Individual Project

The Flowbot

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EECE 5698 - Robotics Sensing and Navigation

Broad Overview

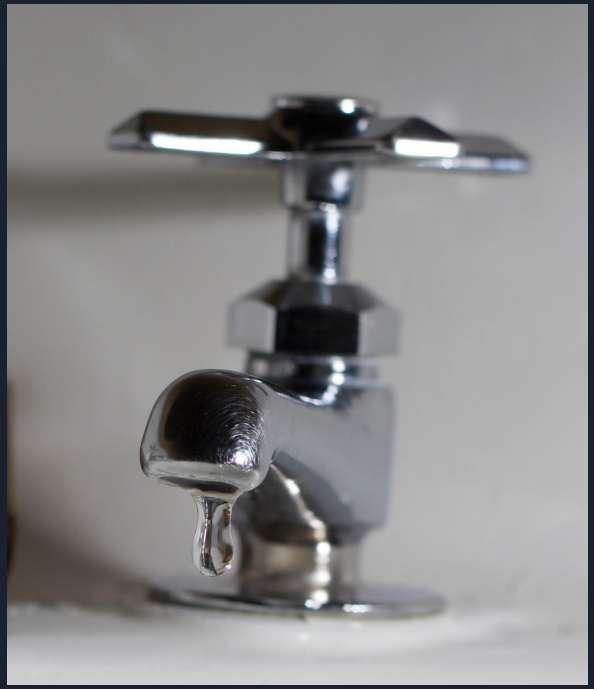
Flobot is a robot that autonomously explores water mains and determines if there are any leaks along the pipe. It maps out the general structure of a pipe and highlights areas where there are leaks and takes measurements of flow rate and water quality along the pipe.

It is meant fully autonomous once deployed in the pipe, and only requires human intervention for initial placement and subsequent retrieval.

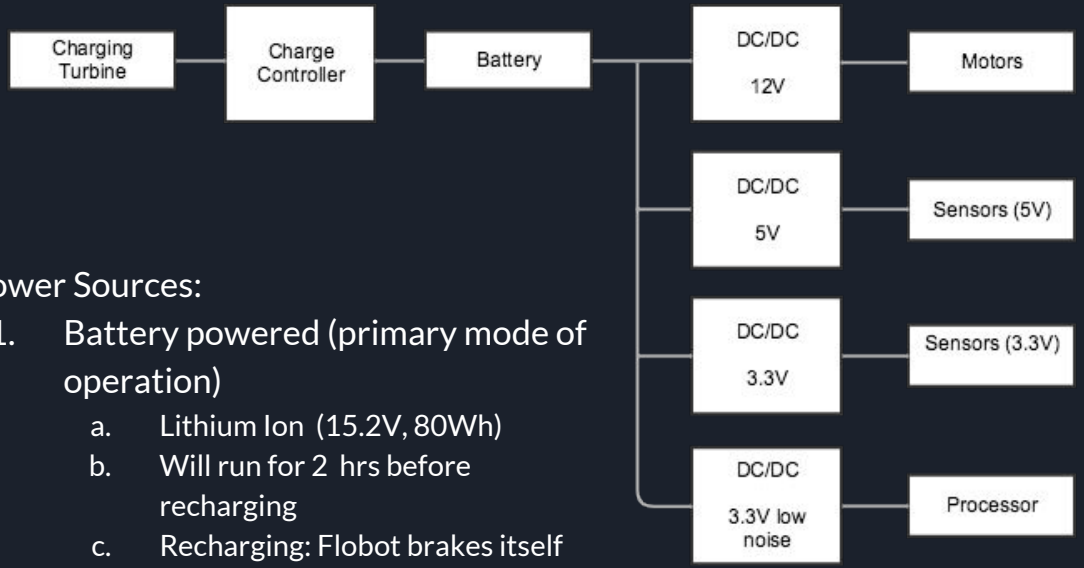
Mechanical design similar to this existing robot (Inuktun VT100)

1. Social value to the world

- It is critical to reduce wasted water, especially in arid environments such as southern california, south africa, and other water scarce environments.
- According to the EPA:
  - Worldwide, up to 60% of water is lost due to leaky pipes
  - In the US, an average of 700 water main pipes break every day
- According to the UN:
  - Water use has been growing more than 2x the rate of population growth in the world
- One step in fixing these problems is to ensure that as little water is wasted as possible. That involves examining and fixing leaky pipes
  - Proposed: a robot that can easily find leaks automatically



2. Power



Expected power use, by system:

Peripheral	Power (W)
Processor (ARM)	5
Motors (tracked wheels)	10
Cameras	3
Lights (strobe)	10
Sensors	10
TOTAL	38 W

Power Sources:

1. Battery powered (primary mode of operation)
   a. Lithium Ion (15.2V, 80Wh)
   b. Will run for 2 hrs before recharging
   c. Recharging: Flobot brakes itself in the pipe, and uses a small turbine to recharge its battery

2. Corded Usage (secondary method)
   a. Allows for continuous use without recharge time, but requires an operator to manage the cable.

3. Sensing

- Cameras (front and rear, wide angle)
  - Strobe lights for cameras
- IMU (VectorNav VN-100)
- Encoders on tracks
- Water quality sensors
  - Water speed
  - Temperature
  - pH
  - Conductivity
  - Dissolved Oxygen
  - ORP/Redox

Flobot saves its data to a memory card, which can be retrieved after its mission is complete, downloaded, and further examined.

Automatically highlights areas it predicts to be a problem (e.g. abnormal water quality, cracks in pipe wall, unusual water speed, etc.)

4. Navigation

Primary mode of navigation: distance from encoder movement combined with inertial mapping

- Expected error:
  - Low error in overall distance, due to very little slippage between tracks and wall
  - Higher amount of error expected in roll, pitch, and especially yaw due to IMU
- Pipe system likely not very complex, limited number of potential to map
  - Explores every branch of a pipe system until blockage or constriction
  - Optional setting: only explores a certain distance of pipe, to reduce time spent mapping and charging
- Additional sensing from IMU to estimate height changes/turns in pipe

After the mission

- On-board GSM texts operator when it is time to be retrieved. Also flashes lights and beeps periodically while waiting for retrieval.

Optionally, the robot can be manually controlled.

5. Systems Level Design

Overall, this system allows for automatic inspection of water pipes. It:

- Is placed in a water main
- Runs, navigating and collecting data about water quality and presence of leaks
- Goes back to starting position for operator retrieval
- Creates map of piping system and potential problem areas/water quality for post mission analysis

Social Value

- Reduce wasted water in the world.

Power

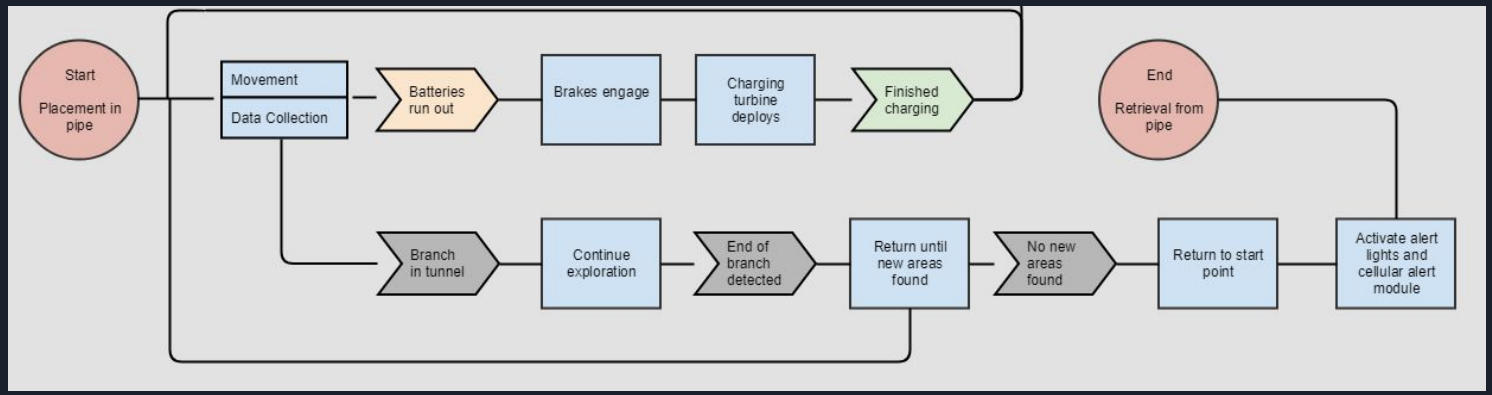
- Around 40W total
- Runs for 2 hours between charges
- Recharges with turbine when necessary

Sensing

- Camera, IMU, encoders, water quality sensors

Navigation

- Position estimation with encoders
- inertial measurements for yaw, pitch, roll



Safety Considerations

Battery:

The battery and power system is contained inside a titanium container rated to at least three times the highest expected pressure in a water main.

System Failure:

If the motor or other critical system fails, it will engage its brake and enable the “detection” mode for easier retrieval.

Further Thoughts

Existing pipe inspection robots:

- http://inuktun.com/en/vt100-vertical-crawler-inspection-vehicle/
- https://www.environmental-expert.com/products/pan-tilt-camera-556611
    - Both robots:
        - Manually controlled, not fully robotic
        - Tethered only operation
- http://www.whoi.edu/main/remus-tunnel-inspection-vehicle
- REMUS
    - For larger scale water mains
    - Uses propellor and fins, not tracks

ossible further upgrades to Flobot:

- Sewage/other pipe inspection (needs to be more robust to fod)
- Smaller and larger versions for wider range of pipe sizes