Technical University of Munich
TUM School of Engineering and Design
Chair of Computational Modeling and Simulation

Master Thesis Proposal

Simulation framework for Collaborative Construction: Towards collaborative robots and human-multirobot collaboration in construction

Robotics has emerged as a revolutionary technology in the construction industry with the potential to improve productivity and occupational safety. A rapidly expanding literature field of robotics in construction (RiC) has made proposals covering construction equipment with robotic features (e.g., robotic excavators), using robots from other industrial sectors for construction purposes (e.g., drones), and robots customized for the construction industry (e.g., façade cleaning robots). However, adopting robotics in the construction industry is still facing many challenges due to the unique characteristics of the construction process. Robotics in Construction has become a highly cross-disciplinary research field that integrates robotics with many urgent technologies including additive manufacturing, building information modelling (BIM), and deep learning.

Thus, a comprehensive framework for simulating robotized construction processes would be of utmost importance for enabling a virtual laboratory environment for experimenting and developing new robotized construction methods. A major scientific challenge lies in the provision of coherent digital representations of the facility to be constructed and the involved production processes at different, yet interconnected scales in space and time. The framework must be designed in a modular and flexible manner to allow the integration of new types of robotic systems, sensors, and construction methods.

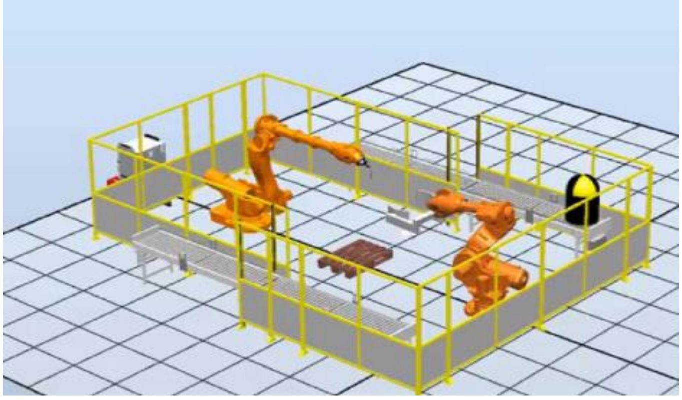
Figure 1 Example of two Kuka robots exchanging a target object and placing it on a production belt

The overall objective is to conceive a capable framework for simulating robotized construction. The framework is required to be flexible and modular enabling easy extensibility and adaptability to allow its application for a large range of construction tasks and robotic systems. The architecture of the framework will implement the data, information, knowledge (DIK) pyramid providing a clear separation of the different layers of abstraction. A core component of the framework is the representation of Fabrication Information Models (FIM) that deeply integrate both the product view and the production process view. To allow iterative elaboration and refinement, data structures for represent FIM on multiple, coherent abstraction levels will be developed. A challenge to be tackled lies in the variety of n:m relationships between building elements and fabrication processes: **a)** On the one hand, the completion of an element requires the application of different robotic systems with diverging capabilities (concreting, drilling, finishing etc.). **b)** On the other hand, robotic processes are likely spanning multiple elements. The digital representation of the

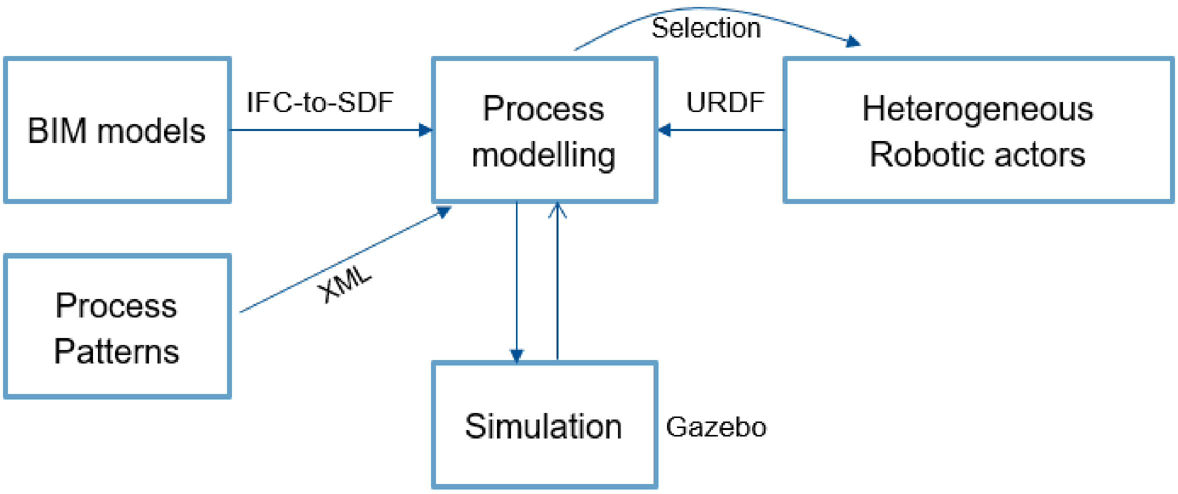

Figure 2 Collaborative construction process

facility under construction developed in this subproject will form an integral component of the simulation platform. It must thus provide suitable interfaces to be able (1) to be queried by other platform components and provide information on geometry/function of building elements, and (2) receives information from various subprojects concerning concrete robotic processes.

Task

1. Literature review on the state-of-the-art in heterogeneous and collaborative robotic construction and relevant frameworks
2. Implementation of a suitable workflow in Gazebo or similar framework that:
   - imports BIM and construction elements
   - imports, models and simulates heterogeneous robotic agents and their behavior,
   - models and simulates autonomic intelligent functionality for collaborative construction via deep learning and reinforcement learning approaches.
3. Evaluation of the simulation framework in multiple scenarios

You have

1. Programming skills (Python) and motivation to develop a system for collaborative robotic simulation.
2. As a plus:
   - Experience with ROS,Gazebo, Moveit.
   - Experience with deep learning frameworks (e.g., PyTorch, Tensorflow).

Supervision

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