Design and Simulation of a Multi-robot Architecture for Large-scale Construction Projects

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Abstract

Large-scale construction projects can benefit from having a team of heterogeneous building robots operating autonomously and cooperatively in unstructured environments. In this work, we present a flexible system architecture, MARSala, that allows teams of distributed mobile robots to construct motion support structures in large and unstructured environments using purely local interactions. The work primarily focuses on the deliberative layer of the architecture which provides a means for formulating a construction project as a motion support structure construction problem.

MARSala is highly modular; each individual building agent is composed of modules that represent its actuation and sensing capabilities. The low level motion primitives such as material selection and handling, manipulation and motion are defined based on the user's requirement. The generalized notion of navigability used is adaptable to any ground-based robot. The reactive building approach is based on the Minimal Additive Ramp Structure (MARS) model, which is a function of the environment and the robot's kinematic constraints. It calculates the amount of construction volume needed to make a given area navigable for the robot. This reactive construction approach allows the robot to respond to changes in the environment made by itself or other agents, and imperfect assembly, even in unstructured environments. Rather than designating the deposition model, construction materials or methods, MARSala evaluates the validity of each construction action using MARS. This allows for heterogeneous robots to work cooperatively in the same structure. The final structure is the composition of several intermediate structures, each of which can be traversed by the building agent. This principle allows for the continuous expansion of the built structure and thus, the architecture allows for construction volumes that are many times the size of an individual agent.

We implemented the architecture in simulation and demonstrated the benefits of the proposed formulation in two different construction projects operating in large unstructured environments. In this first scenario, robots were tasked to collectively build a navigable structure to a known target location, while in the second scenario, robots were tasked to level an uneven terrain. We also developed a modular multi-robot simulation framework for ground-based mobile building agents that allows us to design and analyze large scale construction problems.