Conference or Workshop Item:

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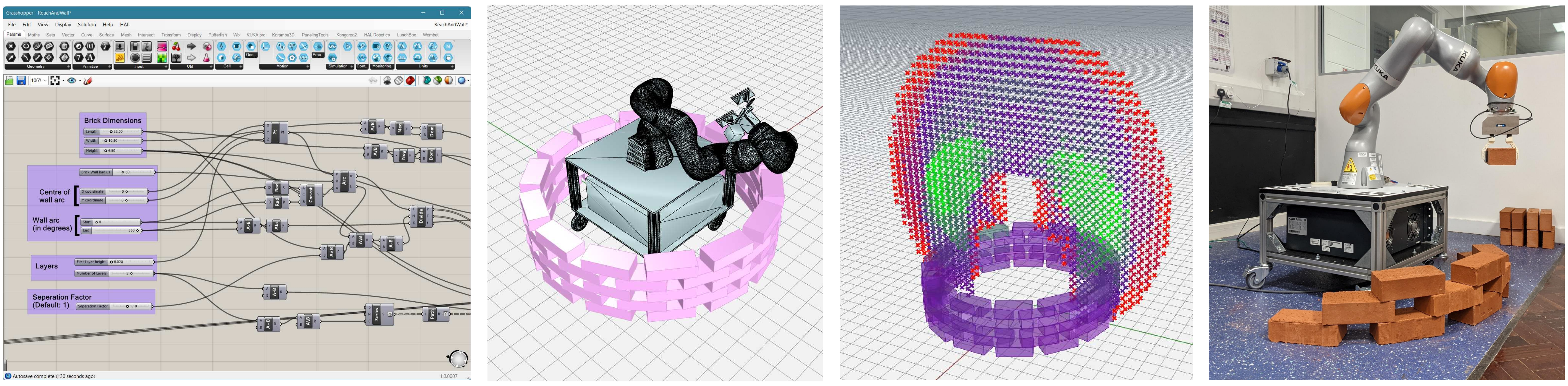
Transforming Construction Through Parametric Modelling and Robotic Assembly

Sam Wilcock, Emil Korkis, Ornella Iuorio

UNIVERSITY OF LEEDS

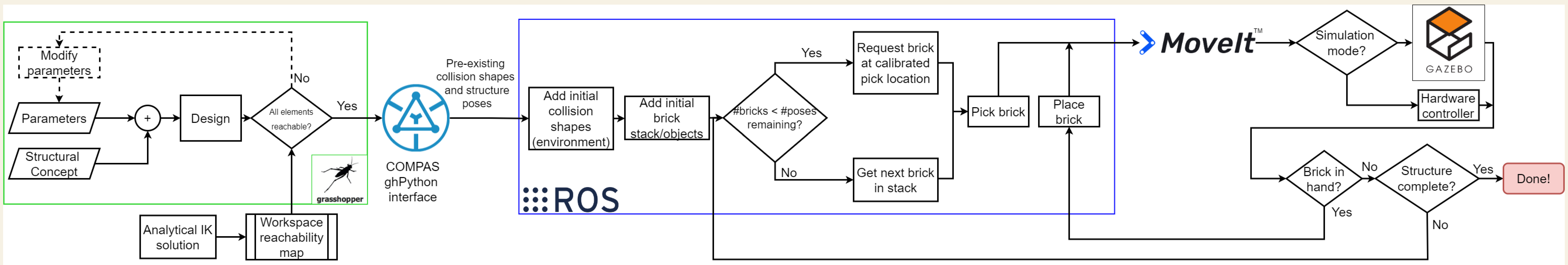
Aim: To develop a software **pipeline** for **online control** of industrial robots from **parametric design software**, to demonstrate assembly of **discrete structures.**



Motivation

The use of parametric design software such as Grasshopper® is commonplace in CAAD (computer-aided architectural design). Such tools allow the exploration of related geometric models by modifying input parameters, giving designers a quick method of moving through possible solutions. Whilst CAAD systems allow this exploration of forms, the transfer from design to digital manufacture techniques remains primarily a manual process. Many plugins now exist for Grasshopper which allow the generation of robot trajectories and manufacturer specific control code; however, the use of such offline code generation is limited by a number of factors, including the inability to adapt to changes in the environment. Through developing an online control method, and integrating with general robot control software outside of the CAAD tool, it will be possible to add sensing and process monitoring for assembly in unstructured environments.

Workflow



Python packages **COMPAS FAB** and **ROSLIBPY** allow the connecting of Grasshopper to ROS services and topics.

The **ROBOT OPERATING SYSTEM (ROS)** is used as a general purpose middleware for interfacing robotics packages and dealing with communications to hardware.

Custom **ROS NODES** maintain sequencing for pick and place procedures, whilst providing the user further control via a simple GUI.

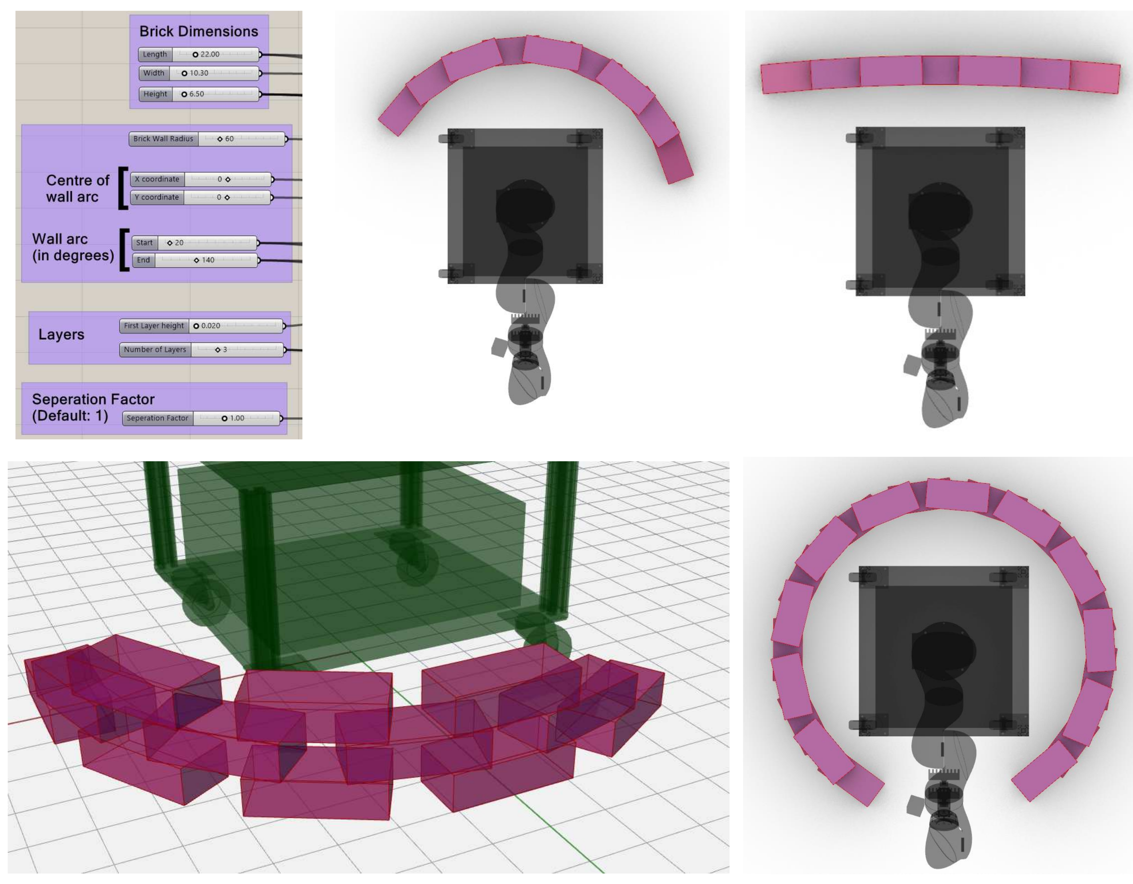
MOVEIT motion planning framework maintains collision objects in a central planning scene and generates trajectories via the **OMPL** motion-planning framework.

The **IIWA_STACK** ROS package allows the control of the robot hardware, but can be switched out for robot specific control.

Parametric design of walls

A parametric brick wall was designed for assembly by a single stationary robotic arm. The parameters governing the design prioritise reachability while maintaining flexibility to generate the desired shape for the wall.

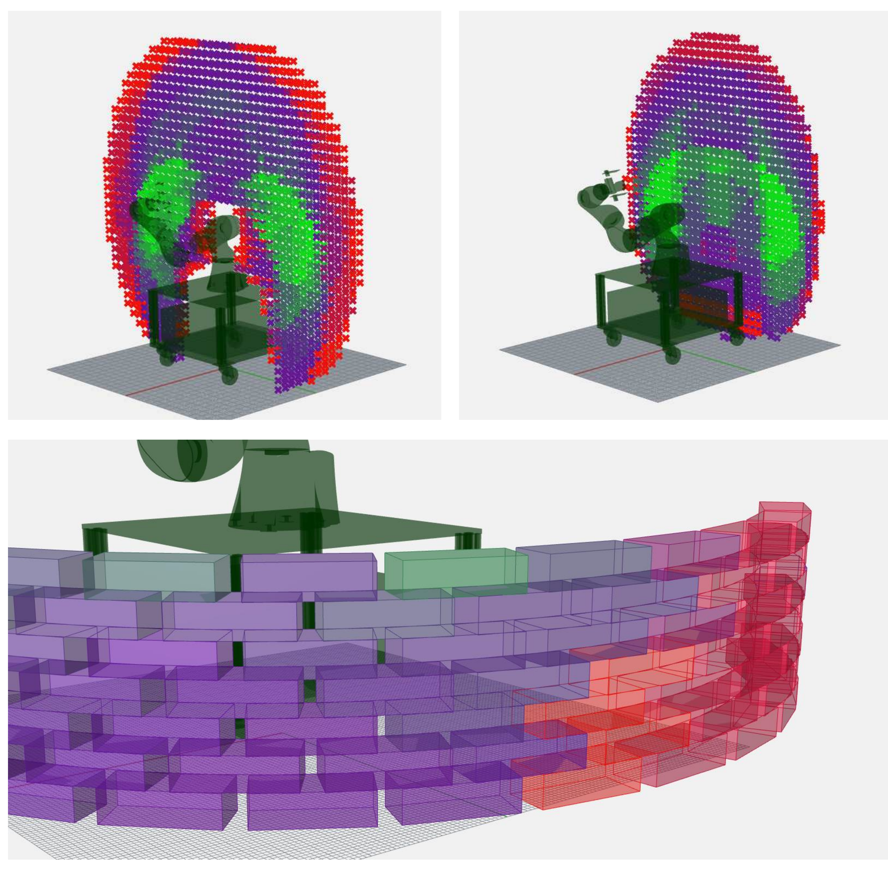
The number of the bricks generated is automatically defined to prioritise contact between bricks in different layers, however, the spacing can be adjusted using a separation factor if required.



Design assessment based on robot specific kinematics

Using an inverse kinematics solution (IKFast) for the manipulator, a reachability analysis was performed to map the reachable workspace of the manipulator. Discrete points in the workspace are scored by the percentage of orientations about them which are reachable.

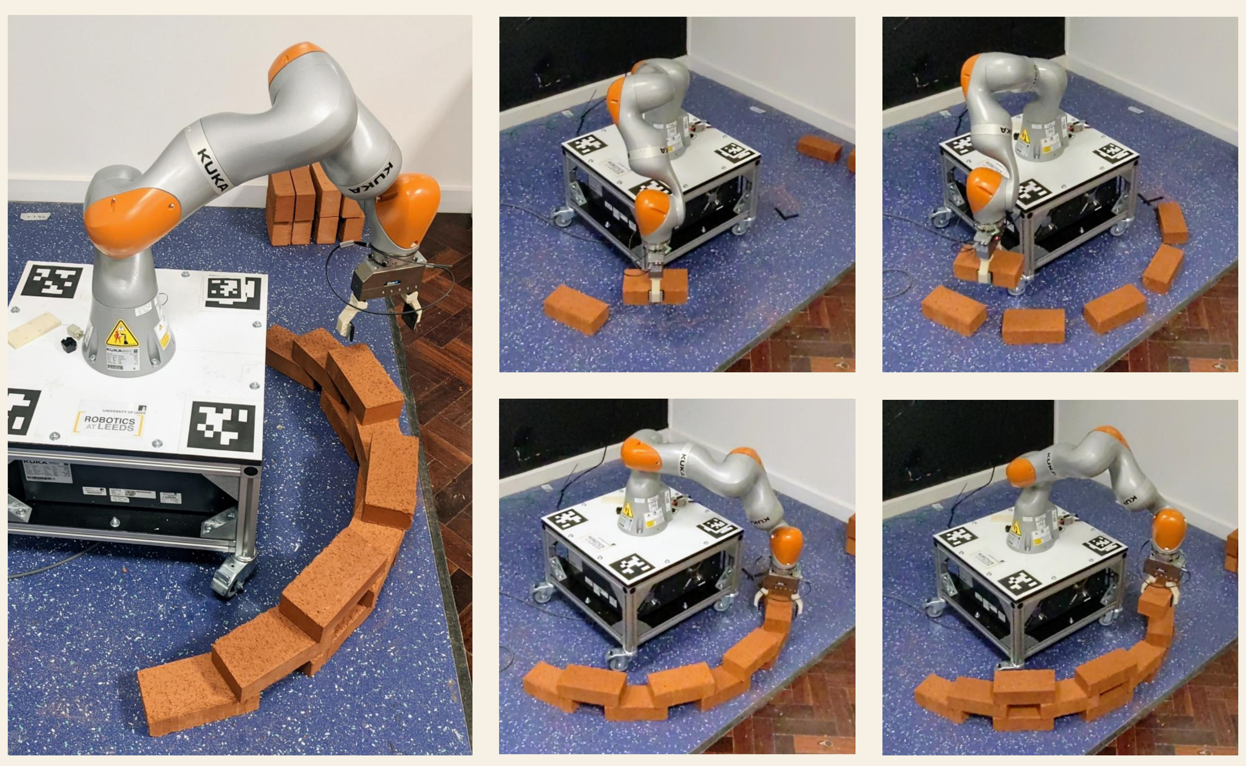
Using this mapping, it is possible to quickly infer whether a specific structure is feasible for assembly by the robot without running through (potentially slow) motion planning and collision checking.



Results

The parameters were set to generate a 3-layer brick wall with a 55cm radius, and 120 degree arc footprint.

The reachability analysis of the 12-brick wall generated showed the structure to be feasible and the wall was successfully assembled.



Future work

- Use of visual fiducial systems (e.g. Apriltags) is being investigated to locate and determine the orientation of the bricks.
- General inclusion of process feedback to Grasshopper for updating model
- Stability analysis/FEA for further structures
- Apply previous assembly sequencing/NDBG work of authors
- Move towards design of discrete panel shell structures
- Further testing of disassembly of previous existing stacks/walls