LeakLink

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Electrical and Computer Engineering Department

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Product Pitch

Meet LeakLink! Our small but mighty structural inspection robot, which is **designed to go where humans can't**. Civil and HVAC engineers often need to inspect small, pressurized ductwork where space is tight and visibility is poor. However, engineers currently lack a **cost-effective, accessible solution** to inspect the internal integrity of ductwork. LeakLink fixes this. Our robot goes inside these narrow passages, sending clear visual data in real time while moving as an **autonomous robot**.

LeakLink **identifies signs of damage** across different ductwork metals and is used by an HVAC engineer to assist them in their daily maintenance. Our robot detects the presence of cracks and corrosions, while also pinpointing their location to help **HVAC technicians** make faster and safer decisions. This robot is a **$400** product.

With at least an **85% detection accuracy rate**, it improves current HVAC detection by 15-20%, while pinpointing the location with a **10cm accuracy range**. The robot moves through the duct, stops in 10cm increments, inspects the area, and gives a light tap on the duct if a defect is detected! An HVAC engineer is able to see a **report of cracks and corrosion** present in the duct. The robot can stay **powered for up to 30 minutes** at a time before needing to be recharged by the user.

System Architecture

Our system design made use of 3 main control blocks:

- Jetson – taking care of the motion of the robot, the signal processing, and the machine learning as well as the logging and UI.
- Main Control – A Teensy MCU controlling the motor drivers on the robot and the solenoid tapper to signal defects
- Acoustic Sensing – Takes control of our real time camera feed to the user, our acoustic sensing hardware, and our analog to digital converter for signal processing

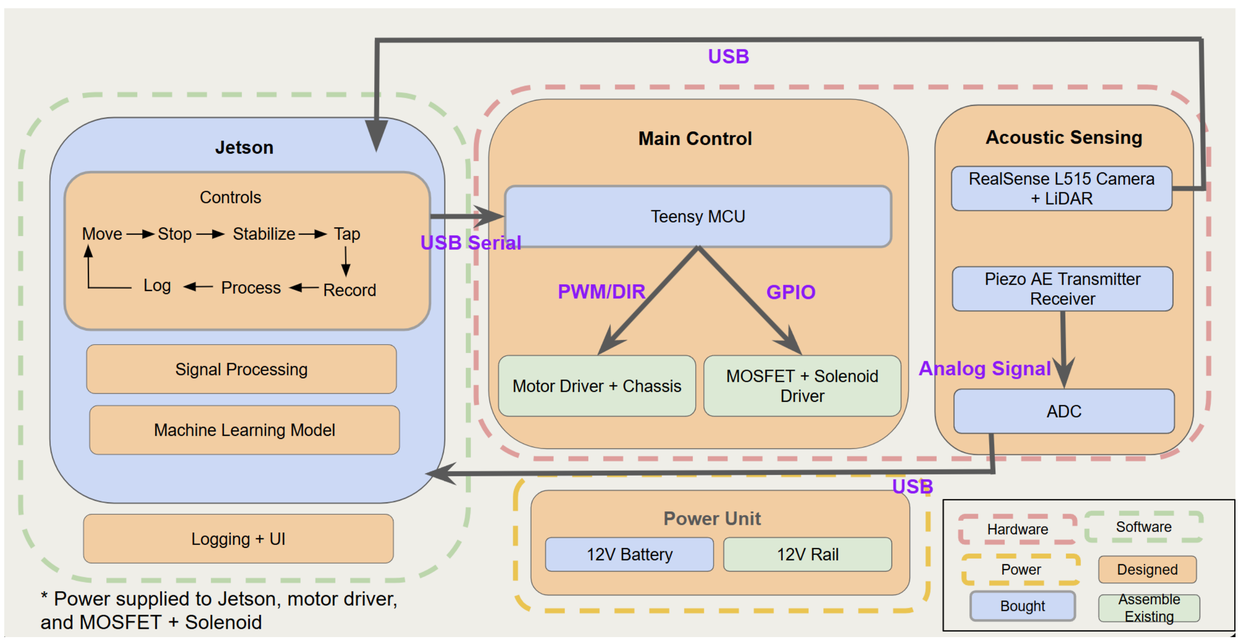

Figure 1: LeakLink System Design Block Diagram

Once our robot begins moving through the duct, because of the LiDAR telling it where it should move, the Teensy MCU controls the motor chassis drivers to move 10cm in front of its original position. Once this is done, the piezo AE transmitter transmits a wave and receives a reflected wave from the side of the HVAC duct. This is put through an analog-to-digital converter before being sent to our Jetson Orin Nano for the signal processing and onboard machine learning model to detect and classify corrosions and cracks.

Once finished, the robot repeats this as it moves through the duct. Making 90-degree bends when detected using LiDAR detection to successfully maneuver. We used a 12V LiPo4 battery to distribute 9V voltage to the MCU and the rest of the power to the other parts of our system.

Conclusions & Additional Information

Check out the QR code for more info about our team!

Overall, our team had a lot of fun with this project! We learnt a lot about an HVAC technician's daily life and what goes into classifying leaks and defects. We met some amazing mentors along the way while enhancing and applying our skills in machine learning, embedded systems, and perhaps even a little mechanical engineering!

As a team, we learnt how to go about testing systems that we build to ensure they meet the use case requirements, satisfy the users, and to ensure they last a long time and solve a problem instead of creating one.

In the future, we want to be able to expand this project to account for more HVAC materials beyond metals, and we want to improve location and accuracy.

System Description

- **Solenoid Tapper:** Simple mechanical subsystem where Teensy CMU will user a MOSFET to drive a solenoid tapper to lightly tap 5-6N of force on the HVAC duct to signal area of defect
- **Piezo AE Sensor:** Making use of a sampling rate of 200kHz to transmit waves and receive them
- **Nvidia Jetson Orin Nano:** Our main compute system to run our machine learning model
- **Machine Learning Model:** Our machine learning model consisted of a simple SVM where voltage values were taken and compared to classify and detect defects.

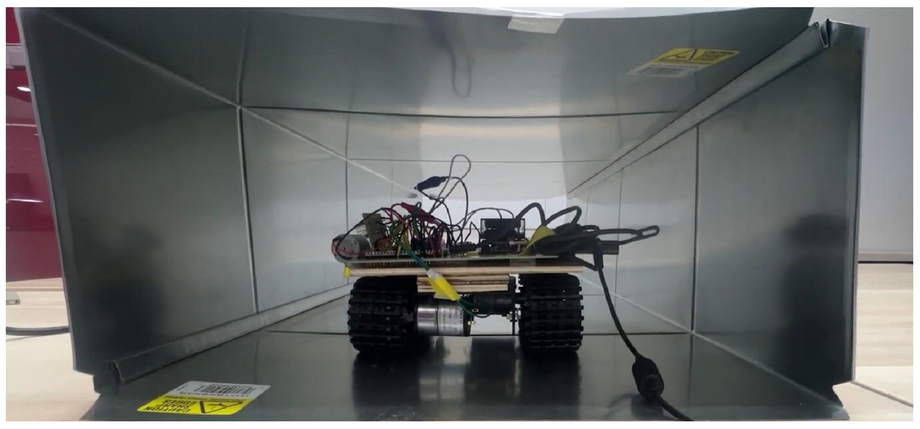

Figure 2: Picture of LeakLink Robot Navigating HVAC Duct

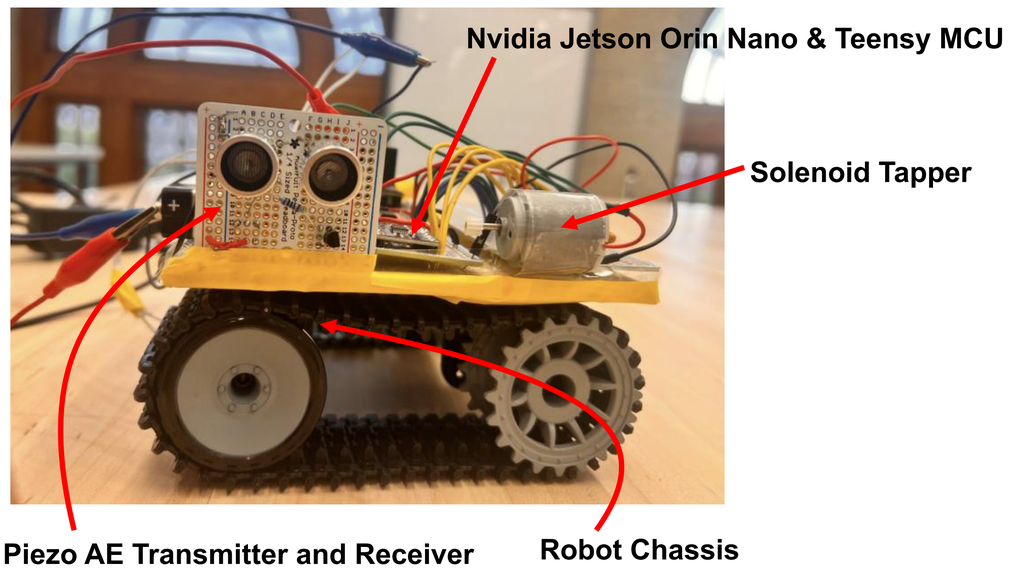

Figure 3: Labelled picture depicting overall LeakLink robot

System Evaluation

We conducted a variety of tests. We conducted user tests, where two HVAC engineers were asked to use the system we designed. We conducted a PCA analysis of our hand-held acoustic sensing system to the system on the robot, as depicted in figure 4. We conducted 90-degree turn angle tests to ensure our robot could complete 90 degree turns successfully. We also checked the machine learning model metrics in our testing of the system to ensure we had achieved our goal of 85% successful detection rate.

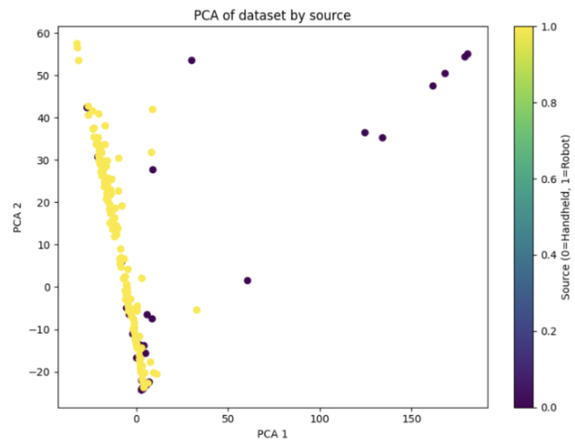

Figure 4: PCA Analysis of handheld acoustic sensing system vs on robot system

Use-Case Requirements:

Metric	Target	Actual
Battery Life	≥ 30 minutes	≥ 30 minutes
Detection Accuracy Rate	85%	83%-89%
HVAC Engineer Usability	Comfortable	Comfortable to great!
Cost	Less than $600	$400
Data Collection Stop Distance	10 to 15cm	10-12cm

Figure 5: Commercial HVAC Ducts

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