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Design of A Multi-Robot Cooperative 3D Printing System
CIE 2018 Graduate Research Poster

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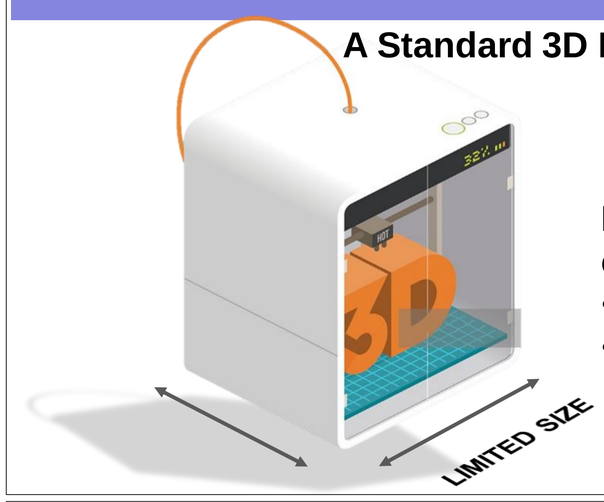
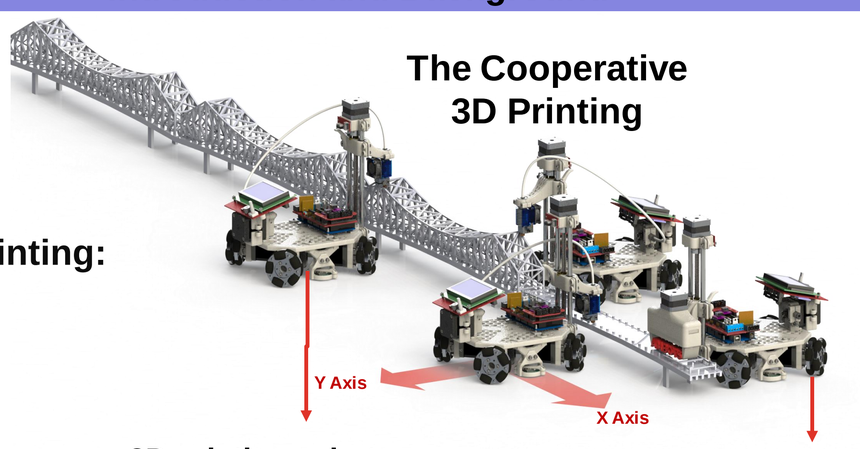
Introduction and Background

A Standard 3D Printer



Limitations of conventional 3D Printing:
- Lack of scalability
- Longer makespan

The Cooperative 3D Printing



Cooperative 3D Printing is a novel concept that integrates multi-robot system with 3D printing. It envisions large number of 3D printing robots along with assembly robots, working together to complete a print job. Cooperative 3D Printing mitigates the prominent issues of conventional 3D printing system without compromising the quality of the part.

Flow of Cooperative 3D Printing

Importing STL File
- Print dimension
- Number of robots (if limited)
- Print material

→ **Chunking**
- Sloped Surface
- Coordinated striping
- Alternating striping
- Divide and conquer

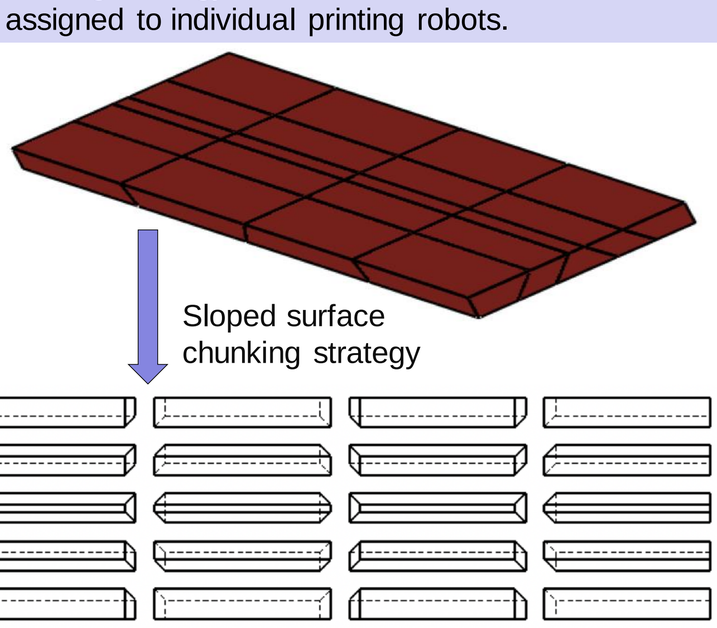
→ **Scheduling**
- SPAR3 strategy
- Chunk dependencies
- Geometric constraints
- Total print time

Research Questions

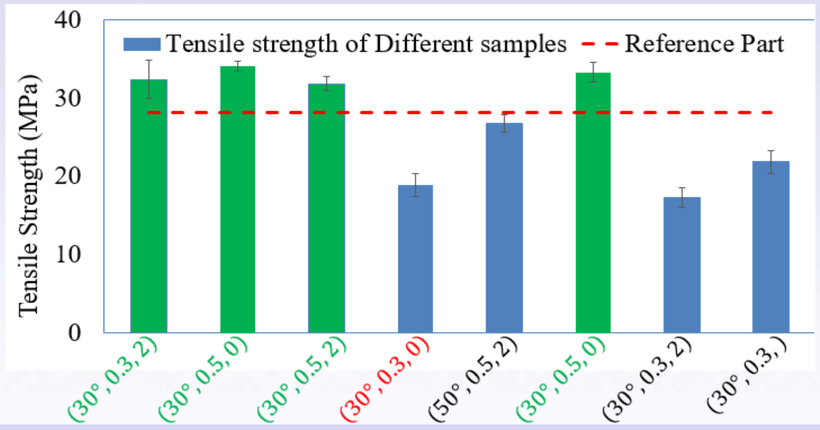
- **RQ1**: What is the mechanical strength of chunk-based printed part compared to that of conventional 3D printed part?
- **RQ2**: What are the geometric constraints that must to be satisfied in order to enable the cooperative 3D printing?
- **RQ3**: What are the potential working print strategies of realizing the cooperative 3D printing?

Chunking Strategy

Chunking is dividing a part into smaller portions using a chunking strategy such that each of the chunks can be assigned to individual printing robots.



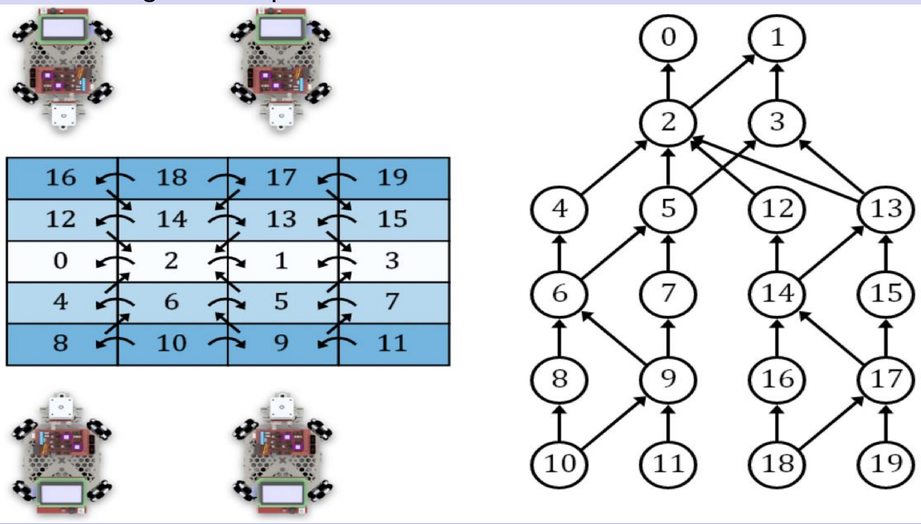
Mechanical Strength of Chunk-based Parts



Conclusion: If proper combination of chunk-based parameters (*slope angle, chunk overlapping, and number of shells*) are chosen, the mechanical strength of chunk-based part can be as strong (if not stronger) than that of standard 3D printed part.

Scheduling Strategy

Scheduling is process of creating print sequence once the chunking is complete. After the chunks are created, they are assigned to individual robots and Directed Dependency Tree (DDT) is used to generate print schedule.



Constraints Development

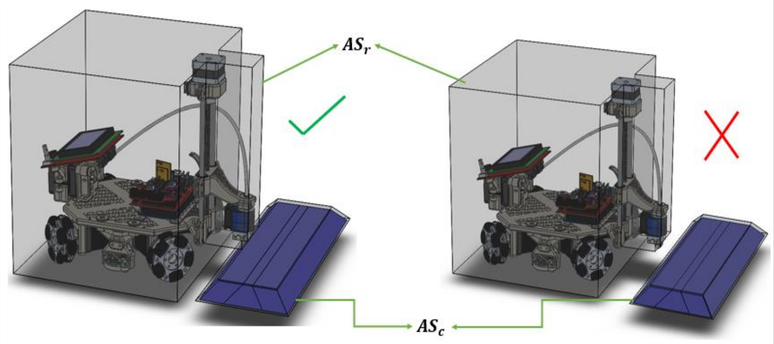
It needs to be ensured that generated schedule results in collision free print. In order to do so, geometric constraints are identified:

Geometric Constraint 1: A robot, i, does not collide with another robot, j, i.e., their swept volume (SV) does not overlap at any time during the print cycle.

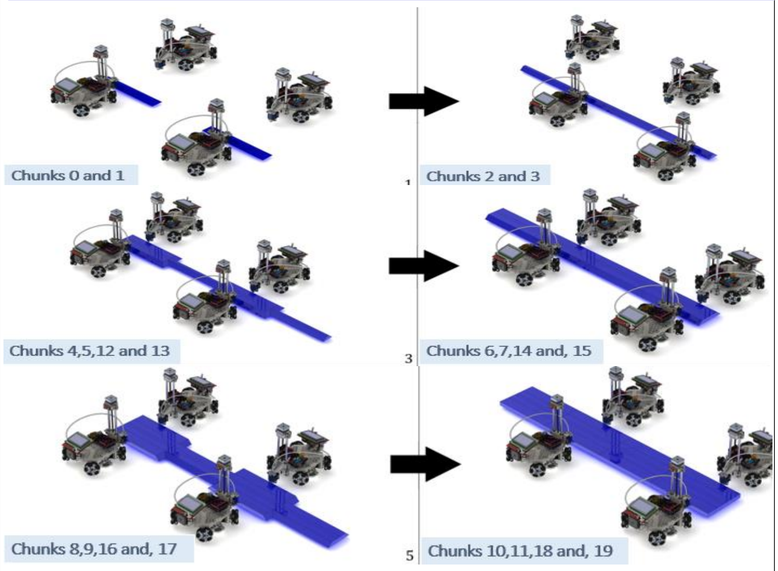
$$SV_{r,i}(t) \cap SV_{r,j}(t) = \emptyset, \qquad i = 1,2,..n; j = 1,2,..n; j \neq i$$

Geometric Constraint 2: A robot, i, does not collide with already printed chunks i.e., the accessible space($AS_{r,i}$) of a robot does not intersect with the occupied space (AS_c) of printed chunks.

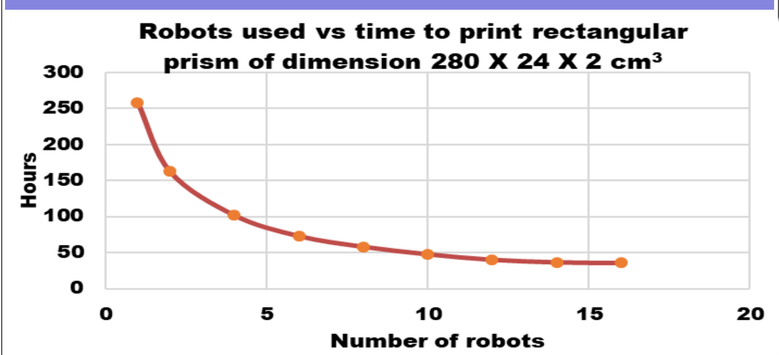
$$AS_{r,i}(t) \cap AS_c(t) = \emptyset, \qquad i = 1,2,..n$$



The schedule that results in collision free printing is simulated and the printing can begin.



Reduction in Total Print Time



References

1. J. McPherson, W. Zhou, *A Chunk-based Slicer for Cooperative 3D Printing.* From Rapid Prototyping Journal, 2018. In press
2. L. Poudel, Z. Sha, W. Zhou, *Mechanical Strength of Chunk-Based 3D Printed Parts for Cooperative 3D Printing*, 46th SME North American Manufacturing Research Conference (NAMRC 46), College Station, TX, Jun. 18-22, 2018.

Future Work

1. Development of Optimization framework for print schedule using Genetic Algorithm
2. Develop a digital manufacturing system containing a team of 3D printing robots and multi-assembly robots working together

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