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CO-DESIGN IN ARCHITECTURE

A Modular Material-Robot Kinematic Construction System

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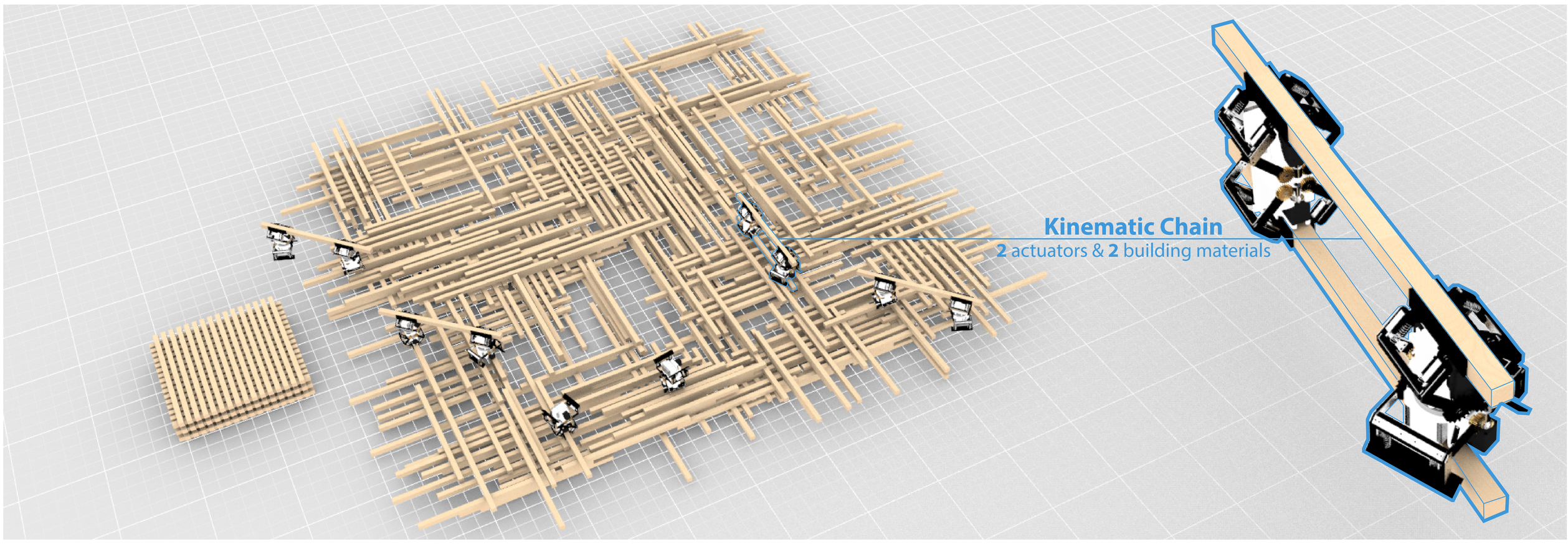
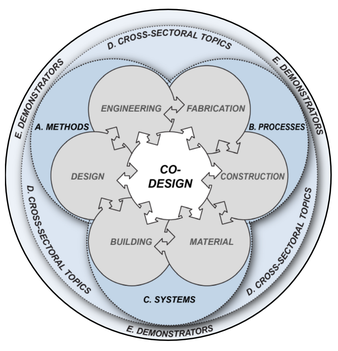


Abstract

Modern developments of construction robotics generally utilize a robot-oriented design approach to develop viable systems for the building industry. This has led to highly sophisticated automation of conventional, but at best slightly altered construction processes. In this paper, we argue for a material-robot oriented design process for the creation of novel construction robotic systems, which can expand the repertoire of current building practice and architectural possibilities. The co-design of a modular material-robot kinematic chain construction system in which the material, robot, and process inform the overall system is introduced from the architectural design, robotic mechatronic development, and task and motion planning perspectives. We present initial research on how material-robot kinematic chains can work in parallel to assemble, disassemble and rearrange large structures.

Introduction

In order to achieve this material-robot oriented design approach to construction robotics, we have built an interdisciplinary team as part of the Cluster of Excellence on Integrative Computational Design and Construction for Architecture (IntCDC). The major goal of IntCDC is to develop an overarching methodology of "co-design" of methods, processes and systems, cross-sectoral socio-cultural studies and building demonstrators. We implement this co-design approach in our research by co-developing methods for designing architectural artefacts, creating robotic hardware and task and motion planning.



For more on co-design, see:
https://www.intcdc.uni-stuttgart.de/

Specifically, the contributions in this paper are:

1. A new design of the mechatronic system,
2. Application of robust task and motion planning methods to plan the movement and the robot-strut interactions
3. Initial exploration of feasible architectural design methods and building artefacts using the developed system.

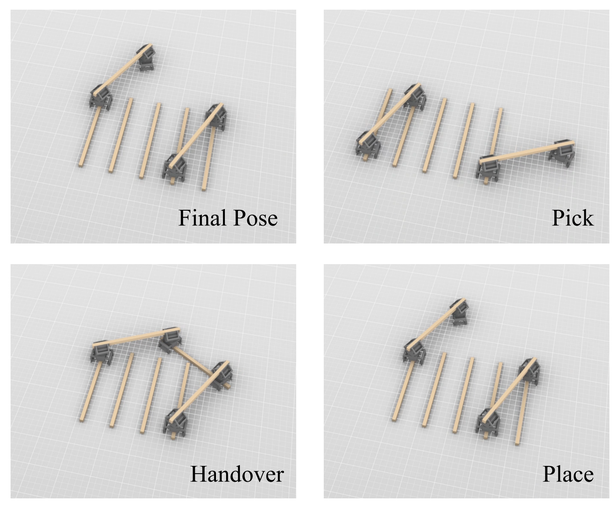
Task and Motion Planning

We need to find **actions** and **motions** to fulfill a given goal
In our case: '*Move the strut to position p on the other side*'

Our approach: Logic Geometric Programming (LGP):
tree search: *high-level action plan* + optimization: *motion plan*

Algorithm:

1. Find an **action sequence** to reach the goal
   e.g. ['Grasp', 'Handover', 'Place']
2. Find a valid **final pose** fulfilling the constraints
3. Find valid **intermediate poses**, e.g. a pose for 'Handover'
4. Find a **valid path** between the intermediate poses



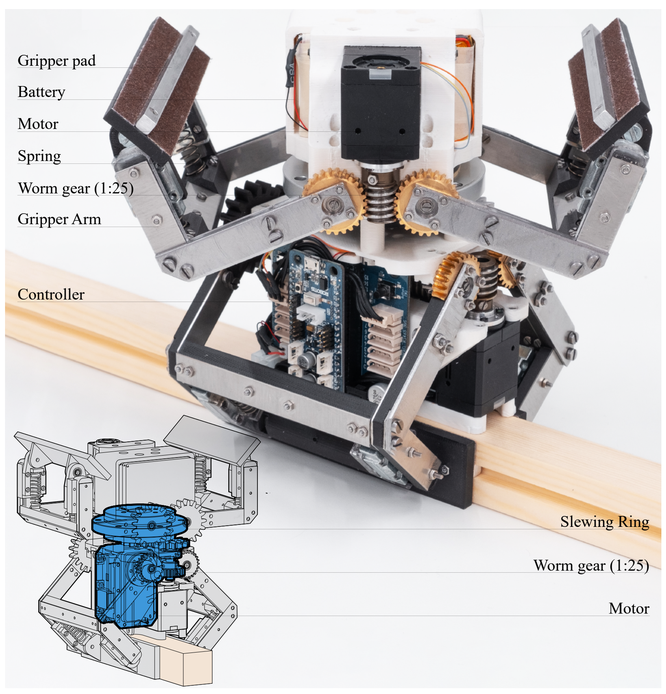
Mechatronic Design

The design process for the robotic actuator is based on two mechanisms: rotating and gripping. It consists of 2 grippers that are connected by a geared slewing bearing.

The torque required for rotation is defined by the length and configuration of a kinematic chain (i.e. physical links of robots and building material). The maximum static torque required occurs when a kinematic chain is fully stretched in the horizontal plane and can be calculated as

$$\tau_{\text{required}} = g l_{\text{bm}} \left(\sum_{i=2}^{n_{\text{r}}} (i-1) m_{\text{r}} + \sum_{i=1}^{n_{\text{bm}}} (i-0.5) m_{\text{bm}} \right)$$

The gripping mechanism is designed to grip and lift the building material. Calculations for the lifting mechanism are details out in the paper.



Architectural Design

The research on architectural design is interested in developing design methods in which both top down and bottom up methodologies can be implemented. In allowing for both methodologies, the design of architectural artefacts becomes an informed negotiation between designer intent and system affordances and constraints in which processes work in both directions, implying constant feedback between the various developments on the construction system.