Planning Non-repetitive Robotic Assembly Processes with Task and Motion Planning

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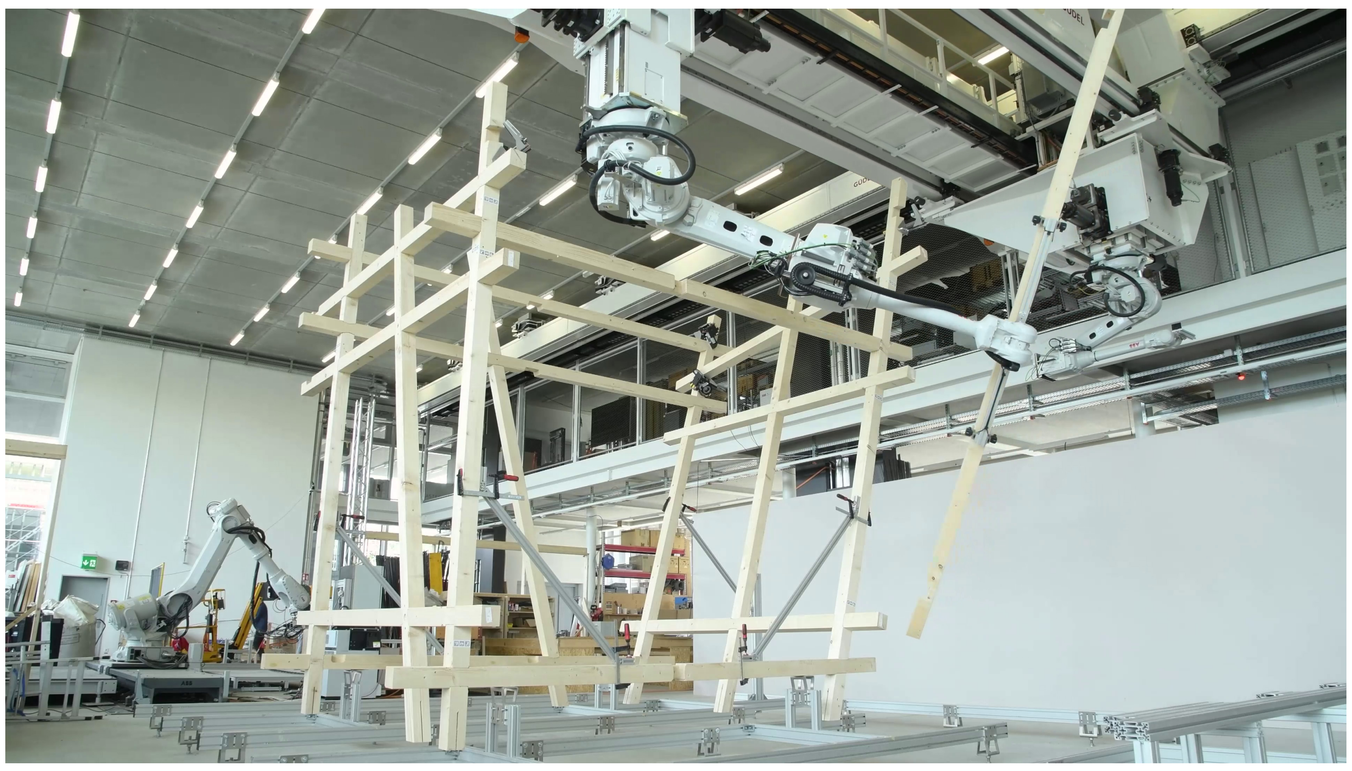


Introduction

Task And Motion Planning (TAMP) methods promise to simplify robot programming efforts in architectural construction by automatically generating optimized actions from high-level goals and action descriptions. However, due to the domain knowledge gap, converting construction intention to TAMP solver remains challenging [1,2,3].

In this work, we show:

- **an incremental programming approach to encode a construction assembly process for PDDLStream [4], a TAMP solver**
- **automatic generation of action plans with significant execution time reduction without manual programming efforts**
- **real-world deployment for assembling a real-scale timber structure**

These results show that through TAMP, we can achieve **modular and reusable domain modeling and planning** that can be easily extended to address new fabrication processes and associated constraints.

Programming repetitive behaviors by teaching. Ready Robotics

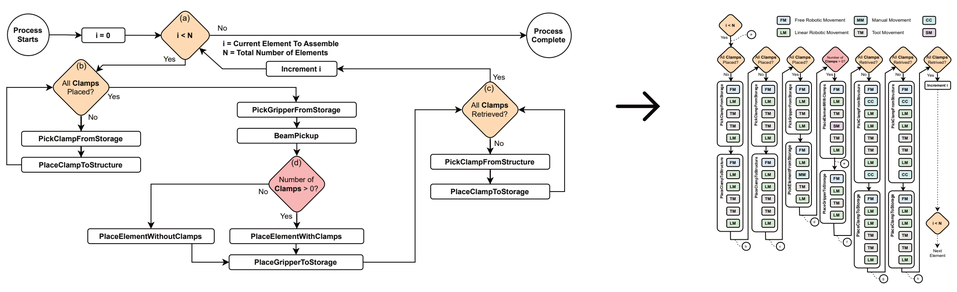
The Endless Wall, GKR 2011

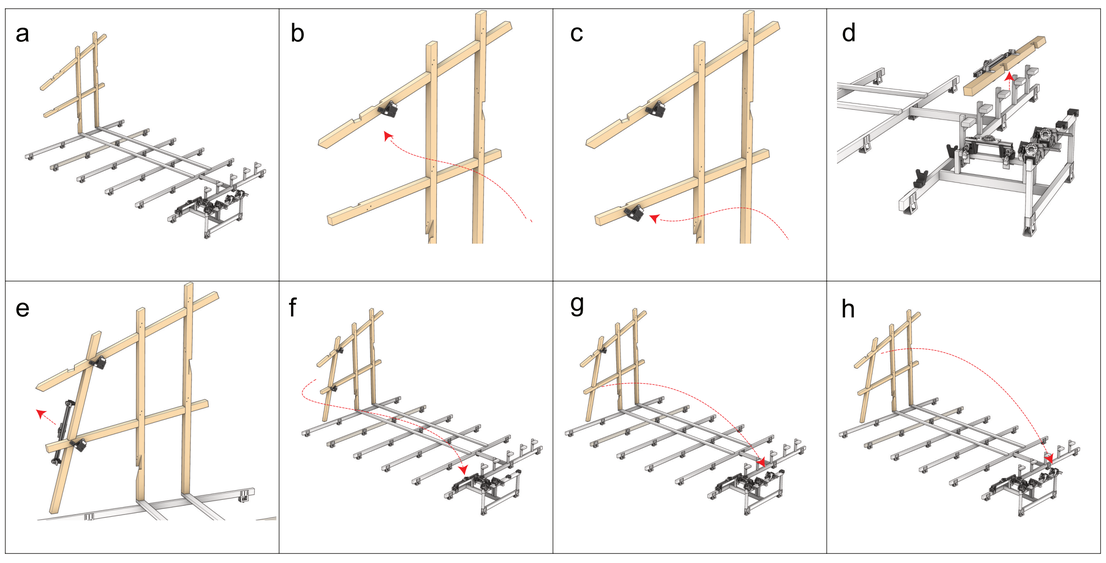
Parascho et al. 2017 [5]

Eversmann et al. 2017 [6]

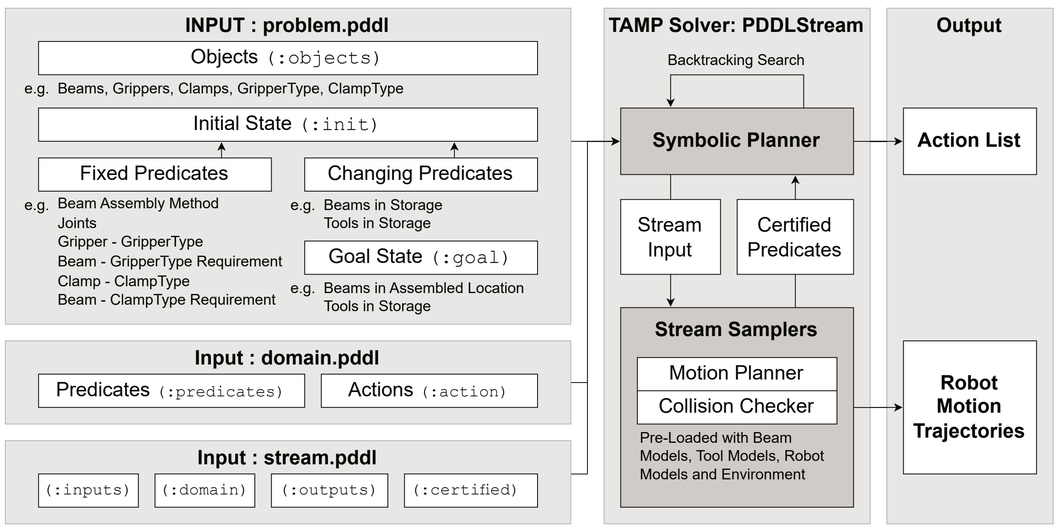
Mass Production	Mass Customization and State of the Art	This paper
Repetitive Action Template (Loop)	→ Selecting Templates with Conditional Statements	→ Plan Skeleton generated by Actions and Goal
Repetitive Geometry	→ Non-Repetitive Geometry	

Previous approach





Technical Approach



Case Study

Results

a. Flowchart composer (repeated for each beam)

Phase 1 : Attach Clamp Actions (repeated for each required clamp)
- ReC — Retrieve Clamp from Storage
- AtC — Attach Clamp to Structure

Phase 2 : Clamping Actions
- AsC — Assemble Beam with Clamps

Phase 3 : Detach Clamp Actions (repeated for each required clamp)
- DeC — Detach Clamp from Structure
- StC — Store Clamp back to Storage

b. Action List by Flowchart (for two beams)

c. More optimized List of Actions

Beam	b. Action List by Flowchart	c. More optimized List of Actions
Beam 1	ReC C1	ReC C1
	AtC C1 , J1-1	AtC C1 , J1-1
	ReC C2	ReC C2
	AtC C2 , J1-2	AtC C2 , J1-2
	AsC B1, C1, C2	AsC B1, C1, C2
	DeC C1 , J1-1	DeC C1 , J1-1
	StC C1	AtC C1 , J2-1
	DeC C2 , J1-2	DeC C2 , J1-2
	StC C2	AtC C2 , J2-2
Beam 2	ReC C1	AsC B2, C1, C2
	AtC C1 , J2-1	DeC C1 , J2-1
	ReC C2	StC C1
	AtC C2 , J2-2	DeC C2 , J2-2
	AsC B2, C1, C2	StC C2
	DeC C1 , J2-1	
	StC C1	
	DeC C2 , J2-2	
	StC C2	

Example Case - Two Beams

	Required Clamp at Joints	
Beam B1 :	C1 , J1-1	C2 , J1-2
Beam B2 :	C1 , J2-1	C2 , J2-2

- C1 and C2 represent two clamps
- J1-1 and J1-2 represents Joints on Beam B1 , J2-1 and J2-2 represents Joints on Beam B2

	Planning methods	TAMP (This work)	Flowchart [1]
Execution Time for Actions (min)	Assemble Actions	558	558
	Gripper Actions	314	330
	Clamp Actions	574	839
	Total	**1446 (-16.3%)**	1727

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