Swarm Manufacturing: Cooperative 3D Printing

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Background

Project Goals

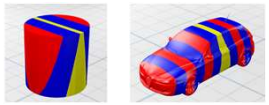
Enable the creation of highly versatile, decentralized manufacturing facilities by:

- Dividing parts into multiple chunks
- Assigning chunks to robots in a set schedule
- Establishing a feasible path for robots to move on and around the print area

Chunking

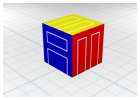
Chunking is the process of dividing a large print job into smaller pieces to be printed by individual robots [1].

- Bonded by overlapping prints
- Sloped surface ensures Mechanical Strength

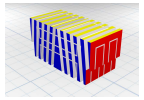


Chunk results of a cylinder

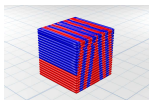
Chunk results of a car



Original Job



Chunked Job

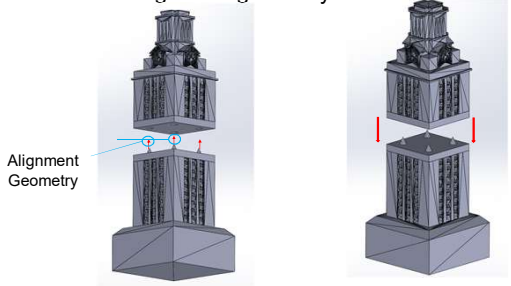


Sliced Chunk

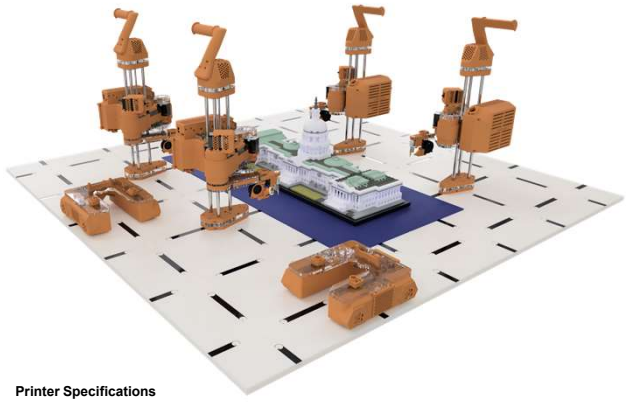
Vertical Chunking

For jobs that are taller than the height limit of the printer, additional chunking is required.

- Joined with alignment geometry



Cooperative Additive Manufacturing



Printer Specifications

Design Parameter	Value Range
Arm Reach	50mm-350mm
Max Z-height	300 mm
Filament Feed	Bowden, 1.75mm
Nozzle	Single extruder
Maximum Temperature	295° C
Hot End	Single extruder
X/Y Motion	2-axis SCARA
Z Motion	300 mm by lead screw
Layer Resolution	10 µm
Print Speed	50 mm/s
Print Repeatability	5 µm
Power Input	From floor tile or mobile platform
Power Consumption	78.62 W
Firmware	RepRap Firmware
Connectivity	Wireless

Mobile Platform Specifications

Specification	Value
Wheels	Mecanum wheels
Travel Speed	60 mm/s
Navigation	Infrared sensors, camera
Communication	Wireless communication
Power Source	Battery pack, charging station
Battery Life	2 hours use, 6 hours idle
Power Consumption	78 watts
Dimension	25 cm×33 cm×9 cm

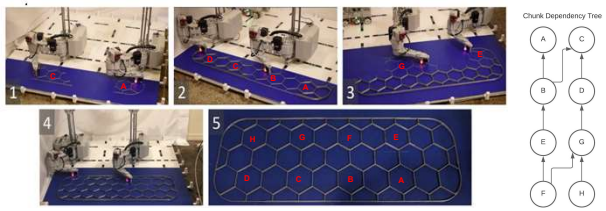
The Vision

PROCESS	COLOR	MATERIALS	SIZE	FUNCTIONALITY
Multi-process with cooperative robots	Multiple robots with different colors	Multiple materials carried by different robots	Unlimited scalability (x,y)	Opto-electro-mechanical production with digital assembly robot

Scheduling

Scheduling is the process of establishing a print sequence and assigning chunks to individual robots to print.

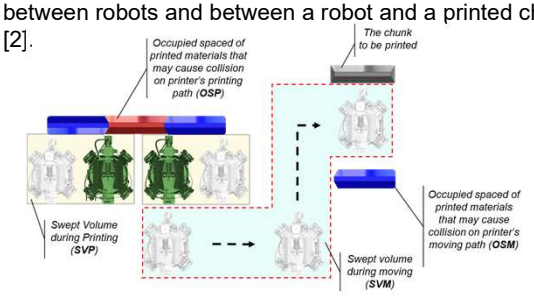
- Randomly generated using adjacency matrix
- Evaluate schedules by total print time using dependency



Path Planning

Determines the feasibility of a given schedule

- Considers geometric constraints to avoid collisions between robots and between a robot and a printed chunk [2].



Future Work

- Develop a self-sustaining software platform that can take a 3D model, generate chunks, search though design space to generate optimal print schedules for swarm manufacturing.
- Develop a digital multi-process manufacturing system containing a swarm of versatile manufacturing robots.

Acknowledgments

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References

1. 1.J. McPherson, W. Zhou, A Chunk-based Slicer for Cooperative 3D Printing. Rapid Prototyping Journal, Vol. 24 Issue: 9, pp.1436-1446.
2. L. Poudel, W. Zhou, Z. Sha, "Resource-Constrained Scheduling for Multi-Robot Cooperative 3D Printing", Journal of Mechanical Design, Transactions of the ASME, volume 143, issue 7, pp: 072002 (12), July 2021.