Collaborative Mutli Robotic 3D Printing With Slurry Based Materials For Construction Applications

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Research Motivation

3D printing in construction offers significant advantages, including the elimination of formwork, faster construction speeds, and cost savings, all of which meet the urgent need for rapid urbanization. Despite these benefits, scaling 3D printing for large structures poses challenges, traditionally addressed by using machines larger than the intended objects. This has driven the industry to adopt on-site gantry systems for 3D concrete printing, as shown in Figure 01. However, this approach has drawbacks, such as high costs, complex transportation and setup, and limited flexibility. Another approach is to distribute 3D printing tasks among multiple smaller robots that work together to construct large-scale objects. This multi-robotic approach enhances flexibility, reduces dependency on massive equipment, and offers a more adaptable and efficient method for utilizing slurry-based materials in construction.

Figure 01: On-site gantry System for 3D Concrete Printing

Current Research Progress

Preliminary experiments illustrated in (Figure 02, and Figure 04) and a comprehensive literature review, indicate that the common approach for multi-robotic 3D printing involves segmenting objects into multiple chunks, with each robot responsible for a specific chunk. This method enables simultaneous or cooperative printing but often results in seams appearing in the same locations, which compromises the mechanical and structural integrity of the objects. Slurry materials, the most widely used in 3D printed construction, are particularly susceptible to these issues, leading to surface irregularities and poor aesthetic quality. Despite efforts to minimize overlap in work zones, potential collisions between robots remain a significant technical challenge. To address this, the case study implemented a custom Python script for collision detection, which uses the joint positions of the robotic arms as input. The script first wraps a simple convex hull around each robot (as shown in Figure 3) and then applies the GJK (Gilbert-Johnson-Keerthi) algorithm. This algorithm iteratively searches for the smallest distance between two convex sets to determine if an overlap has occurred, thus efficiently detecting potential collisions and ensuring smoother multi-robotic coordination.

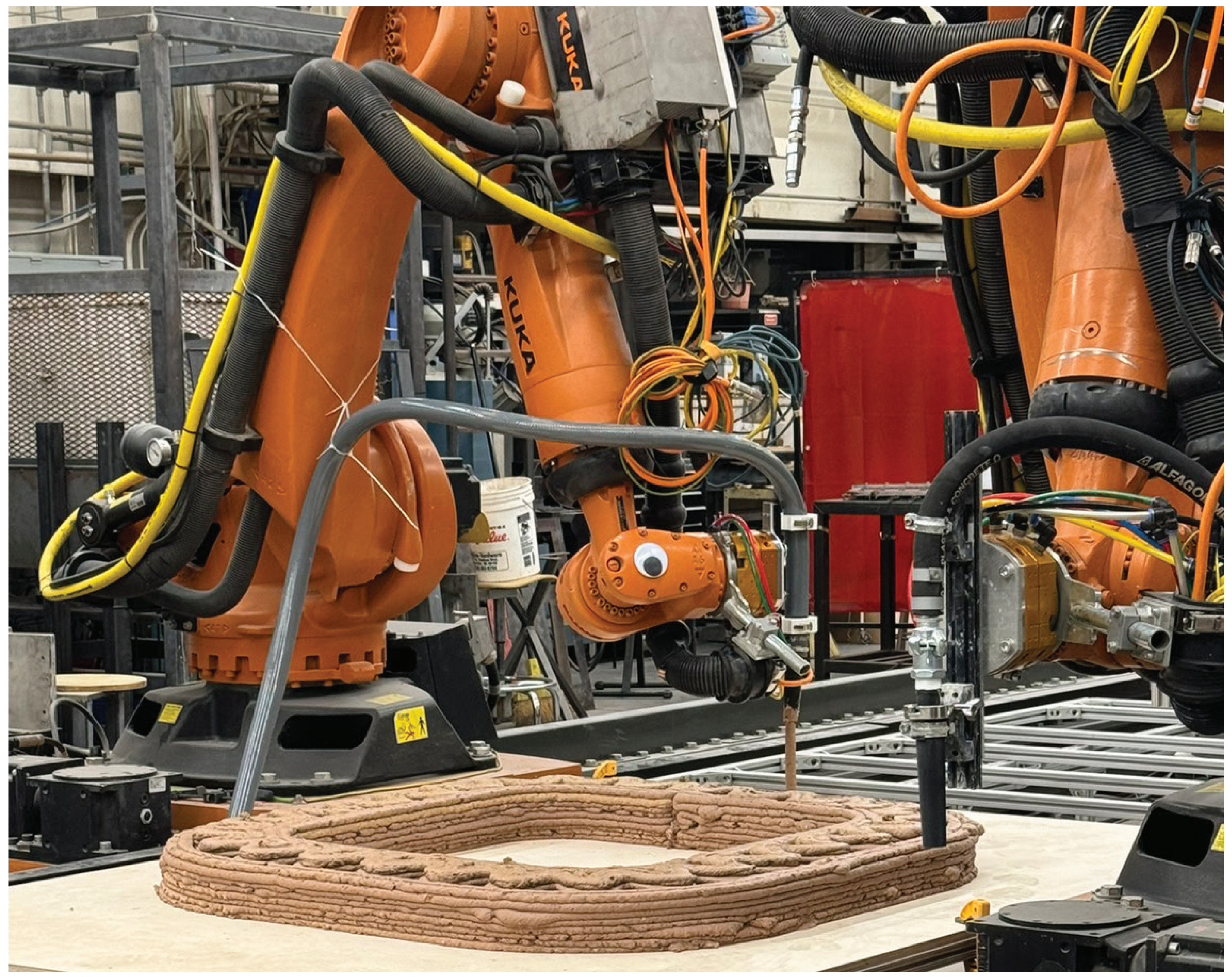

Figure 02: 1.8 x 1.8 meter base prototype

Research Objectives and Future Direction

The primary goal is to develop a system that assigns printing tasks and calculates motion trajectories for multi-robotic printing based on given objectives. Future research includes understanding the impact of seams on object performance and finding the best method for collision detection due to overlapping zones. The research will create a time synchronization policy for collaborative robot operation and use sampling-based algorithms for motion planning. To speed up

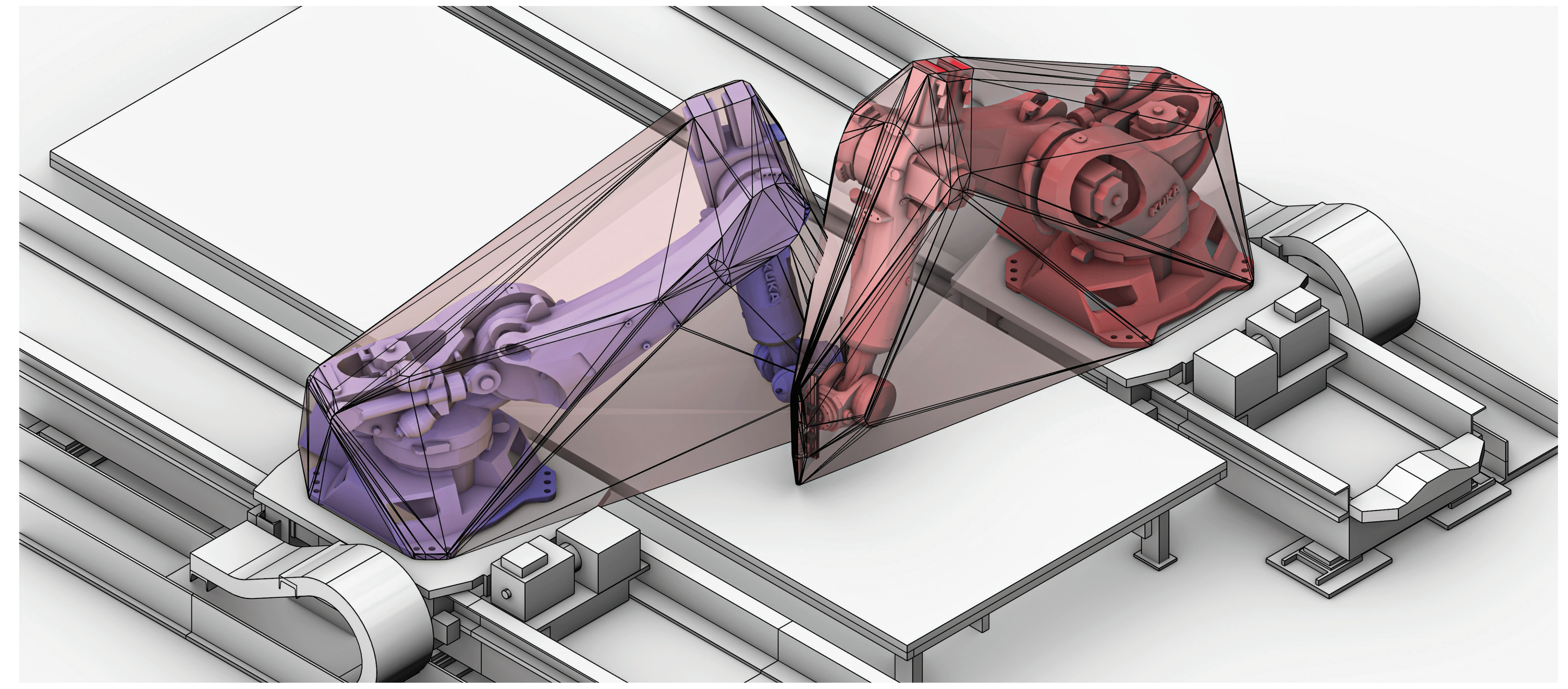

Figure 03: Collision detection using a simple convex hull

this time-intensive process, a machine learning model will be trained with collected data, improving the efficiency and reliability of multi-robotic 3D printing systems.

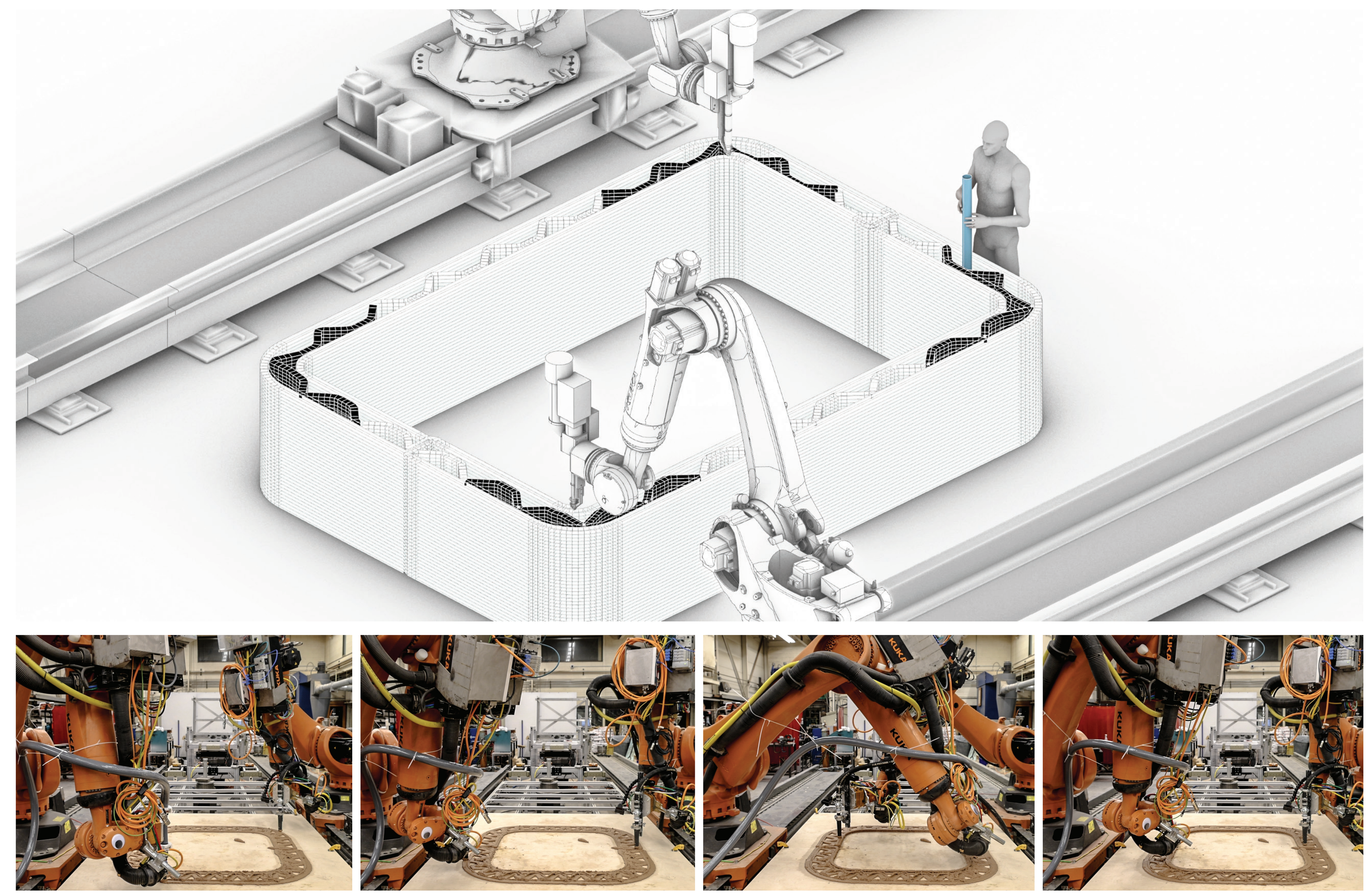

Figure 04: Top image shows a visualization of the collaboration between human and robots, bottom images shows a progression of the multi robotic 3D printing process