Angle of repose in robotic construction

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Building dry-stacked structures with in-situ objects is a new and valuable application for robots in disaster areas or remote site preparation. Our previous work [1] proposed dry-stacking strategies for constructing single-stack freestanding stone walls based on heuristics adapted from masonry manuals. Planning for single-stack walls is difficult since all of the stones are only supported by the layer below and the rocks form a single row with no side supporting forces. Fortunately, in most applications, such sophisticated planning is not necessary. For example, robots can build a rock riprap along a river using random assembly or minimal planning if construction materials or agents are restricted. Given the variety of building strategies, it is necessary to evaluate their effectiveness systematically. This paper proposes the angle of repose as an effective tool for assessing minimally planned building strategies in robotic construction.

The angle of repose is the steepest angle that a material can sustain [2]. It is a fundamental material property when building using irregular objects. Depending on different packing methods and different material types, this angle is different [3-4]. The angle of repose is a well-studied topic in the granular material field, but it hasn't been explored much in robotic construction. In this project, we are particularly interested in the angle of repose and stability of structures formed by random and planned assembly, as well as how much better minimal planning is compared to random assembly.

When building with irregular found stones, the stones' irregularity and placement planning strongly affect the final angle of repose [4,5]. In this work, we first propose an irregularity measure to quantify the stones' irregularities from different perspectives. Then two construction methods are investigated: random assembly and naive sequential assembly. With random assembly, we study the angle of repose of different stone irregularities. With naive sequential assembly, we show that the angle of repose can be significantly increased compared to the random placement. Finally, the collapse dynamics [6] of the constructed structures are measured by applying them under shake tests.

Since the measured angle of repose may vary with the method used, in this work, we use the fixed funnel method, where the material is poured through a funnel to form a cone. The experiments are conducted in simulation. The structures are built on a 6mx6mx1m cuboid platform. During the random assembly experiments, stones are poured through a stone generator located on top of the platform along the center of the platform, and we keep all the stones that rest on the platform while removing the stones that fall outside of the platform.

References:

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