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Development of Telemetry system for Student Formula Cars and All-terrain vehicles

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Abstract

A reliable method for observing the performance of various systems in a student-designed formula car or All-terrain Vehicle (ATV) is quite expensive, and choices are seemed to be bounded. This paper proposes a lightweight, low power consumption and most affordable system which can collect data from various sensors placed in student formula vehicles and send it to a pit stop or ground station. We have attached multiple sensors to collect data which includes temperature from brake discs, engine, cockpit, RPM of Shaft, Load exerted by driver on brake pedals, and steering angle. An onboard microcontroller is programmed to collect and transmit data via the LoRa transceiver. At the ground point, a microcontroller with the same LoRa module tuned as the receiver is programmed to receive the data and display it to the crew. This data can be used to analyse the performance of vehicles in test conditions and compare them to design data.

1. Introduction

Formula Student is a platform for a team of enthusiast students where a small-scale formula vehicle is designed and manufactured by the students. A Student ATV competition is where the students are expected to design and manufacture an ATV which can perform well in off-road conditions. The most famous event among Student ATVs is SAE BAJA. These vehicles undergo various tests and finally experience a traditional track race to compete with other teams from various institutes. The conditions that need to be considered while designing the vehicle are drafted by the organisation handling the events. In such a complex scenario, an electronic system to monitor the performance of various mechanical systems in the vehicle is required for evaluating and analysing the performance. This data can be used to tune the vehicle accordingly. The "Formula SAE," or Society of Automotive Engineers (SAE), is a competition in which academic teams compete in the design, manufacture, and testing of single-seater prototype vehicles (Barakat). The completed electronic system can collect data from the mechanical system and vehicle dynamics and communicate it wirelessly to a base station where technicians may monitor it at all times (Visconti, Primiceri, and Orlando Visconti, Primiceri, and Cavalera). An intelligent multifeatures statistical technique was used to present a driving condition control system for a hybrid electric vehicle (HEV) (Huang, Tan, and He Ashok) created a telemetry system for agricultural monitoring.

The built data acquisition and telemetry systems for industry and aerospace applications; the authors offered a real-time DAQ system with decreased size and weight that could interface to various pressure and temperature sensors via 32 low frequency and two high-frequency channels. (Satija, Ramkumar, and Manikandan) created a telemetry system for monitoring the functioning of a solar-powered vehicle. For example, in (Martins et al.), the authors presented an electrocardiogram (ECG) telemetry system for continuous cardiac health monitoring applications. They created a lightweight ECG SQA method for automatically analysing the quality of obtained ECG signals in various situations and locations. The authors of (Rahman et al.) devised a valuable instrument for acoustic signal monitoring. Many other research works deal with telemetry systems for automotive and other application fields (Primiceri et al.). The STM-32 Nucleo F411RE prototyping board (Visconti et al. Bhat et al.) has a conditioning section that adapts the signal levels produced by sensors to the input range of the STM-32 Nucleo F411RE prototyping board.

A telemetry system built using Arduino development boards can help the team retrieve the outputs of various sensors attached to the mechanical systems on the vehicle. For example, a linear potentiometer can be connected to the suspension system and get the data of the displacement of the coil. This can help the team tune the suspension according to the race track conditions. Similarly, a temperature sensor placed in the driver's cockpit can help understand the temperatures faced by the driver and improve the insulation. To keep the cost low and use a simple telemetry connection method, it uses a microcontroller-based system. RF interfaces are mostly preferred over other methods due to their long-range capabilities. It is also the cheapest and most power-efficient method for Formula Student applications.

2. Methodology

2.1. Telemetry system and Working Methodology

The main modules involved in our proposed solution are Data Transmitter and Acquisition circuits. This allows the teammates to monitor the status of the mechanical system attached to the sensor. In our project car, we placed Non-Contact Thermal Sensors at brake discs, a load cell on the brake pedal, an IR sensor for collecting the rpm of the wheel shaft and a potentiometer for sensing steering angle.

In the car, an Arduino Mega 2560 Dev. Board is placed and attached with sensors mentioned above are mounted on the respective positions. For Transmitting the collected data, a LoRa SX1278 Module is mounted along with a suitable antenna for long-range transmission. On the Data Acquisition side, another LoRa Sx1278 module attached with the Arduino dev board is programmed to collect the data from the car (Anjum et al. Chanwattanapong et al. Eridani et al.). The collected data is post-processed using MS Excel for visualising the vehicle performance on the track.

2.2. Arduino Mega 2560 Development Board

The Arduino development board acts as the brain of both transmitter and the data acquisition station. This specific board is chosen for this application due to many GPIOs and flash memory requirements. Also, the Mega board provides a more significant flash memory; hence we can work with programs larger than those on Uno.

It needs a serial peripheral interface for a microcontroller to utilise the Lora module. This can be found in Arduino boards (Opipah et al.). The serial peripheral interface helps the microcontroller to interact with nearby devices. Using SPI, we can communicate between two or more microcontrollers. The Arduino Mega is shown in Figure (1)

In SPI, there is always a master which controls its slave devices. Generally, there are three standard wires to all the devices.

MISO (Master In Slave Out) - The Slave line for sending data to the master,

MOSI (Master Out Slave In) - The Master line for sending data to the peripherals,

SCK (Serial Clock) - The clock pulses which synchronise data transmission generated by the master and one line specific for every device:

SS (Slave Select) - the pin on each device that the master can use to enable and disable specific devices.

When a device's SS pin is low, it communicates with the master. If it is high, it ignores the master.

This allows us to communicate with multiple Slaves sharing the same MISO, MOSI, SCK Lines.

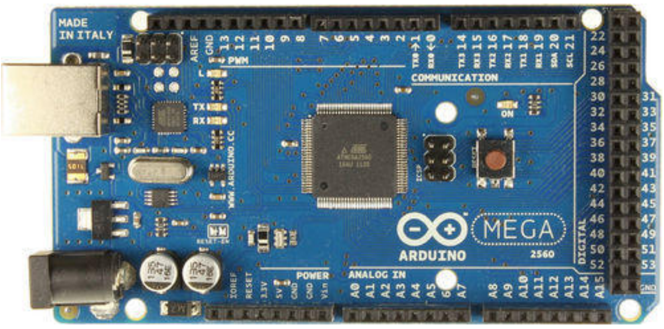

FIGURE 1. **Arduino Mega Board**

2.3. LoRa SX1278 Module

The SX1278 is an ultra-long-range (15+ miles) transceiver for 868MHz or 915MHz band. It features the LoRa® long-range modem, which provides ultra-long range spread spectrum communication and high interference immunity while minimising current consumption. This device is perfect for remote area networks, industrial automation, innovative city applications, etc.

Lora SX1278 (433MHz) is a low-cost, high sensitivity, long-range modem. It has a sensitivity of over -148dBm and a link budget that enables it to transmit at ranges of up to 5km+ and interact with many sensors that radiates radio waves. This highly sensitive modem is perfect for any application that requires a degree. The module used is shown in the below figure (Figure 2)

FIGURE 2. **Lora Ra02 Module**

2.4. Non-Contact Thermal Sensor (MLX90614)

The MLX 90614 is a non-contact temperature sensor that uses infrared technology. It features non-contact, small size, high precision, and low-cost advantages. Contact type sensors can only measure temperature after the object to be measured and the temperature sensor has reached temperature equilibrium, so the reaction time is long and easily affected by ambient temperatures; infrared measurement, on the other hand, can measure the temperature before the object to be measured and the temperature sensor has reached temperature equilibrium. Temperature is used to determine the temperature of an object in terms of the object's infrared emission. It does not affect the thing being measured, but it does affect the temperature distribution of the measured object. The temperature range is limited, and the stability is excellent.

FIGURE 3. **Non Contact Thermal Sensor**

The MLX90614 includes the MLX81101 infrared thermopile sensor and the MLX90302 signal processing chip, including a power stabilization circuit, low-frequency amplifier, A/D converter, DSP unit, PWM circuit, and logic control circuit. The heat signal is released with an infrared thermopile sensor, amplified with low internal noise, a low-offset amplifier (OPA), and converted to a 17-bit digital signal by an A/ D converter (ADC) after processing and extraction using low-level FIR and IIR filters (i.e., DSP); the output result is stored in an internal RAM storage unit. The MLX90614 has two memories: EEPROM and RAM. In MLX90614, which has the address 000H-01FH, there are 32 EEPROM memory cells with a 16-piece letter length. SMBus can read all EEPROM registers, but only part of them (addresses 0x00, 0x01, 0x02, 0x03, 0x04, 0x05 *, 0x0E, 0x0F, 0x09) can be rewritten. These sensors are mounted near each wheel's brake discs to collect temperature.

2.5. Load Cell

To measure the force exerted by the driver on the brake pedal, an S type load cell has been included in the design. S Type load cells are generally used for measuring tensile forces, but they also offer good feedback on compressive forces. Hence, this can be the ideal load cell design for measuring the brake pedal effort.

Like all other modern load cells, S Type load cells are transducers that convert force or weight into an electrical signal through strain gauges. When experiencing a load, the main body of the load cell deforms slightly. The strain gauges, which are firmly bonded to the load cell body, also distort, altering their electrical resistance. This generates a voltage signal proportional to the initial force or weight.

FIGURE 4. **S Type Load Cell**

2.6. Load Cell Amplifier

It can read the loadcells to measure the weight using the loadcell amplifier. By connecting the amplifier to the microcontroller, we will be able to read the change in resistance of the load cell. Calibrating according to a standard weight can help us measure the load precisely and accurately.

The Strain gauges in the load cell are very tiny. Thus, the strain values obtained from these gauges are minimal; hence it's complicated for microcontrollers to detect changes. Therefore, adopting a wheat stone bridge into the system is a better way to raise the value of resistances so that the microcontroller can understand the difference in the resistance. HX711 (Figure 5) has an ADC, which has a resolution of 0.298uV, which is very low compared to the solution of 4.88mV of the onboard ADC of Arduino. Hence Having HX711 is mandatory for using a Load Cell.

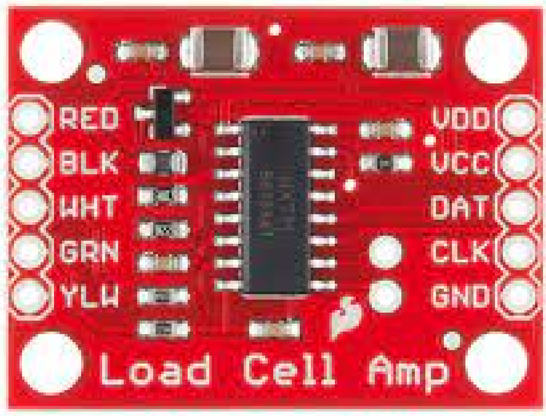

FIGURE 5. **Load cell Amplifier**

Figure 6 visualises the circuit placed in the car for collecting the data from various car points. The LoRa module is programmed to emit the radio waves at 433MHz. The following flow chart represents the program flashed into the Arduino Mega board.

The data acquisition circuit is simple and shown in figure 3. It just has the LoRa Module programmed as a receiver that listens at 433MHz; after collecting the data, it shows on the serial monitor window. We can either visualise the data using the in-built serial plotter or use Parallax Data Acquisition Tool to export the data into an excel sheet and visualise according to the need.

For this project, we preferred using PLX-DAQ since we have multiple data for visualisation, and

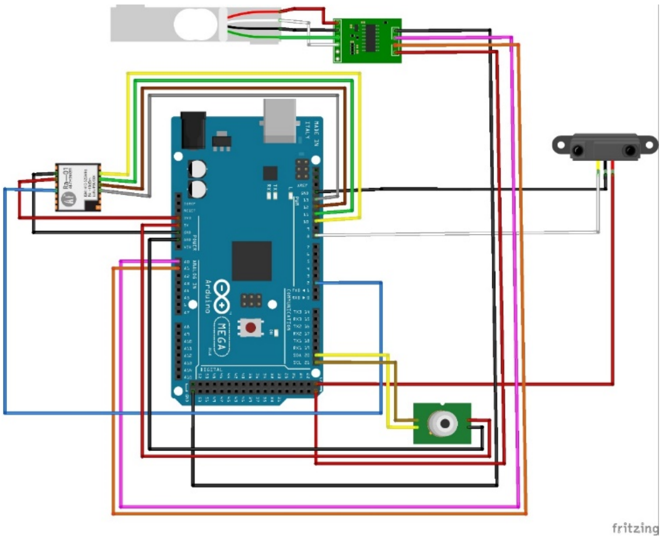

FIGURE 6. Circuit Diagram of Transmitter attached on the vehicle

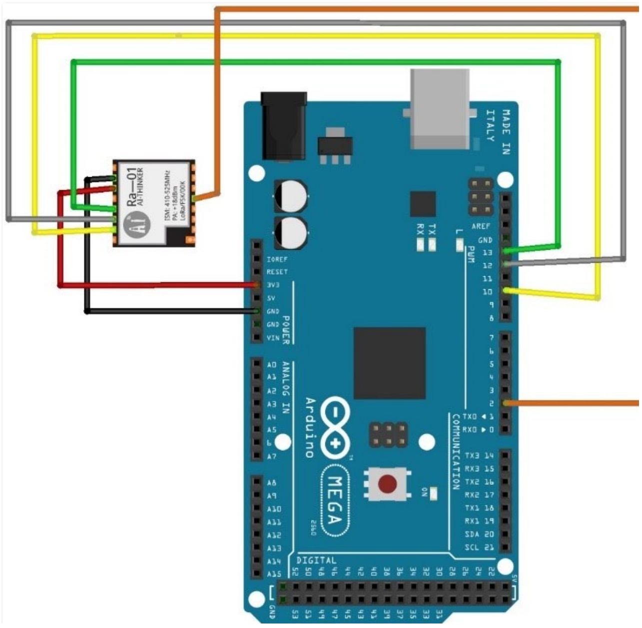

FIGURE 7. Circuit of Data Acquisition System at the Pit shop

also, the data collected can be saved for further references.

The program loaded into the receiver end Arduino board is shown using the following flow chart.

3. Result and Analysis

The proposed methodology has been tested on a student formula car designed for ISCC 2019, South Korea. It is an electric car designed by the student team of Vel Tech Institutions, Chennai. The design of this car is done by considering the sensors to be mounted on it. The test runs are done in a highway environment, and the results collected on the Data acquisition system are represented using various graphs. The range achieved using the LoRa SX1278 Modules is 2KM. This range is obtained using the stock antenna without any power boosters. The complete vehicle performance stats were plotted and shown in figure 8.

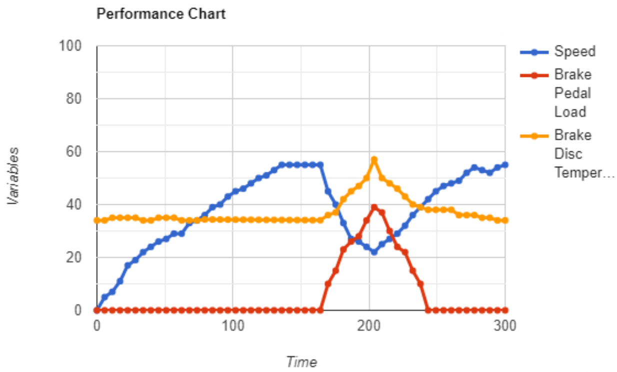

FIGURE 8. Trend of Speed, Brake Load and Brake Temperature

4. Conclusion

The complete telemetry system was developed from the design level, and all circuits were tested in every stage. The methodology was derived from receiving the sensors and vehicle operational data while running. After the performance was evaluated, the required information was sent to change the vehicle's parameters. And it was tested by modifying the required to achieve better performance. The telemetry system was further applied for vehicle performance improvement in the transport industry.

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