Mechanical Engineering Thesis Defense

Excavation in Swarms: Applications to Human Infrastructure Problems

School for Engineering of Matter, Transport and Energy

Zz Haggerty
Advisor: Spring Berman

abstract

Existing robotic excavation research has been primarily focused on lunar mining missions or simple traffic control in confined tunnels, however little work attempts to bring collective excavation into the realm of human infrastructure. This thesis explores a decentralized approach to excavation processes, where traffic laws are borrowed from swarms of fire ants (solenopsis invicta) or termites (coptotermes formosanus) to have a swarm capable of working together and organizing effectively to create a desired final excavated pattern. First, a literature review of different colonies and their behavioral and structural patterns over the course of excavation was completed. After isolating pertinent excavation laws, three different finite state machines were generated that relate to construction, search and rescue operations, and extraterrestrial exploration. Then, agent-based NetLogo software was used to simulate the algorithm until a data-based mathematical model was established. This model was able to control the number of branches in the final model as it relates to the swarm size through a factor called the "critical waiting period." Eventually, by controlling the individual agent's behavior it was possible to control the structural outcomes of collective excavation. The algorithm design eventually led to an experimental setup involving a granular media test bed and a foldable robotic platform. In order to characterize the granular media, force experiments were conducted and parameters were established for resistive forces during an excavation cycle. The final experiment verified the robot's ability to engage in excavation and deposition, with the power to decide whether or not to begin the critical waiting period. A future consideration for the experiment and algorithm include the addition of other robots to observe their work collectively. Then, after establishing the effects of the critical waiting period other factors like tuning digging efficiency or deposition proximity could work to bring bio-inspired swarm excavation closer implementation in the real world.

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