Team 1

Hug the Rails IoT Project

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Section 1: Introduction

1.1 Problem Statement

Current train systems require wifi connection to receive information about weather conditions; however, with the loss of internet and cellular connection it is difficult for operators or train systems to receive data and adjust accordingly. By using sensors that allow us to access data on precipitation and wind speed, we will be able to monitor and adjust the speed at which trains travel without having access to wifi. This will allow passengers to arrive at their destination in a safer manner and will also be more cost effective as monitoring and adjusting speeds locally in hazardous conditions will lead to fewer maintenance issues within the trains themselves.

1.2 Stakeholders and Users

The stakeholders for this project will be the NJ Transit Corporation, who have asked us to add IoT devices and software to their trains to account for inclement weather or other safety hazards. In addition to the NJ Transit Corporation, Reza Peyrovian and Leah Mitelberg are two high priority stakeholders. This will make the job of the user, or the locomotive operator, easier; they will have our software, run by inputs of the sensor data, changing the operation of the train automatically for the train to run in the most efficient and safe way possible, while still being able to enter commands and receive the status.

1.3 Importance and Values

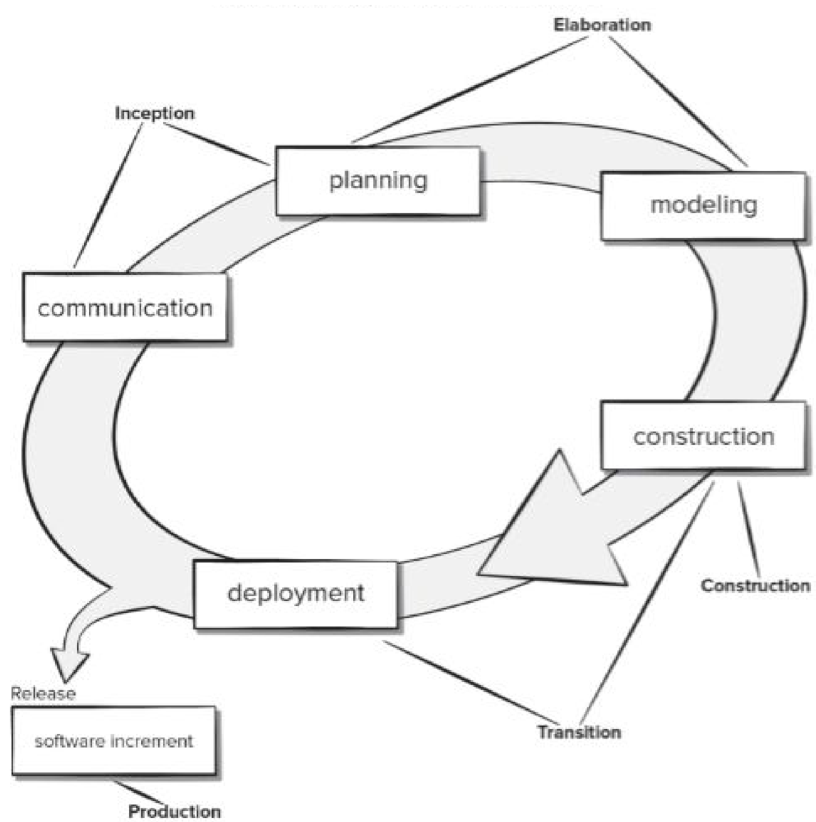
Without any manual intervention, data and tasks will be transmitted and executed. Since IoT reduces human effort, more time will be saved, costs will be reduced and safety will be improved. As a result, increasing opportunities to analyze data in real-time and to further improve operations. For example, IoT significantly improved farmer lives through smart farming. Farmers use IoT enabled tools to monitor soil composition, soil moisture levels, and livestock activity. The tools collect data that can be analyzed to determine the best time to harvest plants.

1.4 Expected Delivery

We began this project on February 9th, and hope to have a complete and functional product which will be ready for deployment by April 1st.

1.5 Approach

Throughout this project, we will be implementing the unified process model. This will allow us to have a large amount of quality documentation for the duration of the project. The quality documentation will ensure that the group has enough information so that the actual construction process will be well defined and easy to follow. Also, as the group gets feedback from Professor Peyrovian and Leah, the requirements will be flexible enough to change or modify based on their requests. The unified process model accommodates requirements changes very well, which is another good reason that the group decided to choose this model.



The chart above outlines the flow of the unified process model. The start date for the group was 2/9, when the group began communicating. The planning phase extends through 3/4, where the group defined the problem and requirements for the solution. The modeling phase will last from then until 3/18, and construction will follow until the deployment date of 4/1.

Section 2: Overview

2.1 Define IoT

Iot or Internet of things refers to a system of interconnected, interrelated objects that collect and transfer data over a wireless network without any human intervention. In other words, Iot is an extension of the internet and other networks using sensors and devices.There are several components that come into play regarding Iot: sensors, connection and identification, actuators, Iot gateway, the cloud, and user interface. Sensors are able to measure observable changes in the environment. The type of data collected is primarily dependent on its function. In regards to connection and identification, data must be communicated from the device to the entire Iot system which is accomplished using its IP address. Iot devices should be able to take action based on data collected from sensors and the feedback received from the network. In addition, the Iot gateway acts as a bridge for different devices' data to reach the cloud. Once the cloud has received the data, software can easily reach this data for processing. This is beneficial in the long run as individual devices do not have to reach the cloud separately (less burden). Lastly, user interface allows users to make necessary changes executed by these devices, which adds quality to the overall user experience since there are several types of communication demonstrated (Device-to Device, Device-to-Cloud, Device-to-Gateway, and Back-End-Data-Sharing).

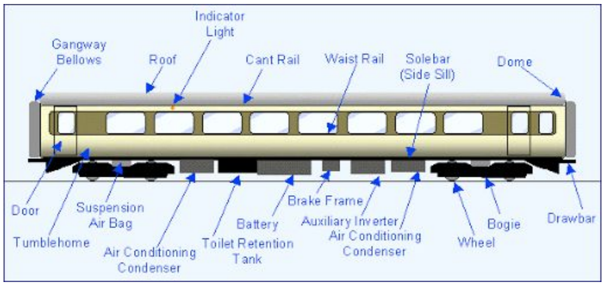
2.2 Define the Problem

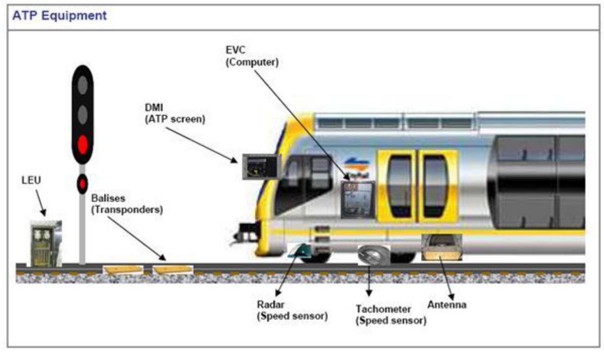
The operation of a train is often dependent on wifi network availability to receive data about environmental, travel, and traffic conditions. Based on those data, the train operator makes decisions about how the train operates. The purpose of this project is to use IoT to make those decisions locally, without being dependent on wifi network availability. This is important because if the train gets disconnected or the network fails, the train is able to continue operating safely.

2.3 Explain how IoT can Solve the Problem

The Internet of Things will help us solve the problem by allowing us to use two different types of sensors. The first type of sensor will allow us to detect how much precipitation is occurring in the area where the trains will be traveling. Based on the information received, the train will slow down (if there is a lot of rain) or maintain normal speed (if there is little to no rain). Similarly, the second type of sensor will allow us to monitor wind speeds in the path of the train. Just like the precipitation sensors, the wind sensors will either maintain the trains current speed (if the wind speed is negligible to low) or slow down the train (in the case where wind speeds could make traveling dangerous). By adjusting the trains speed in hazardous conditions, we hope to achieve a safer method of transportation for customers.

2.4 Overview of Architecture and Components





Components:

- Rain Gauge: Detect amount of rainfall in a given area
  - Hydreon Rain Gauge Model RG-15
- Anemometer: Detect wind speed in a given area
  - Kestrel 1000 Wind Meter
- Sensor to Detect Wheel Slippage
  - Honeywell TARS-IMU Sensors for Wheel Slippage Detection
- Radar Sensor: Detect standing objects on the path with distance; detect a moving object ahead and behind and their speed
  - Infineon´s XENSIV™ 60GHz Radar Sensors
- Separate Display System: Display output and notifications from IoT Engine
  - Advantech 10.4" SVGA / XGA Industrial Panel Mount Monitor
- Camera Sensor: Detect gate crossing open or closed
  - ITS-608 RAIL, 8.6° FOV

Architecture:

- Information from precipitation and wind speed sensors are run through IoT engine
- Metrics are displayed on a separate display system
- IoT engine alerts the operator if changes need to be made

Section 3: Requirements

3.1 Non-Functional Requirements

3.1.1 Reliability Requirements

R-1: Due to the nature of the data being collected by the sensors, the IoT HTR sensors must be able to handle inclement weather. This includes operation in temperatures ranging from -10℉ to 150℉ as well as all types of precipitation and wind speed.

R-2: IoT HTR components shall be able to withstand drops of up to 5 feet.

R-3: IoT HTR sensors shall be powered by the onboard train batteries; this will allow less maintenance of the individual sensors due to power-failure, as their power-source will be directly connected to the train.

R-4: IoT HTR system shall have reliability of 0.999. This will ensure safety of passengers and operators.

3.1.2 Performance Requirements

R-5: The IoT Engine shall have a response time of 0.5 seconds or less, assuming it has been turned on. This will ensure the operator will have enough time to react to the sensor readings.

R-6: The IoT Engine shall be able to support up to 1000 sensors, this will allow sensors to be placed on all relevant parts of the train to detect changes in wind speed and rainfall that may affect the train journey.

3.1.3 Security Requirements

R-7: Any tampering with the hardware of the sensors shall activate security measures to suspend the IoT engine. The data collected affects the alerts and recommended travel speed of the trains, so any tampering that could make the trains travel too fast in hazardous conditions and could have devastating consequences.

R-8: The conductors shall use a User ID and Password to access the data collected by the sensors. This will also prevent any people who should not have access from retrieving the data.

R-9 : Technician and operator log ins shall be recorded for security tracking purposes.

3.1.4 Operating System Requirements

R-10: 5 TB of data shall be used for storage of data while the trains are traveling. Once trains reach a station, they will have the opportunity to upload their data to a server, freeing the allotted 5 TB for their next trip.

R-11: Windows IoT shall be used as the IoT operating system for HTR

3.2 Functional Requirements

3.2.1 Detect the Wind Speed

R-12: The wind speed sensor shall detect the wind speed in miles per hour in the area in which the train is operating.

R-13: If the speed of the wind reached a potentially hazardous level (55+ mph), the operator shall receive a notification on the IoT interface with a recommendation to slow the train down to a specified safer speed based on the particular wind speed detected.

3.2.2 Detect the Amount of Precipitation

R-14: The precipitation sensor shall detect the amount of precipitation in inches that is in the area in which the train is operating.

R-15: If the amount of precipitation reaches a potentially hazardous level (0.3+ inches), the operator shall receive a notification on the IoT Interface with a recommendation to slow the train down to a specified safer speed based on the particular amount of rain.

3.2.3 Detect standing objects on the path with distance and suggest speed changes or brake

R-16: The radar sensor shall detect whether there is a stationary object in the path of the train and how far away it is

R-17: The reading from the radar sensor shall be passed to the IoT Engine.

R-18: If the distance between the train and the object is less than 10,000 feet the operator shall be notified, via the interface, of the object's distance and if the object that was detected requires a speed change for the train or for the brakes to be applied.

<u>3.2.4 Detect a moving object ahead and behind and their speed, direction of move and suggest speed changes or brake</u>

R-19: The radar sensor shall detect any other objects on the rails, and calculate the distance and speed of said object.

R-20: The distance reading from the radar sensor shall be passed to the IoT Engine.

R-21: If the distance between the train and the object is less than 10,000 feet the operator shall be notified, via the interface, of the object's distance and if the object that was detected requires a speed change for the train or for the brakes to be applied.

<u>3.2.5 Detect gate crossing open or closed, distance and speed (based on GPS), suggest speed changes or brake</u>

R-22: The camera sensor shall be used to detect if the gate is open or closed, whether the red lights are flashing, the distance the train is away from the gate, and the speed.

R-23: The information from the sensor shall be passed to the IoT Engine which will analyze the data.

R-24: If the gate is not down, the interface shall notify the operator that the gate is open.

<u>3.2.6 Detect wheel slippage, and its amount using GPS data and the wheel RPM, suggest speed changes, if any, or brake</u>

R-24: The sensor to detect wheel slippage shall be used to detect the amount of slippage occurring in the wheels, the wheels RPM, and based on this data the conductor will be informed of any speed changes that should be made or if the conductor should brake.

R-25: The sensor shall pass the RPM and wheel circumference to the IoT Engine which shall convert and analyze the data and use the GPS location and train speed to determine wheel slippage.

R-26: If the difference between the projected speed and calculated wheel speed is between 20-50 RPM, the IoT Engine shall inform the operator of wheel slippage using the IoT interface and display a caution message in orange.

R-27: If the difference between the projected speed and calculated wheel speed is greater than 50, the IoT Engine shall inform the operator of wheel slippage using the IoT interface and display an extreme caution message and the speed that should not be exceeded in red.

3.2.7 Sensors will store their readings in a local log

R-28: Every reading taken by the sensors shall be stored in a local log.

R-29: The size of the local log shall be 5TB.

R-30: The local log shall be uploaded to the cloud when wifi connection is available, then cleared from the local database.

R-31: The log shall only be accessible with valid login information.

Works Cited

Admin. “Automatic Train Protection Railway Signalling Equipment.” *Railway Signalling Concepts*, 4 Sept. 2019, www.railwaysignallingconcepts.in/automatic-train-protection-railway-signalling-equipment/.

Bustos, Alejandro, et al. “EMD-Based Methodology for the Identification of a High-Speed Train Running in a Gear Operating State.” *MDPI*, Multidisciplinary Digital Publishing Institute, 6 Mar. 2018, www.mdpi.com/1424-8220/18/3/793/htm.

Du, Lei, et al. “Speed Calibration and Traceability for Train-Borne 24 GHz Continuous-Wave Doppler Radar Sensor.” *MDPI*, Multidisciplinary Digital Publishing Institute, 24 Feb. 2020, www.mdpi.com/1424-8220/20/4/1230/htm.

Ltd, PRC Rail Consulting. “The Railway Technical Website.” *Coach Parts | The Railway Technical Website | PRC Rail Consulting Ltd*, www.railway-technical.com/trains/rolling-stock-index-l/train-equipment/coach-parts.html

Trend Micro . “Internet of Things (IoT).” *Definition*, www.trendmicro.com/vinfo/us/security/definition/internet-of-things.