Pipe Mapping via a Pass Through IMU-Based System

Adison Heathcott Caleb Thorne Benjamin Ask Elizabeth Russell

Tennessee Technological University

Goal of the Project

The goal of this project is to create a probe that can be guided through a length of pipe and collect positional data. This data will then be uploaded to a computer, which will receive, process, and plot the collected data to create a map of the pipe system.

Overall Design

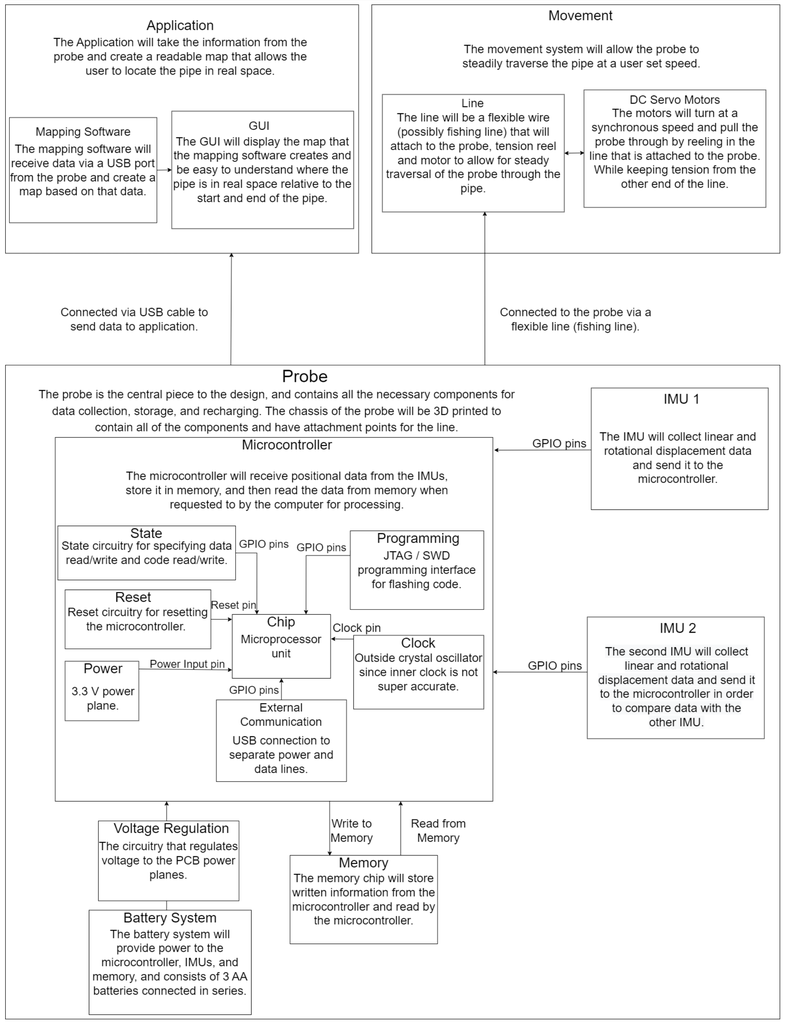
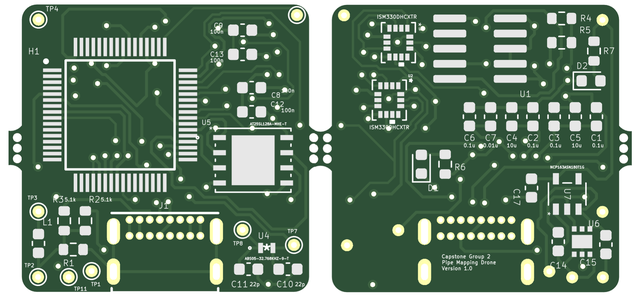


Figure 1. Block Diagram



PCB Front View PCB Back View

Figure 2. Initial PCB

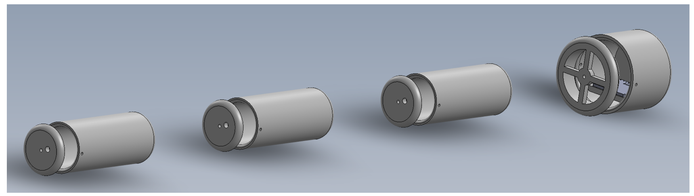


Figure 3. Probe Casing

The initial probe casing design shows the PCB case on the right and the battery casings follow it. Eyelets screwed end to end allow the casings to be tied together via fishing line and wrapped around the motor spools for testing.

Software

The software uses 3-axis position data from the accelerometer and 3-axis rotation data from the gyroscope to map a 3D path. The algorithm uses dead reckoning to map the data, which utilizes integration and Euler angles to calculate position across time. In addition, the software plots the ground truth in contrast to the calculated path and displays the distance between the endpoints.

Testing

The testing of the mapping system was done by guiding the probe along a line taped to the floor and wall of the capstone lab, followed by measuring the accuracy of the positional data against the "true position" of the pipe.

- **The memory** was tested by collecting data for 20 minute intervals and checking to ensure that the memory was not full after that length of time.
- **The battery life** was tested by measuring the initial battery voltage, then letting the system run for 20 minutes and measuring the battery voltage to calculate the total loss of charge. The load current of the probe was also measured, and was verified to be within an acceptable range.
- **The mapping system** was tested by gathering data from the probe, and comparing the resulting map with the physical path that the probe was guided on.
- **The movement system** was tested by pulling the battery casing through a 24 foot length of pipe while measuring the instantaneous velocity to ensure that it had minimal deviation throughout the run.

Results

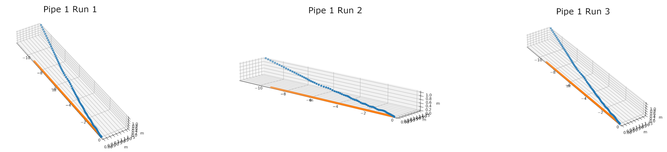


Figure 4. Plotted Results vs Ground Truth

The results show that the current implementation does not meet the initial specifications of being within 1" of the original pipe. However, it does give a general idea of the original pipe within an acceptable degree. After performing various tests to find the source of the error, the team has found a few sources.

Firstly, many subsystems had to be redesigned during implementation to fix errors in the initial design. Due to this the system was not able to fit into a pipe or the casing, so while the data was still obtained through valid methods, it was not the originally intended design. Secondly, natural error obtained from dead reckoning was compounded as the experiment was performed. While this error is not supposed to be significant, and the software helps to mitigate some of the error, it can not be ignored.

The results of the current design experiments show that the redesign in worth pursuing and would most likely give better results.

Future Work

The probe has many improvements that were realized after implementation. Firstly, the system could be greatly simplified by using an Arduino Nano instead of an NXP microcontroller. Secondly, replacing the 6-axis IMUs with 9-axis IMUs can assist the probe in providing more accurate results.

The PCB was redesigned to fit on top of the Arduino Nano and to connect through the GPIO pins. The IMUs and memory were placed onto the new board and connected to the respective GPIO pins for SPI communication. Two LDOs were added to regulate the power from the batteries to the various subsystems.

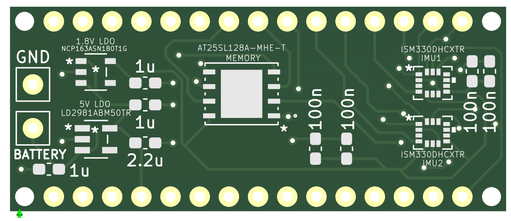


Figure 5. Redesigned PCB

Acknowledgements

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Another mention to xioTechnologies for supplying their open source software for mapping IMU data. https://github.com/xioTechnologies/Gait-Tracking