TEAM # 3

AUTONOMOUS MAINTENANCE VEHICLE

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PURDUE POLYTECHNIC

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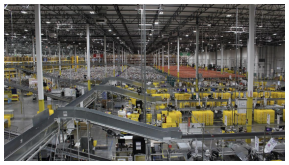
CUSTOMER BACKGROUND

Amazon is the world's largest multinational online retail firm selling a vast array of products such as electronics, clothing, home goods, and more through its online marketplace. Amazon serves millions of customers across the globe, delivering 4.75 billion packages in the United States alone in 2021. Amazon is able to achieve this through its 1,137 fulfillment centers located in the US. Amazon also has fulfillment centers in Canada, Mexico, Brazil, UK, Germany, and many more countries. The performance and success of these fulfillment centers drive Amazon's business. Maintaining the conveyer belts within these facilities is one of Amazon's main priorities and essential to keeping its promise of same-day-delivery to its customers.

PROBLEM STATEMENT/ SCOPE OF WORK



Challenges arise when maintenance technicians manually inspect conveyor systems at Amazon, including the difficulty of accessing parts 20-30 feet in the air, the sheer size of the system, and the possibility of human error. Belt failures account for 75% of severe breakdowns, which can cause the belts to tear due to friction and heat. The original version of the Tote Ranger was ineffective in identifying belt failures and required a technician to manually review recorded data. A new maintenance identification unit that can inspect critical lines and report concerns to the local maintenance team is being developed to improve facility reliability and customer satisfaction by allowing for proactive maintenance planning.

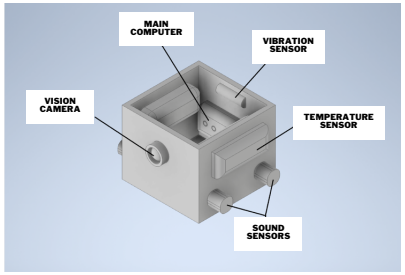
REQUIREMENTS

1. Detect 95% of bearing failures on conveyors it passes over.
2. Measure temperature of components (60-130 degrees Fahrenheit).
3. Detect screeching of failing components (accuracy of 87 decibels).
4. Contained within the tote (18”x15.5”x10” and less than 50 pounds).
5. Generates report of processed data within 5 minutes of cycle end.
6. Battery must last at least 40 minutes (twice the time of a cycle).
7. Build cost must be under $1000 (verified by BOM).
8. Identify and tag location of event (location of failing bearing)

EXPERIMENTATION AND CONCEPTS

The Tote Ranger has specific design requirements that must be tested and confirmed before the end of the project. These requirements include:

1. No components sticking out of the tote
2. All processing done onboard
3. Battery life of at least 40 minutes



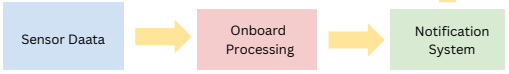
Testing of components:

1. To test the infrared camera, the team will heat a bearing 15 degrees above ambient temperature and confirm that the camera can pick up the change
2. The acoustic sensor will be tested in an environment above a determined decibel threshold
3. The localization algorithm uses acceleration data collected by the IMU, corrected for drift using the color sensor. The team assesses the approach's performance by simulating the Tote Ranger's path using Gazebo and measuring the total error in distance traveled.

FINAL DESIGN

Amazon warehouse tote measuring 18”x15.5”x10” with Raspberry PI, Lidar range sensors, color sensor, IMU, acoustic sensor, thermal camera, regular camera, and microcontroller. Microcontroller parses data from sensors and IMU and sends to Raspberry PI programmed with ROS to localize path, identify points of interest, and email a report. Color sensor detects conveyor belt or roller conveyor for localization drift correction. SLAM and Computer Vision packages enable localization and bearing damage identification. Compact device with low center of gravity and weight less than 50lbs. Stabilized retractable camera mount and clear PVC inner casing for quick visual inspection. Power: 6000mAh battery that lasts 40 minutes after full charge with LED indicator for recharging.

TIME	R AVG	G AVG	B AVG	BELT OR ROLLER
00:43.4	72	99	77	ROLLER
00:43.4	52	87	66	ROLLER
00:43.5	70	92	70	ROLLER
00:43.6	70	92	70	ROLLER
00:43.7	70	92	70	ROLLER
00:43.8	70	92	70	BELT
00:43.8	70	92	72	BELT
00:43.9	70	92	72	BELT



FMEA

Onboard Processing:

- Raspberry Pi is essential for reliable operation of Onboard Processing
- A failure in the current design is power disconnection
- **Solution**: An improved casing with leads for reliable connection and an internal error message to indicate failure

Collecting Data:

- Sensors have occasionally failed
- Accelerometer sensor localizes bearing damage
- Source of error: Minute values not registered
- **Solution**: Testing and comparing accelerometer with required precision

External Battery:

- Liable to get disconnected when maneuvered across lanes in the conveyor system
- **Solution**: Designing and testing a holding case to protect it from shock, and visual inspection of the LEDs to identify the issue

Lost Data Due to Static Shock:

- Data written and stored on SD card sometimes is corrupted due to static shock at key points on the conveyor belt
- All or most of data is lost following review of run
- **Solution:** Anti-static shock mat placed at bottom of tote to protect SD card

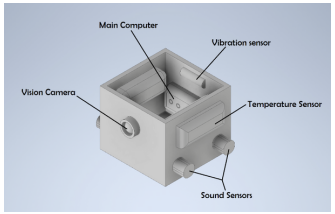
Compatibility Issues between Micro SD and Raspberry Pi:

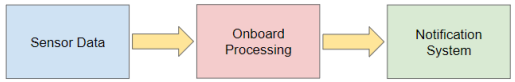
- Off-brand Micro SD card used in Raspberry Pi caused sensors to fail when initializing and resulted in damage to internal processor
- **Solution**: Sticking with SanDisk products

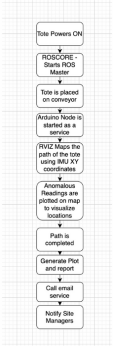
TESTING

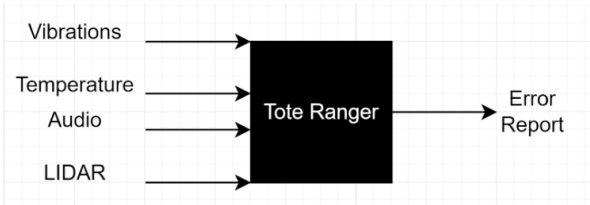
The Tote Ranger underwent various tests during the component testing phase to ensure that all sensors were accurate and met the team's requirements.

- LIDAR sensors were tested for accuracy
- Acoustic sensor was tested for sound accuracy
- Infrared camera was tested using a heat gun
- RGB sensor was tested by placing different colors in front of it.
- Accelerometer will be tested on a small scale on a treadmill before larger-scale testing at an Amazon facility
- Localization is a high priority, and multiple tests will be conducted to ensure that the Tote Ranger can detect its position accurately
- Lastly, the data processing side of the project is being developed to ensure that data can be transmitted to the necessary parties.


Main Computer
Vibration sensor
Vision Camera
Temperature Sensor
Sound Sensors


Sensor Data
Onboard Processing
Notification System


Tote Powers ON
ROSCORE - Starts ROS Master
Tote is placed on conveyor
Arduino Node is started as a service
RVIZ Maps the path of the tote using IMU XY coordinates
Anomalous Readings are plotted on map to visualize locations
Path is completed
Generate Plot and report
Call email service
Notify Site Managers


Vibrations
Temperature
Audio
LIDAR
Tote Ranger
Error Report