Wildlife Dimensional Probe

GVSU Biology NRM Department

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Problem Statement

Improve, develop, and manufacture a modified device that will assist NRM researchers in obtaining accurate information from the living quarters of animals with dens in tree cavities.

Background

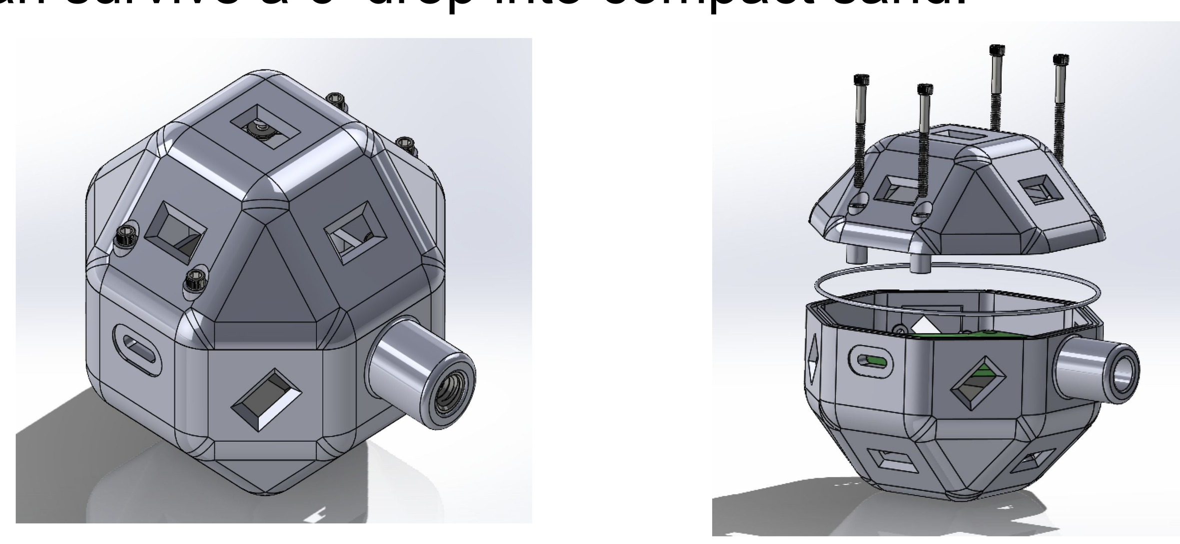
The current approach used by the GVSU NRM Department involves researchers physically climbing trees to access wildlife dens, relying on flashlights to visually inspect through narrow openings. This method poses significant safety risks to the researchers and increases the likelihood of disturbing the animals. Additionally, it does not provide any quantitative data for analysis.

Key Specifications

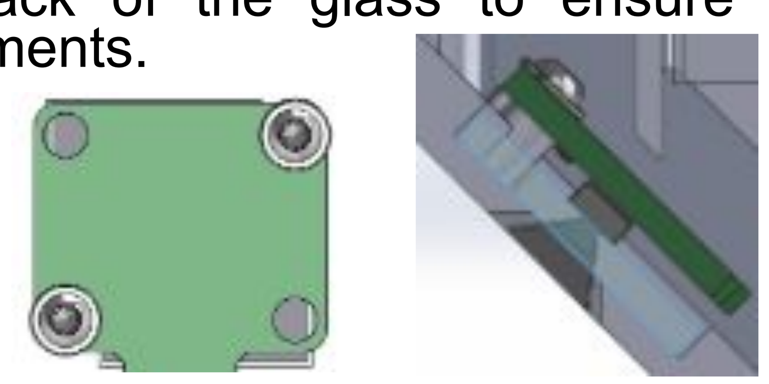
- ~$7000 Budget
- Device needs to fit into an opening 10 cm in diameter
- Device needs to reach a den 20' high
- Device must be drop resistant from 6' onto compact sand
- Device must be water and dust resistant
- Measure volumes within ± 10%
- 30 minutes minimum of battery 7 life
- Must include a tablet to display 3D volume measurements and values
- Tablet must communicate with system to take measurements

Mechanical Design

The device enclosure is where all the Time-of-Flight sensors and electronic components are housed. The enclosure has a 7 cm diameter, sized to fit through 10 cm openings. A 4-bolt compression system with an O-ring seal was selected for reliable sealing, easy access, and environmental protection. The enclosure is 3D printed using a Tough 2000 resin to ensure it can survive a 6' drop into compact sand.

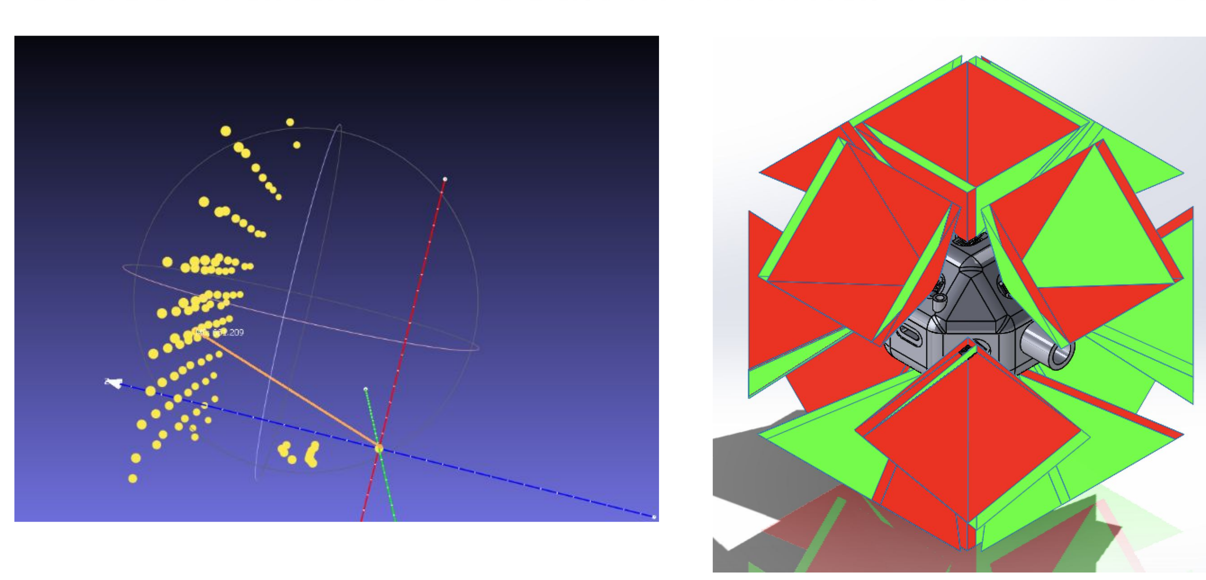


The cover glass is laser-cut acrylic, mounted with perimeter adhesive that also seals it. Sensors are positioned flush and perpendicular to the back of the glass to ensure accurate measurements.



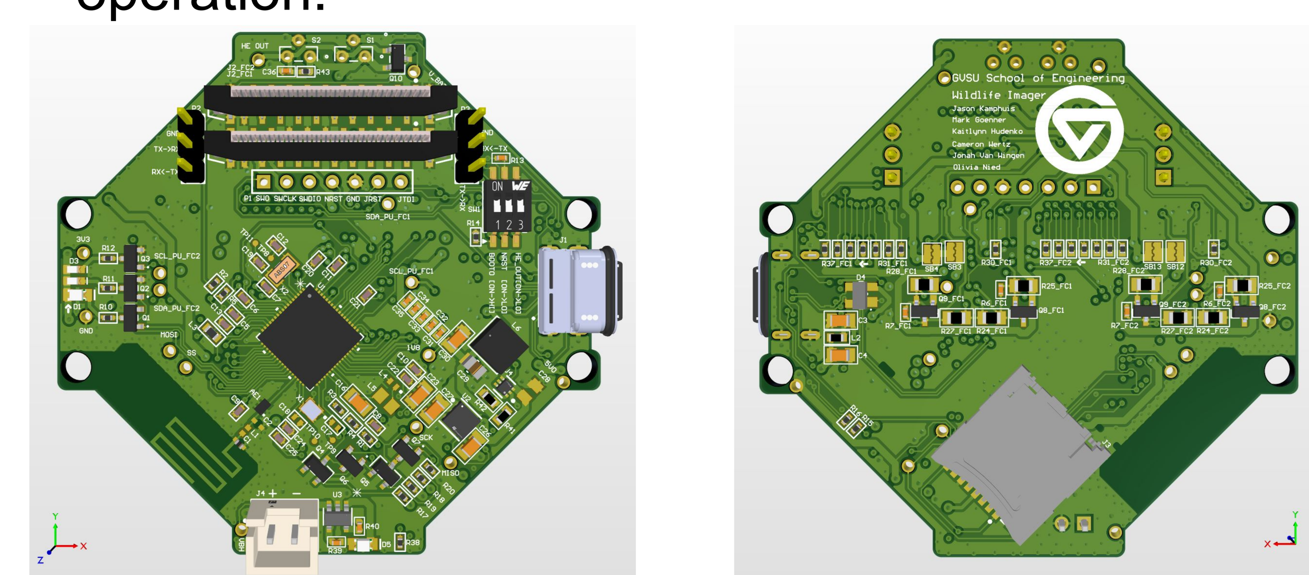
Sensor Layout

To estimate object volume, each ToF sensor generates a 64-point 3D point cloud using its 8×8 array and 60°×60° FOV. The distance data is then converted into (X,Y,Z) coordinates. These individual clouds are fused by transforming each sensor's data to a common origin using 3D rotation matrices and position offsets, forming a full point cloud centered on the probe. Sensors are pre-calibrated to account for cover glass, with a user-friendly calibration box provided for re-calibration. Tolerance studies confirmed that both positional (±0.35 mm) and rotational (6°) sensor variations result in minimal volume error.

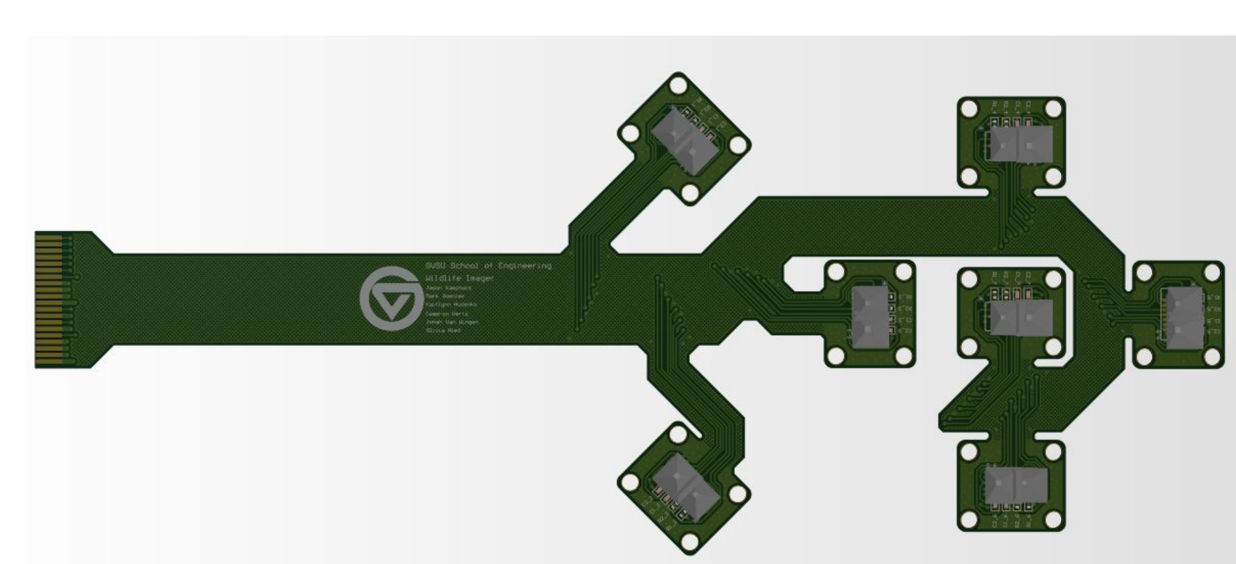


PCB Design

A rigid PCB integrates all key electronics, including power management, microcontroller, antenna, SD card, flex connectors, and debug interfaces. A 6 layer design ensures signal integrity. Power is supplied by a 2500 mAh LiPo battery regulated to 3.3 V and 1.8 V, with USB-C charging and a Hall Effect sensor for activation. The STM32WB55 microcontroller manages Bluetooth, SD storage, and sensor control, with debug access via JTAG/SWD, UART, and USB-C. A 2.4 GHz meander antenna ensures reliable wireless communication. The SD card connects via SPI, and flex PCB connectors feature voltage level shifting and control pins for sensor operation.

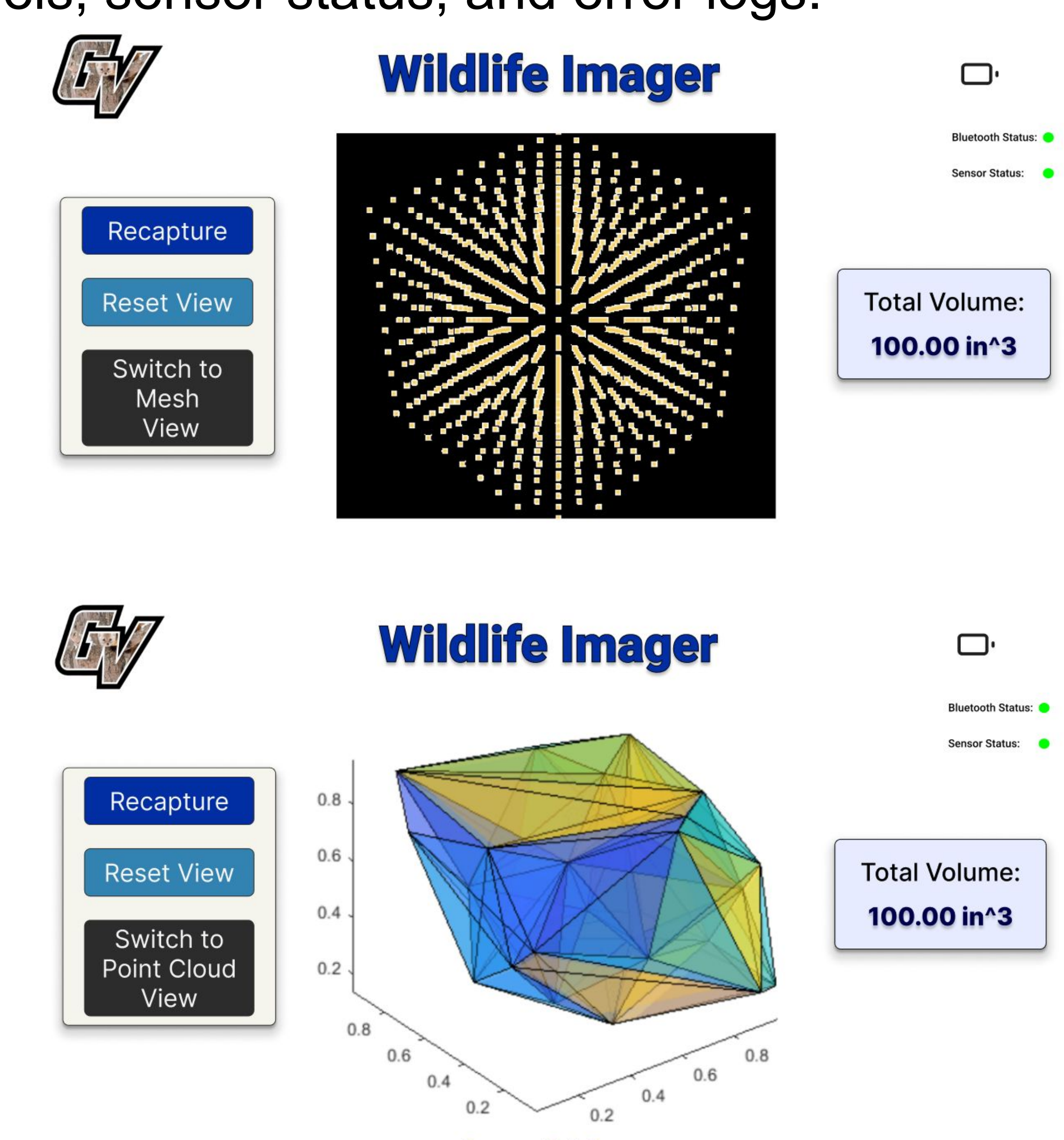


Two flex PCBs holds seven time-of-flight sensors and connects to the rigid PCB via an FPC-to-ZIF interface. The flex PCBs are 2-layer boards, with signal traces on one layer and routing to sensors via the second layer. Hatched ground planes provide signal return paths, and teardrop vias prevent copper cracking in flexible regions. Aluminum stiffeners support each sensor location for mechanical stability and accurate alignment behind the cover glass, with additional stiffening at the connector. Each sensor connects to shared I2C and reset line, separate communication enable lines, and power for each flex PCB. Required resistors and decoupling capacitors are included across both PCBs.



Software Design

The Wildlife Imager software consists of an Android app and embedded STM32WB55 firmware, communicating via a custom BLE GATT profile. The app, is built in Kotlin with an MVVM architecture, allows users to start captures, view sensor data, and monitor device status. The results are shown in point cloud, mesh view and overall calculated volume. The embedded firmware, structured with FreeRTOS and a centralized finite state machine (FSM), manages sensor control, data processing, and communication. It coordinates 14 ToF sensors across dual I2C buses, processes point cloud data, and reports data to the app. Robust error handling, modular design, and non-blocking operations address past system shortcomings and ensure field reliability. The user interface is simplified for quick operation in outdoor conditions using a tablet, while BLE characteristics handle commands, data, battery levels, sensor status, and error logs.



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