpoints
- Construction robot executes the planned motion

VIEWPOINT SELECTION



CASE STUDY (Frame Installation)



EXPERIMENT VALIDATION

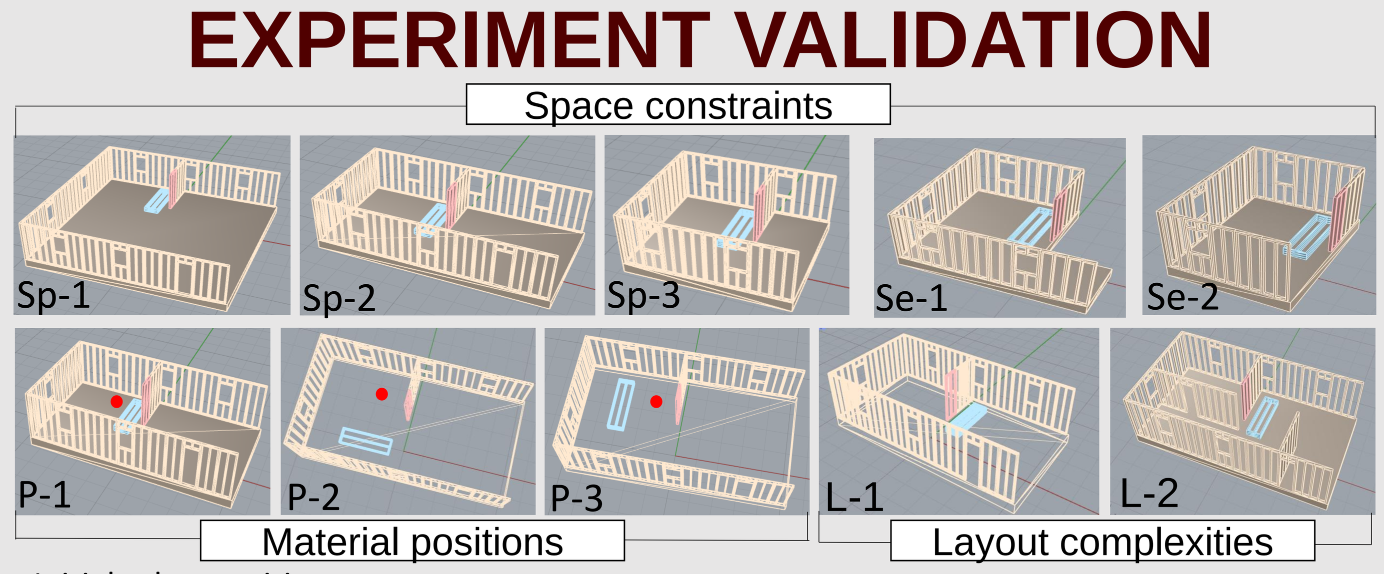


Table 2: Experiment results

Scenario	Pick			Place					
	$C(V)$	$d(G(s), v_1)$	$d(G(s), v_2)$	$C(V)$	$d(G(s), v_1)$	$d(G(s), v_2)$	$d(\text{obj}, v_1)$	$d(\text{obj}, v_2)$	$AvgVis(V)$
Sp-1	1.00	1.99	2.37	1.00	3.34	3.61	2.68	2.72	0.86
Sp-2	1.00	1.69	2.45	1.00	3.20	3.53	2.75	3.26	0.73
Sp-3	1.00	1.92	2.46	0.998	3.29	4.12	2.66	3.47	0.91
Se-1	1.00	2.07	2.51	0.986	2.23	3.28	2.46	2.99	0.80
Se-2	1.00	1.75	2.57	0.995	2.82	3.11	3.73	4.23	0.76
P-1	1.00	1.69	2.45	1.00	3.20	3.53	2.75	3.26	0.73
P-2	1.00	2.02	2.51	1.00	3.15	3.35	3.39	3.38	0.72
P-3	1.00	1.79	2.41	1.00	2.59	3.32	2.59	3.46	0.74
L-1	1.00	2.28	2.09	1.00	2.79	3.32	2.11	2.70	0.86
L-2	1.00	2.08	2.17	0.996	2.78	3.57	2.31	2.72	0.81

- Picking Trajectories: Achieved full coverage ($C(V) = 1.00$) with distance $d(G(s), v) \leq 2.51m$ of all conditions.
- Placing Trajectories: Maintained high coverage ($C(V) \in [0.986, 1.00]$) and target object visibility ($AvgVis(V) \in [0.72, 0.91]$).
- Consistent performance across scenarios demonstrates the robustness of the proposed method.

CONCLUSION

- **Framework:** Supervising robots support the construction robot by capturing task-relevant visual data
- **Viewpoint Selection:** Optimizes poses for coverage, proximity, and visibility
- **Two-Step Method:**
  - ✓ Step 1: NSGA-II selects candidate viewpoints based on coverage and proximity
  - ✓ Step 2: Chooses the best viewpoint based on visibility from the candidates
- **Validation:** Demonstrated through case study and simulation under various constraints

REFERENCE

Xu, J., Dixit, M., & Wang, X. (2024). Adaptive Visual Perception for Robotic Construction Process: A Multi-Robot Coordination Framework. *arXiv preprint arXiv:2412.11275.*