Drone Maneuverability Around Built and Natural Structures: Phase I, Fabrication and Testing of Mock Environments

LIBERTY UNIVERSITY

Hannah Deter and Dr. Hector Medina

TRACER Lab

Abstract

Drones can be used for numerous applications, one of which is to monitor or inspect buildings and building envelopes. Consequently, it is favorable that drones used for this purpose can autonomously maneuver around obstacles encountered in different environments, such as those around built structures. Another useful application of drones is navigation in densely packed environments, containing trees and vegetation. For example, for the latter application, drones can be used to help track and rescue people in forest and remote locations. This research aims to build mock environments that can be used to test the ability of autonomous drones to navigate successfully around them. The first phase of this research comprises the design and construction of small-scale buildings and dense tree environments. The buildings' designs will utilize both common and unique features; the tree environments will consist of different sizes of trees with assorted amounts of cover due to their leaves. Therefore, varying levels of difficulty will be faced by the drones, which will be using sensors for navigation. After these buildings and trees are designed and constructed, drones will be flown around them, and data will be collected via the drones' sensors. It is the hope that as a result of this research, improved strategies in calibrating and programming the drones and their sensors will be learned for the drones to be able to successfully navigate the most challenging of environments within some time constraints. Additionally, it is the goal to be able to apply the results of this research in helping facilitate the job of professionals such as engineers who inspect both new construction and older projects and building owners deciding whether to retrofit their buildings with energy-saving amenities. Finally, this research can contribute to researchers exploring drone/sensor systems for agile navigation in dense environments such as forests.

Introduction

In order to train the drones to navigate through different environments, a mock environment will need to be designed and built, which is what Phase I of this project consists of. This mock environment will include both structures that represent buildings, in addition to tree-like structures. These structures were designed to include many different elements and features, such as varying shapes, protrusions, openings, and glazing. While designing these structures, the goal was to minimize the number of structures that need to be built in order to represent the wide variety of design aspects that would be encountered in a real-world environment. As is seen in Figure 4, one of the designs includes protrusions that vary in size, a slot going down the middle, and two openings covered with clear material to replicate windows. Consequently, the encounters the drones will have with these design features will allow for the collection of a multitude of data from their sensors. As a result, upon examination of this data, the drones' sensors will be calibrated accordingly.

Methods

Phase I of this project consists of the design and construction of structures in order to create mock environments that drones will be flown around. These structures were designed using SolidWorks primarily in the Translational Robotics and Controls Engineering Research (TRACER) Lab located at Liberty's Center for Engineering Research and Education (CERE). The designs currently consist of a variety of buildings, all of them featuring different design aspects meant to challenge the drones in ways that might be experienced in the real world. While the materials required for the construction of these structures have not yet been finalized, they will most likely include wood and acrylic, with additions such as very thin metal attached to corners to make them more prominent to the sensors on the drones. For the testing of the structures, DJI drones will be used; however, the exact model of drone to be used is not yet known.

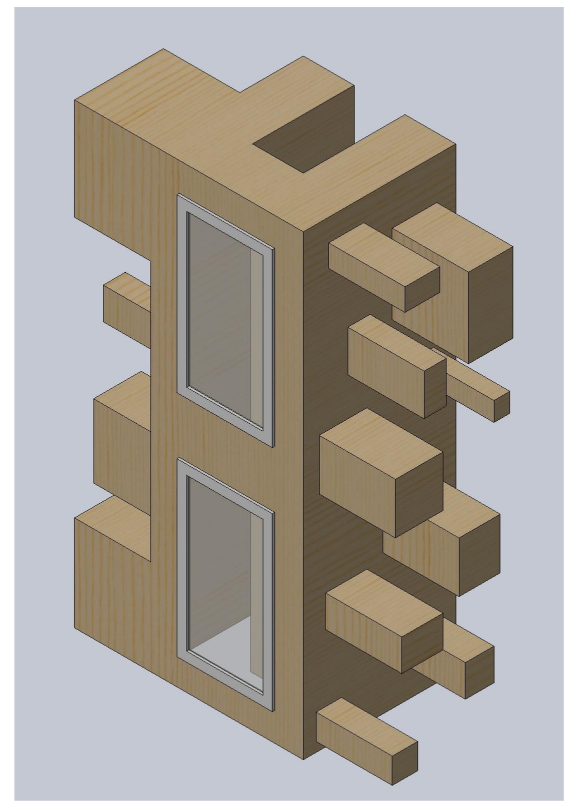
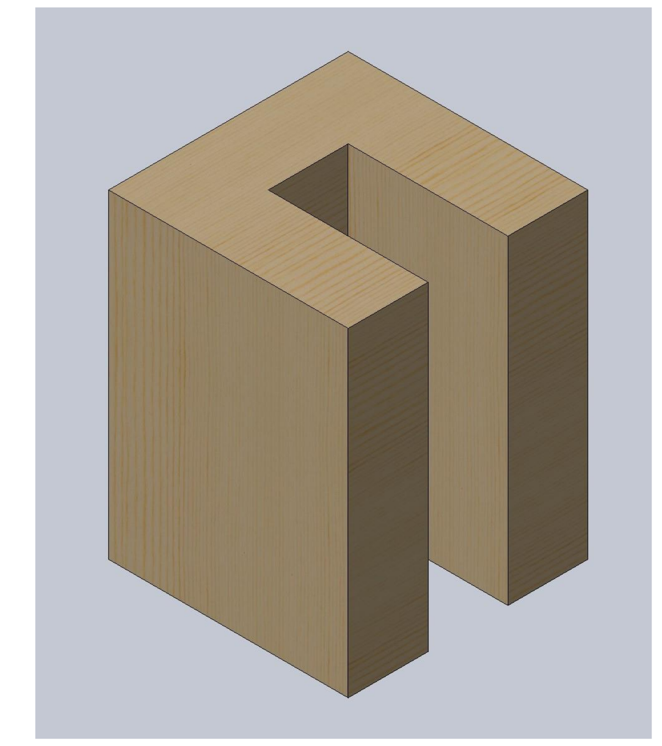


Figure 1: Complex Building
This building is 8' long, 4' wide, and 12' tall and was designed to challenge the drones in multiple ways. It utilizes design aspects that are meant to simulate possible obstacles that drones could encounter, such as highly varying shapes, roofs, and different glazing.

Figure 2: Simple Building
At 4.5' long, 4.5' wide, and 6' tall, this building exhibits a much simpler design. With only a small channel running down its center on one side, this may serve as a good initial test piece for the drones to navigate around.



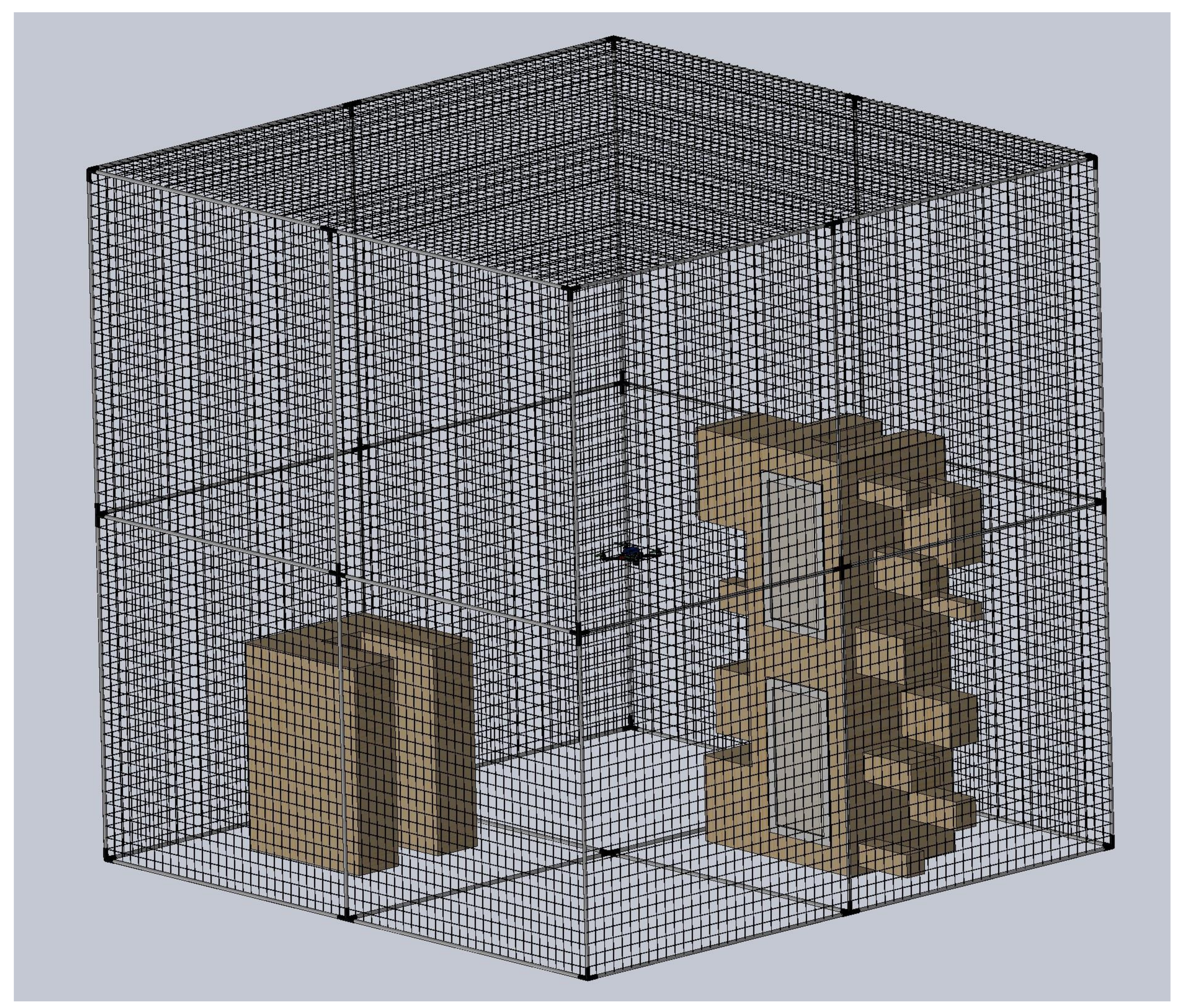


Figure 3: Drone Cage
This cage will enclose the drones inside the mock environment. The cage is constructed from PVC pipes and fittings, and measures 20' long, 20' wide, and 20' tall. A net attached to the cage ensures that the drones cannot travel outside of the testing environment. This picture features two buildings inside the cage, in addition to a drone.

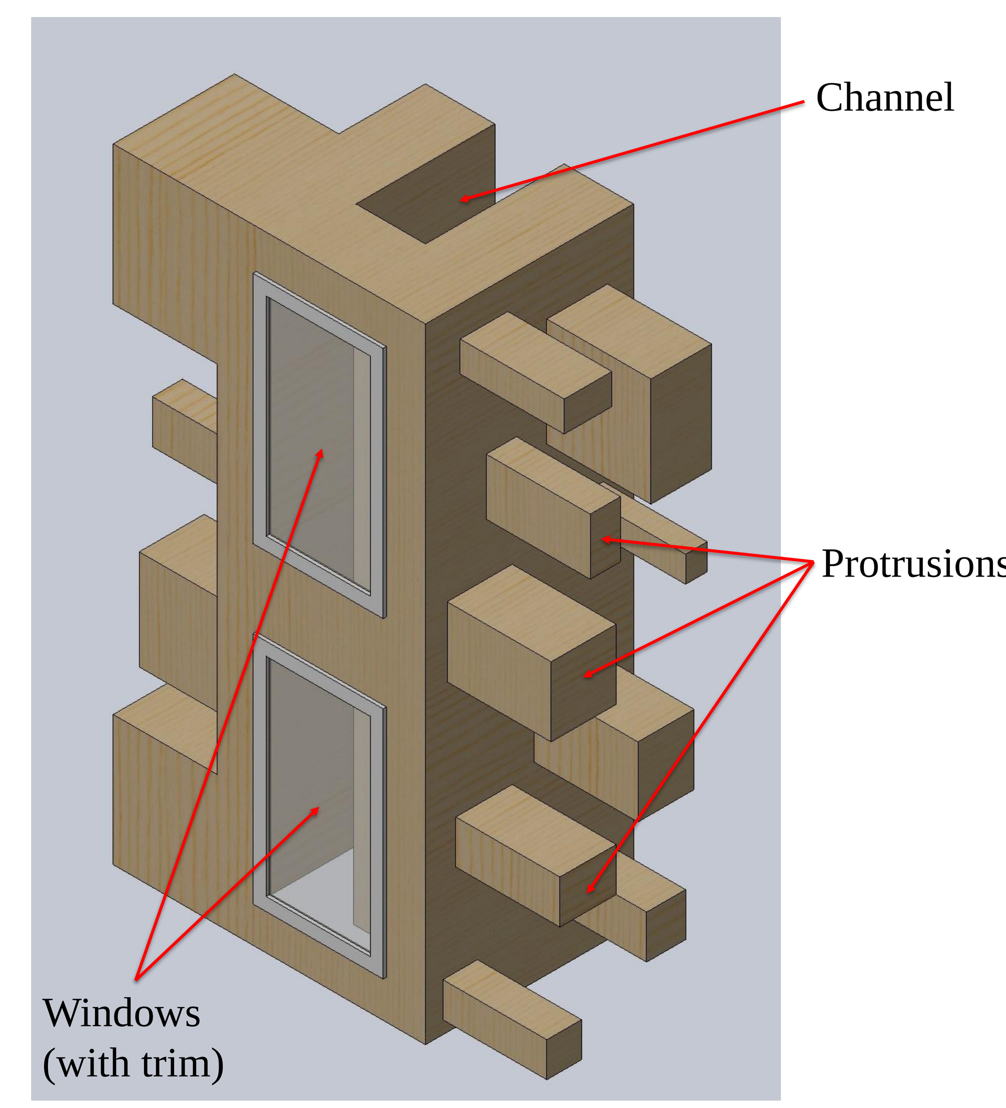


Figure 4: Design Features
Structures are designed with various features meant to challenge the drones in ways that may be encountered in real-life situations. This structure includes randomly-sized protrusions from two sides, a channel going down the middle, and two windows complete with trim.

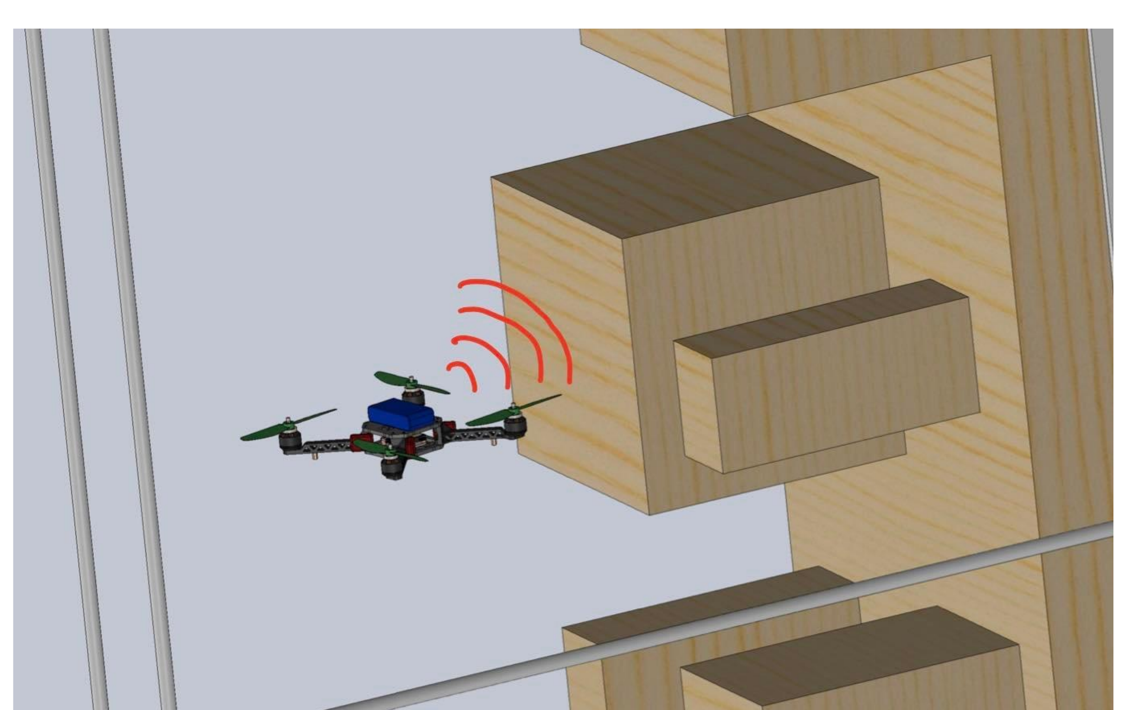


Figure 5: Drone Sensing
Fitted with sensors, the drones will be able to detect obstacles in their path from a certain distance. In this case, it is a protrusion from the complex building design.
Note: this image does not contain an accurate representation of the drones that will be used.

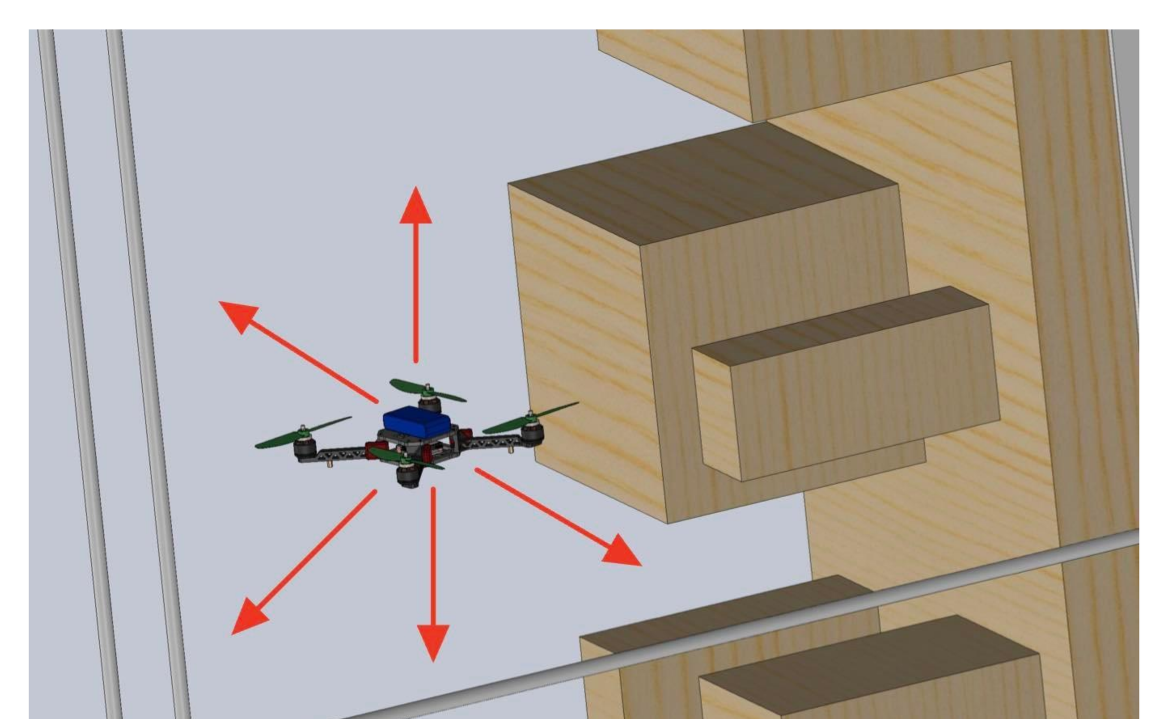


Figure 6: Drone Navigation
After sensing obstacles, the drones will have to decide on where to fly in order to avoid said obstacle, which includes many different directions.

Results

Hopes for Research
Because this research is currently in the first phase and therefore not yet completed, there are no results or conclusions to discuss. However, through this research, it is the hope to be able to better train drones to autonomously navigate through different environments that may be encountered in real-life scenarios.

Applications
Drones having the ability to autonomously navigate through different environments has an abundance of applications, including building inspections and rescue operations. In the case of building inspections, these drones would be able to aid engineers in areas of interest such as making sure buildings are being constructed correctly or are following the proper protocols for LEED certification. Additionally, these drones could help building owners in deciding whether to retrofit their existing buildings with energy-saving amenities. When it comes to rescue operations, these drones could be used to fly through dense forest environments in order to aid in the finding of lost individuals, who could then be rescued.

Future Work

1. Construct building-like and tree-like structures.
2. Conduct preliminary testing to ensure these structures can be used to train the drones.
3. Create mock environments inside drone cage using structures.
4. Allow drones to fly around structures and gather data from sensors.
5. Calibrate sensors based on data acquired from drone flying.

References and/or Acknowledgments

Jiang, Y., Han, S., & Bai, Y. (2021). Building and Infrastructure Defect Detection and Visualization Using Drone and Deep Learning Technologies. *Journal of Performance of Constructed Facilities*, *35*(6), 1–17. https://doi.org/10.1061/(ASCE)CF.1943-5509.0001652

Sarmiento, T. A., & Murphy, R. R. (2018). Insights on obstacle avoidance for small unmanned aerial systems from a study of flying animal behavior. Robotics & Autonomous Systems, 99, 17–29. https://doi.org/10.1016/j.robot.2017.09.002

Yang, S., Yu, G., Meng, Z., Wang, Z., & Li, H. (2022). Autonomous obstacle avoidance of UAV based on deep reinforcement learning1. *Journal of Intelligent & Fuzzy Systems*, *42*(4), 3323–3335. https://doi.org/10.3233/JIFS-211192