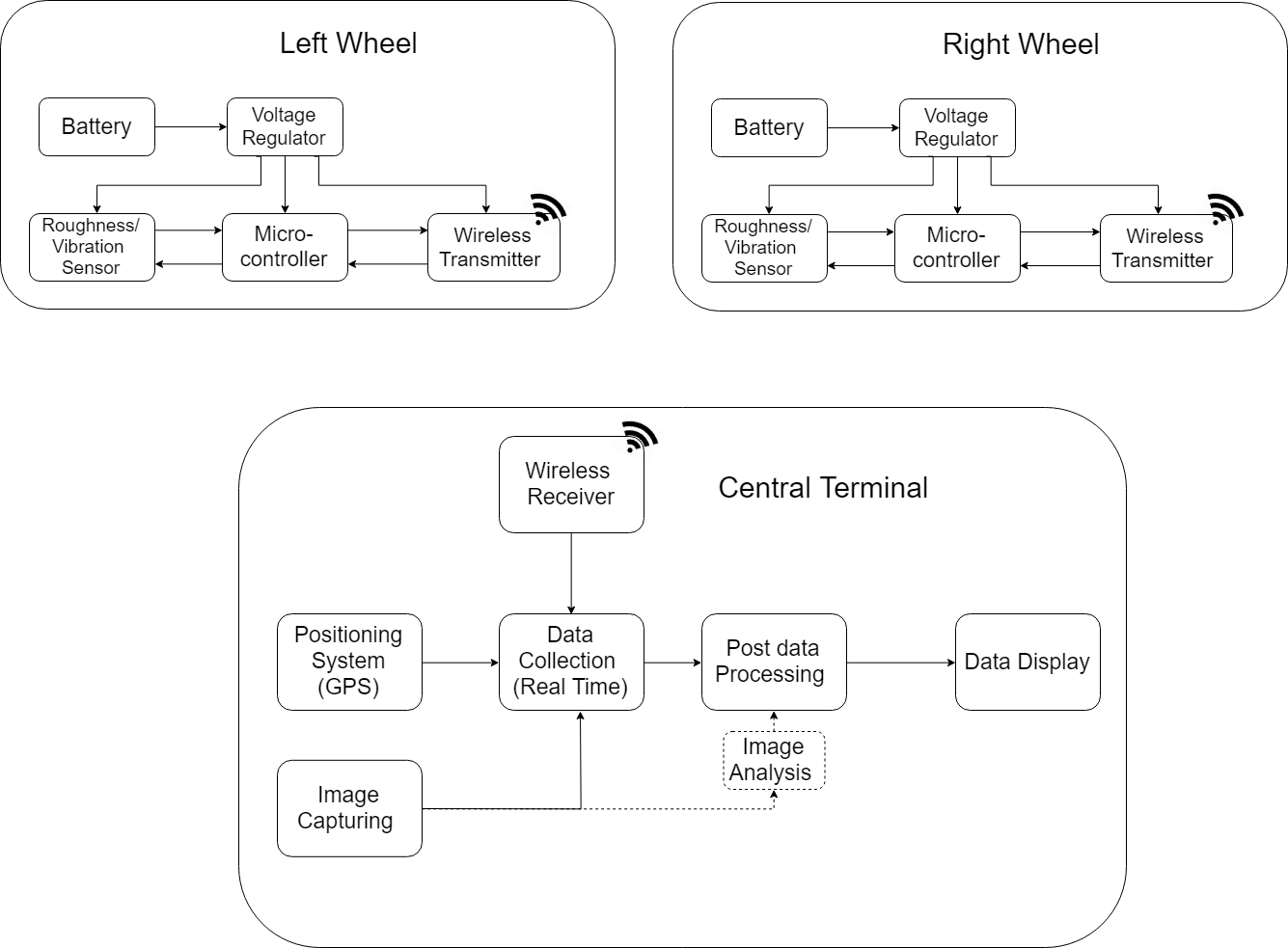
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|  | Integrated System for Measuring Road Roughness |
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# Project Description

Saskatchewan Ministry of Highways and Infrastructure currently spends close to half a million dollars annually to gather surface roughness and overall condition data of over 20,000 km of highways. The City of Regina uses also uses a similar system to gather data from major city roads every three years. We plan to minimize this cost by building a low cost and modular system that can be used to take measurements of the road roughness and can be used to supplement the more expensive equipment to map all of the roadways. This system will also be able to support the measurement of road surface roughness where data is not currently being collected such as smaller rural municipalities roads and residential city roads. The measurement of road roughness along with images that provide visual reference are used to quantify road surface conditions.

The system uses two roughness sensors (accelerometers) mounted directly over the two back wheels in a car that transmit real time roughness data wirelessly to a central terminal situated in the car. The car position is tracked with a GPS sensor that organizes the data transmitted to the central terminal with location coordinates of the car. At the same time a camera, attached to the central terminal, captures images of the road surface and the surroundings as the car is moving. The captured roughness and image data are stored in the central terminal. Afterwards, automated scripts process the data using digital signal processing tools to analyze the accelerometer and image data to extract usable information from the data. The required information is stored on the central terminal, which also acts as a server to upload the required data to a website. The website is used to display the information regarding road roughness and conditions in an intuitive and accessible format.



# Project Design Specification

The project design specifications are described for each subsystem as follows:

**Roughness Sensor/Analysis**

* Designed to be able to detect and characterize roughness of at least 5 cm vertical displacement over a 30 cm length of the road
* Proper characterization of the road requires sensors to be able to sample at least 1 m long section of the road at the posted speed limit of the road under normal condition
  + 100 km/h = 27.78 m/s -> 27.8 samples/sec – minimum sampling rate of 30 samples/sec required (may sample higher if required)
* Noise and other variables such as car speed, or car suspension system dynamics are either minimized or controlled in order to get a true indication of road surface roughness
* Comparison with data logged from a cell phone accelerometer to ensure that calibration is accurate (±10 %)

**Wireless Data Transmission**

* Data rate for the system should satisfy the minimum specified sample rate (minimum 30 samples/sec\*16 bits/sample = 480 bits/sec = 60 bytes/sec minimum required data rate)
* Receiver is able to simultaneously receive two separate incoming signals from both left wheel and right wheel and is also able to discriminate between the signals
* Adequate range to reach the receiver attached to the central processing unit (tested inside the car where system will be mounted)
* Signal interference should be minimized (signal transmitted == signal received)

**Positioning System (GPS)**

* GPS takes a minimum of one sample per second to precisely determine where the car is
* Positioning system maintains a similar accuracy (±20 %) as a cell phone GPS to accurately map out the car’s position on the road

**Image Capture/Analysis**

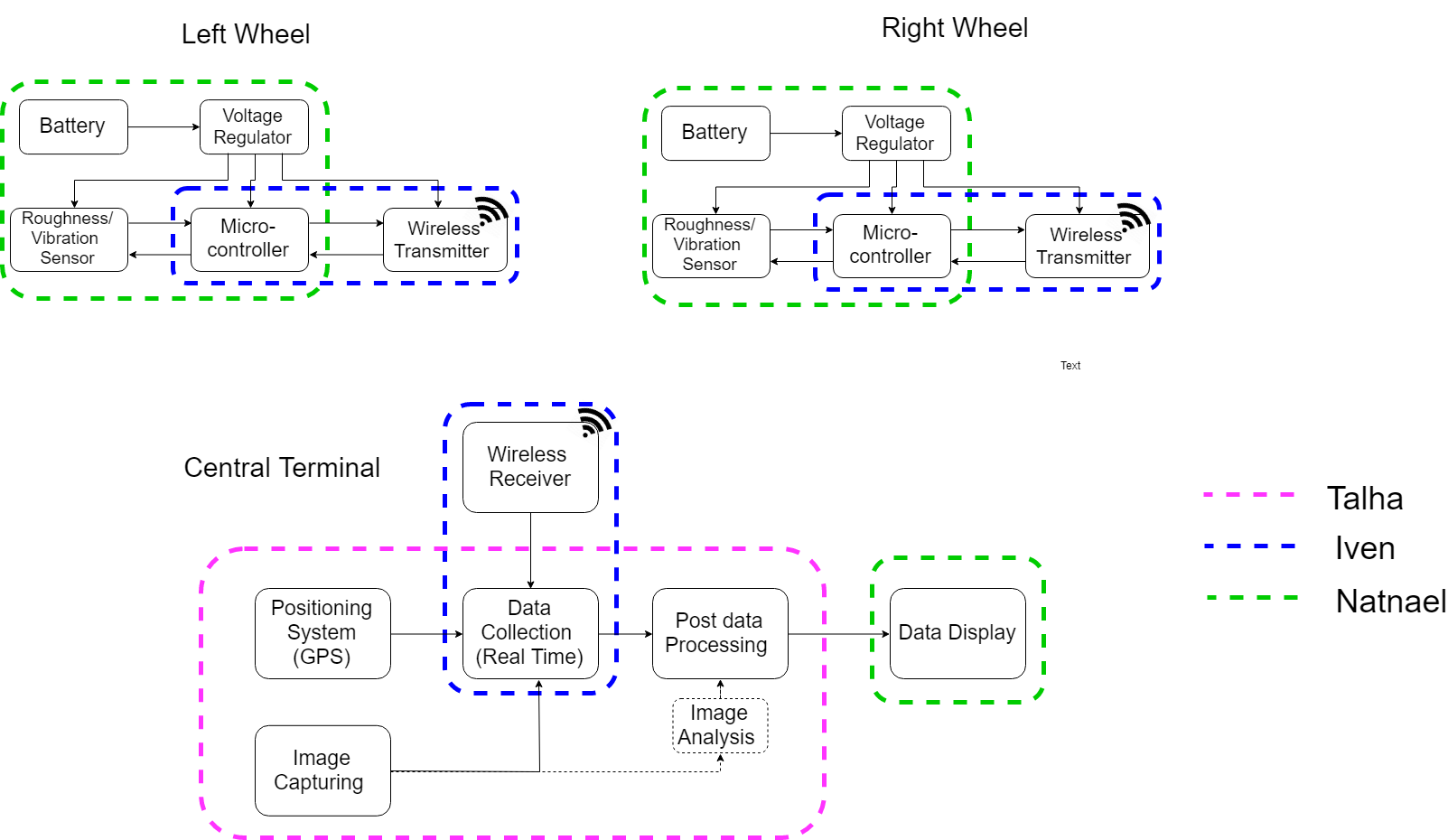
* Images are captured fast enough to capture the whole road surface: image taken every 10 meters (max speed 30 m/s, requires minimum of 3 pictures/second)
* Image analysis is able to identify at least 75% of major cracks/potholes in the road surface (snow on road surface might give inaccurate results)

**Battery/Voltage Regulator**

* Able to provide power to the components for a minimum of one hour of charge time
* Voltage regulator is able to provide the required voltage to power the connected device (3.3 V ± 10%)

# Project Testing Plan/Requirements

The project testing requirements and workload is divided based on the following block diagram showing various parts of the project, their interactions and the workload shared among the group members.



## 3.1 Individual Module Testing

**Roughness Sensor Testing**

Testing roughness sensor will entail that basic functionality such as being able to communicate with the device is tested all the way to being able to read acceleration values from the sensor.

1. Output data to terminal and check if acceleration data is correctly being read and sample rate is as specified (essentially move accelerometer up and down and observe changing of data).
2. Log accelerometer data and compare logged data with data captured with a phone accelerometer (most accurate reference available) to ensure sensor is roughly calibrated against a known reference.
3. Test accelerometer at rest and test what the effects of noise are on the system. Using noise spectrum as a guide for designing appropriate filters for reducing noise.

**Wireless Data Transmission Testing**

1. Test data transmission by sending minimum of 60 bytes/second from one Xbee communication device to another and checking if data transmission rate is adequately achieved (tested using XCTU tool).
2. Simultaneously transmit two different messages from each transmitter to the Xbee receiver and check if messages received can be differentiated based on sender. Check for delay in between messages.
3. Test Xbee device communication inside the car to ensure there is no packet loss, range is adequate and messages sent are the same as the messages received.

**GPS Testing**

1. GPS signal is tested for accuracy in comparison to a known reference, most likely cell-phone or other reference, if available. Latitude and longitude coordinates are logged and compared with an error rate calculated to ensure it is within performance specifications.
2. GPS data is logged with respect to time signal in order to ensure that sample rate is adequate.

**Image Capture Testing**

1. Mount camera in car travelling on road and test images taken to see if the whole road surface is being captured (every 10 m long section of the road)
2. Compare captured images to images analyzed using DSP and find what percentage of major potholes in the road are identified (tentative as snow on roads might give inaccurate results) .

**Voltage Regulator/Power Supply Test**

1. Test regulated voltage using multimeter to ensure it meets specification for voltage (3.3 V ±10%).

## 3.2 integration Testing plan

**Power Unit**

During the power unit testing phase, we will be performing a series of tests that will determine the overall power consumption of different components when working together. It will help us determine if we have adequate power available for all our components under normal operational conditions.

Components Under Test: Wireless Nodes (Accelerometer, Microcontroller, Xbee)

1. Record the initial voltage of the battery.
2. Run all the components simultaneously and test for maximum load.
3. Run system for at least 1 hour under maximum load.
4. Record the final voltage of the battery to see if battery meets performance specifications.

**Data Collection and Transmission**

Our first data collection test will be on our remote devices mounted on the car. We will be conducting a series of tests that will check the integration of our components to collect data using the roughness sensor with microcontroller and transmit the data using xbee automatically.

Components under test: accelerometer, xbee and microcontroller, raspberry pi (central processing unit).

1. Collect the data using accelerometer and store it into a buffer in the microcontroller. To check if acceleration data is correctly being read and sample rate is as specified by outputting the buffer to a terminal.
2. Test Xbee data reception with all wireless nodes connected to ensure that sampled data is received in correct/predictable order.
3. Test throughput of the data with the selected sample rates. With the receiving node being the limiting factor it will be tested to ensure it can receive the data being transmitted simultaneously from all the nodes.
4. Throughput will be tested with the minimum specified data rate to see if that is possible.
5. Throughput will also be tested to try and find the maximum possible rate with all the nodes transmitting.

Our second data collection test will be performed on central processing unit. We will be testing the timing or GPS data collection conjunction with the timing of our image capturing process and Xbee data reception.

1. Test data collection from GPS, sampled data received from xbees and images captured to ensure data is synchronized and received in the correct order. GPS to be used as the synchronization mechanism.
2. Test to ensure that sampled data is received and logged. Error handling for missed data.

**Data Analysis/Organization**

Using our analysis algorithm, we will be conducting tests to see whether the data we are collecting is adequate to assign IRI to the road surfaces. We will also run tests on different algorithm to find on optimum for presenting the information in a usable format.

Components under tests: raspberry pi, accelerometer, xbee, microcontroller. Analysis using Matlab/Python.

1. With the integrated system mounted in car, drive car over smooth road surface and record data.
2. Drive car over smooth road with a known bump (piece of plywood) and record data.
3. Using different sample rates starting from the minimum specified and moving up until maximum possible data transmission rate is reached, repeat steps 1 and 2 for each selected sample rate.
4. Design and test different filters (low pass IIR, low pass FIR, band pass, moving average) to analyze the data.
5. Test various integration methods (trapezoidal, Simpson’s, etc.) on the collected (filtered) data.
6. Analyze the combination of the filtered and integrated data at various sample rates to select the combo that best characterizes the roughness of the car based on driving over the piece of the plywood in contrast to travelling on the smooth surface.

# 4.0 gANTT cHART

