Pipe Inspection and Cleaning Robot

Team 47

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Problem Statement

Corrosion is an incessant problem; it's costly, elusive & dangerous. The global estimated cost of corrosion is 2 trillion dollars, along with an untraceable amount of ecological damage. Our robot is here to solve that - we are providing a way detect corrosion in one quick swoop. We clean soft sludge and run a corrosion detecting machine learning model right after, allowing it to be caught easily & early.

Constraints

1. **Pipe Diameter:** The pipe diameter must be 30 cm, which is the average diameter of oil & gas pipes.
2. **Isolated Pipe:** The pipe must be isolated and empty to avoid damaging the circuits.
3. **Semi-Solid Sludge:** Only semi-solid sludge will be cleaned, as solid sludge requires additional tools to be removed.

Target Specifications

1. **Corrosion Detection Accuracy > 80%:** The computer vision model must be above a certain threshold to make this project useful
2. **Max Speed > 1 km/hr:** The robot needs to go through long pipes to detect the corrosion and clean the sludge.
3. **Max Weight < 12 KG:** The robot should be relatively light to be able to travel through the pipe
4. **Operation Time > 30 min:** This will allow the robot to clean & scan a much larger portion of a pipe for each charge
5. **Image Resolution > 1080p:** Crisp image resolution will improve the machine learning model's accuracy

Project Impact

1. **Economic**: The robot cost 6000 riyals, which is much cheaper than traditional sludge cleaning & corrosion detection methods.
2. **Environmental**: Allows corrosion to be detected much earlier, lowering the risk of environmental spills
3. **Health**: Cleans sludge, lowering the risk of contamination and build up of bacteria

Prototype Design

The robot's design consists of an exterior 3D printed PLA+ shell. The shell is connected to three track belts, allowing it to traverse through pipes with ease. On the front, there are three rotating steel brushes that break up and clean sludge from within pipes, preparing the pipe walls for corrosion detection. There are 3 compartments inside the shell, which are exposed on the other side of the shell, and are holding a Jetson Orin Nano Board, an Arduino, and a powering circuit. The Jetson Orin Nano is connected to a camera and a flashlight, lighting up the inner pipe and allowing the camera to get a clear view of the pipe. The Jetson Orin Nano runs a Flask server and a machine learning model, detecting corrosion and transmitting the results through an Ethernet cable.
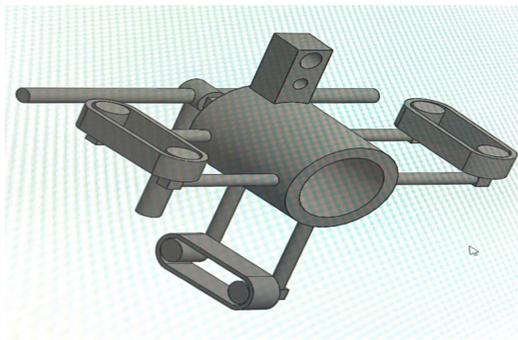

3D model
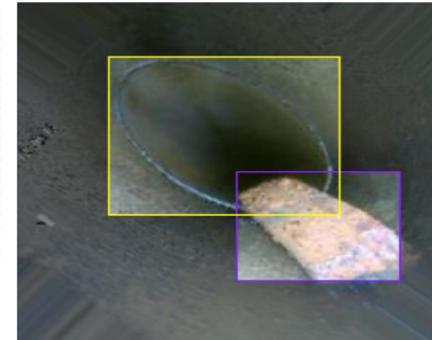
Corrosion detection

The Arduino is connected to a remote and the motor circuit, allowing the operator to control the robot. All the devices on the board are connected to a power source with different voltage levels, which is located outside of the pipe. The ethernet cable is connected to a laptop which receives the data and displays it for the operator. The interface allows the operator to relabel and retrain the model as needed.
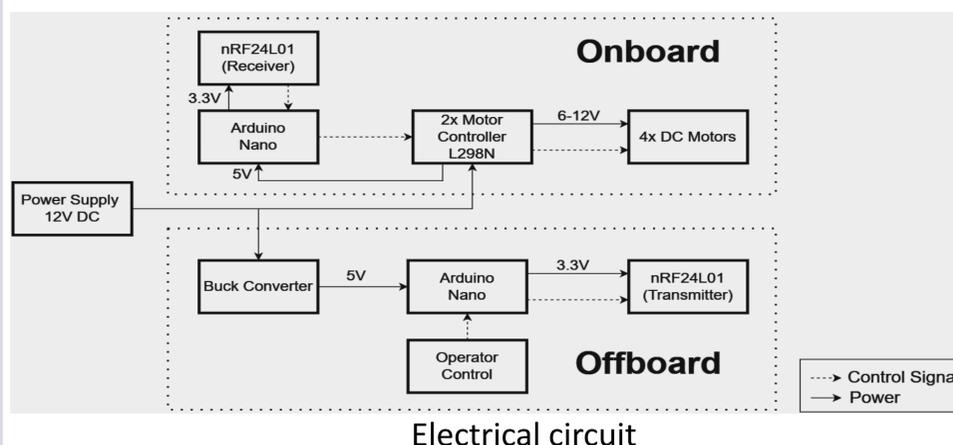

Electrical circuit

Testing & Validation

Operation Time: The total power consumption of The robot is 69.5 W at 12 V, utilizing a battery of 20,000 mAh the robot will last for more than 2 hours.

Robot Speed: To test the maximum speed, we measured the propulsion of the robot for 1.5 m and the robot covered it in 2.95 sec which corresponds to 1.83 km/h.

Robot Weight: After calculating the weight of the robot, it was found that the total weight is 2.39 Kg which is a satisfactory.
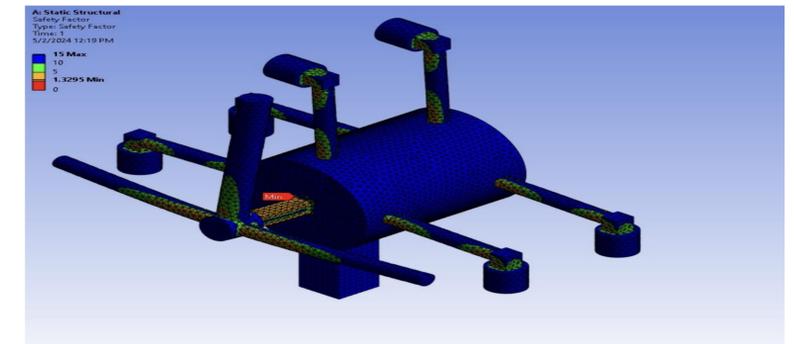
Corrosion Detection Accuracy: The model trained on our own dataset has a mAP50 of 96%, F1 at 91%, precision at 89% and recall at 93%. This meets the requirement for the default model.
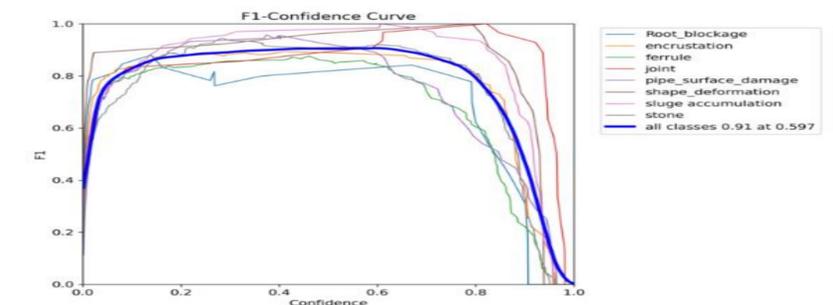
Camera Resolution: the robot utilizes a 1080p camera with high FOV

Conclusion

Our robot provides an innovative and unique attempt at tackling corrosion - we combined both cleaning and detection, resulting in an efficient and effective solution. Adaptability was also a core part of our design, allowing operators to retrain the model to meet their specific needs. In the final design, we managed to meet all specifications we originally set, along with managing to improve the project's design and scope.