Abstract

Using human resources for data collection is considered as a time and resource consuming process. Humans can be substituted by autonomous systems and machines for automatizing the process. In this project an unmanned vehicle will be used in a simulated city (a scale model) as an instrument for statistical applications. The robot is expected to collect and report statistics on network coverage of Base Transceiver Station (BTS) antennas on the simulated city. The usage of this Autonomous data collector robot (ADCR) can automatize the process of data collection in order to reduce the use of human resources and improve the process timing. Mobile service provider companies may use this data to understand and improve their network coverage.

Introduction

Project background

Mobile service providers shall guarantee their full network coverage in order to ensure the complete consumer coverage and satisfaction. To do so, companies must establish survey groups to navigate every area of the city and report the data for further checking. Since the user congestion and the urban structure will may change from time to time, the data collection must be repeated frequently. This process is very similar to census, therefore it is known to be very costly and time consuming for the companies especially in large and crowded cities.

AT&T has introduced a system for collecting customer feedbacks about their signal reception. However, the company has been struggling with the fact that customer experiences are not easy to be evaluated. Some problems may be related to the devices that the customers use and not the network coverage. (Austin & Wish, 2010)

It is reported that the US government has been concerned about the expensiveness of population census. They had planned to use handheld devices for that effort, but it was forced to revert to paper-based follow-up surveys after testing turned up problems with the handhelds. The estimated cost of census for the year 2010 was reported to be $13 Billion while reverting handheld data to paper-based ones could add another $3 Billion to the total costs. (United States Government Accountability Office, 2010)

On the other hand, it’s claimed that the process of data collection in censuses can be highly time-consuming for not only census collectors but also the populace in case of population census. (Shughart II, 2010)

Importance of the project

By referring to the costs and difficulties of the data collection in the past it can be mentioned that the problem will be critical in near future. The costs will be unaffordable and the time of people will be more valuable than before. Therefore, it is essential to approach alternative methods for data collection. In this project the problem of data collection for network coverage will be overcome through substituting humans by autonomous machines. To emulate the real world, an unmanned robot will be used to gather required data in a simulated city.

Project scope

The simulated city includes some basic and advanced attributes of a real city such as streets, constructions, traffic lights, traffic sign and BTS towers. A Base Transceiver Station (BTS) or cell site is a piece of equipment that facilitates wireless communication between user equipment (UE) and a network. UEs are devices like mobile phones, computers with wireless internet connectivity, WiFi and WiMAX gadgets. The network can be that of any of the wireless communication technologies like GSM, CDMA, WiFi, WiMAX etc. (Wikipedia,2011)

The robot navigates across the simulated city based on the city map to recognize and gather statistics on network coverage. The method and the obtained data could be used in networking organizations to improve their services.

Implement based on Intel platform

Among four available platforms, the Intel Track has been chosen to provide satisfactory performance for image processing duties for the robot navigation and for communication tasks. The low power consumption of the Intel Desktop Board D525MW makes it suitable for a battery powered embedded system while there are expansion slots to upgrade the board functionalities. The robot requires communication channels to the server while the provided I/O flexibilities on the board facilities it. In addition the Mini-ITX form factor of D525MW board is small enough to fit on a medium size robot. Consequently, the robot will be able to get the best out of the Intel platform provided there are no difficulties with the high performance requirements of image processing jobs.

Expected performance

The robot is expected to navigate across the simulated city based on an optimal route. While navigation, the robot follows the basic rules of any real-world city including respecting the traffic lights by using image processing techniques. The robot is designed to gather stats about the congestion of BTS antennas and their coverage on the simulated city. The robot transmits the stats to the master unit to demonstrate the distribution of BTS antennas on the city map. In real world, the demonstration can be used by telecommunication service providers to recognize their network coverage in different areas of the city.

Design Methodology

A simulated city with simple real-world attributes hosts a vehicle-shaped robot to depict what is necessary in the project implementation. The simulated city is basically a scale model with gadgets on it while the robot is capable of recognizing them. The gadgets on the city are to emulate mobile BTS towers/antennas and the robot navigates across the city to recognize them.

Simulated City

Scale mode

Scale model consists of Streets, intersections and it is surrounded by walls. The materials that have been used in making this scale model are same as all other scale models. Scale model is made with poly traps, foam, balsa wood or paper. The streets are lined by white sign to make the scale model similar with real city streets.

Traffic lights

Traffic lights on the simulated city look like real traffic lights but with smaller dimensions providing red and green lights only. LEDs (Light Emitted Diodes) are used as source of the light and there is a central controller for handling all traffic lights. The central controller is powered by a circuit to provide a specific interval to switch between red and green lights to ensure the actuality of the simulation of each traffic light.

Mobile BTS Towers

Real BTS antennas provide a circular coverage around itself; however the signal coverage may be affected by geography and the physical obstructions in that area. The signal coverage is also affected by the power of the transceiver of the tower.

The BTS tower is roughly emulated by Infrared transmitters all over the city. The designed infrared transmitters cover a limited circular area whereas its coverage can be affected by physical obstacles; very similar to real mobile BTS towers.

Robot

Recognizing traffic lights

Using computer vision techniques helps in recognition of traffic lights existed in the simulated city. As mentioned before traffic lights include red and green colors. Color of traffic light will be recognized by camera in intersections and the robot stops moving while the color is red, when the color turns green it will continue moving. The C++ programming language is used and the library for computer vision and image processing tasks is OpenCV. Traffic light recognition is used to ensure actuality of the simulation and is done on the Intel Desktop board to guarantee its performance.

Identifying street intersection

The robot is capable of recognizing the approach to each street intersection. The recognition is based on output of a set of infrared sensors placed under the robot. Once the robot has found itself placed behind an intersection, the process of traffic light recognition will be started to identify whether the vehicle is permitted to pass the intersection or not.

Recording emulated BTS-antennas

Since the BTS towers are emulated by Infrared transmitters, the network user must be emulated by Infrared receivers on the robot. The robot navigates across the city, identifies the signal from BTS towers and records the reception at those coordinates.

Processing Unit

Human uses senses and their brain to drive a vehicle and the robot has several sensors and a processing unit to control these sensors. A Mindstorm NXT 2.0 unit has been used as a platform for interfacing robot motors and sensors. The Mindstorm unit itself is under control of the Intel Platform for getting commands based on the route, navigation and other functions. The camera being used for traffic light recognition is directly controlled by the Intel Platform. All the processing, planning and demonstration will be done on the Intel Desktop board with some help from the NXT's ARM Processor.

Demonstration

The navigation of robot across the city and all other tasks will be displayed on a monitor.

After the complete navigation of city and recording all the data about network reception, the data will be used on the map of city to demonstrate the network coverage of the city. Areas with network coverage will be differentiated with the areas which lack of network reception in order to display the functionality of the project.

Positioning system

In the real city, location of robot can be figured out by GPS but in a simulated city it is not implementable because dimensions are too small to be measured by GPS. Consequently, we must use a technique to overcome the problem. Utilizing an accelerometer is expected to solve this problem by giving acceleration than can be used for finding location. Since the location of the robot is known, the robot can move properly through the city. In addition, a gyroscope sensor is used in the robots to measure angular changes on the road and at the intersections.

Functional Description

Today, mobile telecommunication and ISP companies use human resources to measure strength of mobile, radio and Wi-max signal by sending their personnel to various regions of a city. However, it is an inefficient approach for huge scale measurements. It is notable that using human resources is the only way for these companies nowadays.

On the other hand, mobile telecommunication and ISP companies have to measure strength of the signals frequently due to numerous factors such as signal absorption loss, construction of new buildings, changes in consumer population and increase of rate of disturbing noises which may create dead zone (Areas where cell phones cannot transmit to a nearby cell site, base station, or repeater are known as dead zones).

In addition, some companies might be interested to gather statistics on some specific targets such as Wi-Fi hotspots. These companies need to employ human resources to achieve the data regarding these targets.

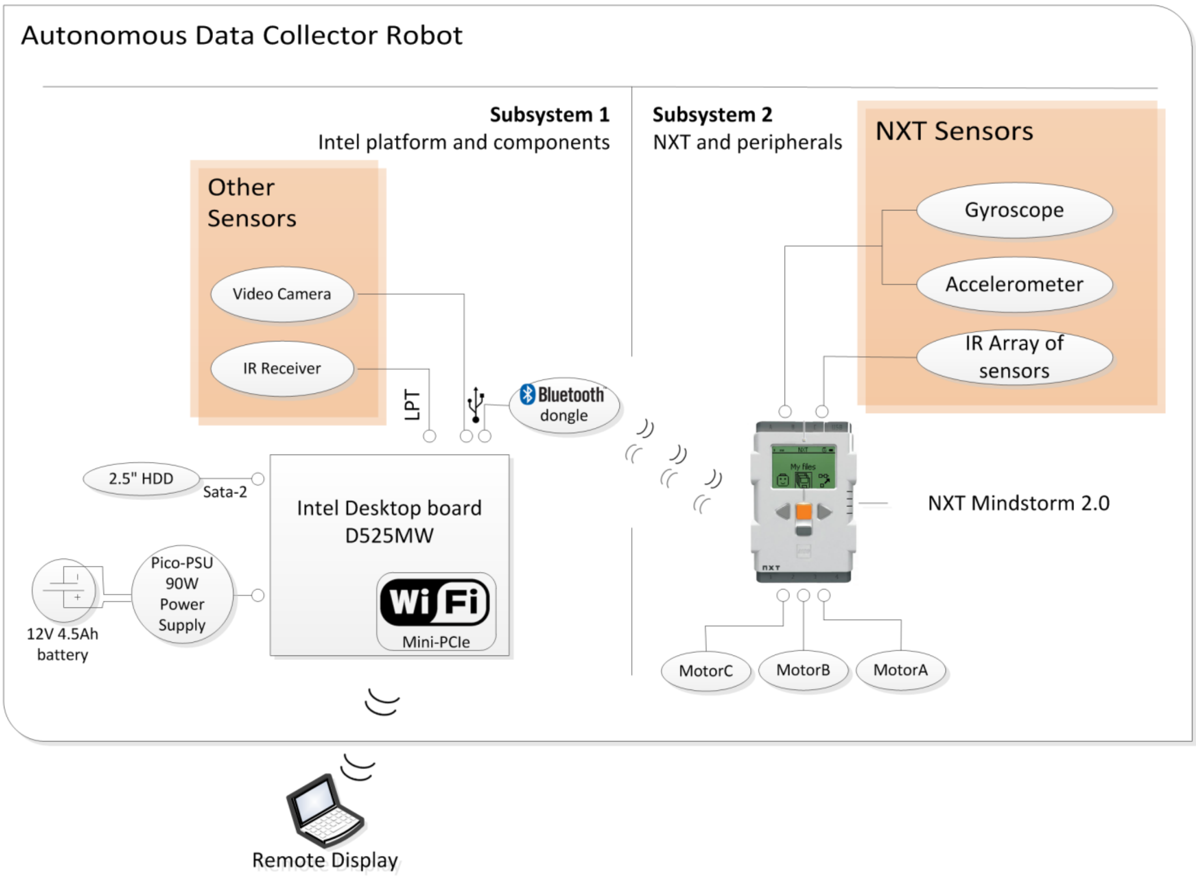
In this project, we proposed a novel method in order to expedite the processes of both measuring strength of signals and collecting statistical data by automating the process of data collection in order to reduce the use of human resources and to improve the process timing. The method will provide the companies a well-structured demonstration of data coverage autonomously without any human’s hand in its process. This approach will also diminish the errors, time, costs and increase reliability and accuracy since it is fully automated.

Design Architecture

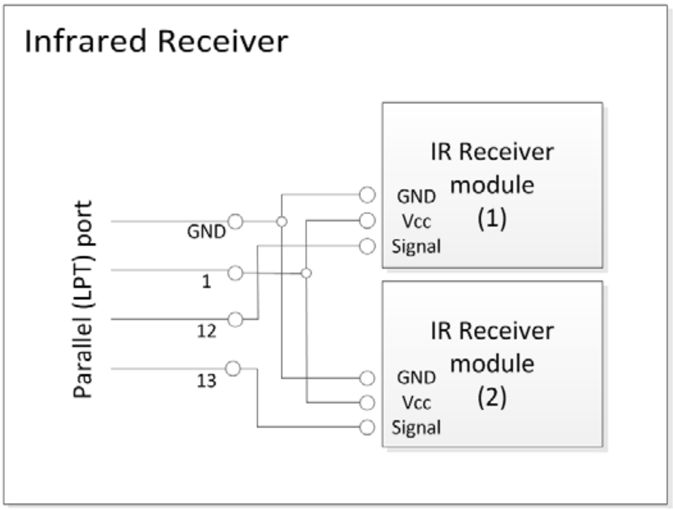
System design

Autonomous data collector robot

The system is a vehicle robot that is designed to operate independently such that it can perform all the required tasks in a small package. The system itself can be divided into two subsystems; the Intel platform and its related components, the NXT unit with specific sensors and motors. Intercommunication between subsystems will be established using Bluetooth technology. For demonstration purposes, the platform is expanded with a Wi-Fi Mini PCI Express card to allow remote display functionalities. Figure below shows an overall structure of the system.



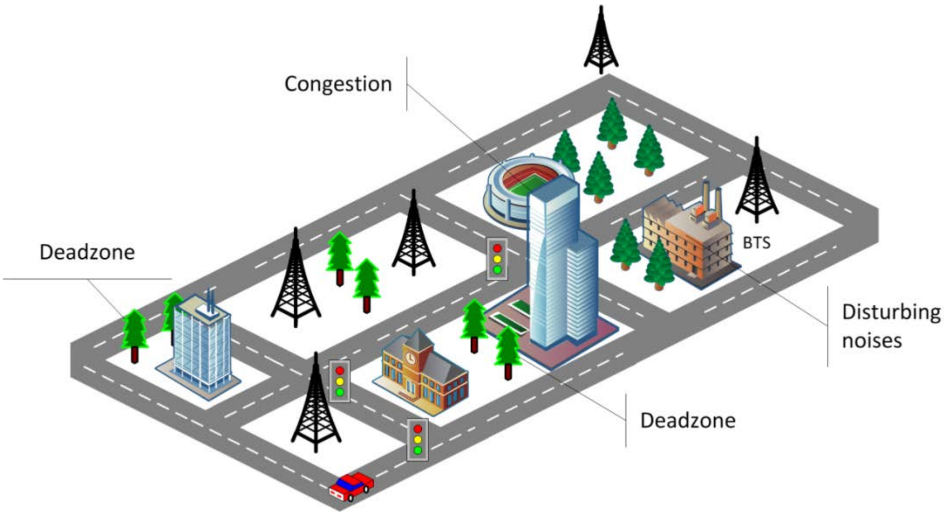
Subsystem 1 consists of Intel D525MW board and components that are hosted by the same board. The Intel board is supplied with a 90W PicoPSU power supply and 12V 4.5Ah battery source; suitable for this Mini ATX motherboard. The board is operated under Microsoft Windows XP Embedded with necessary components to minimize the operating system footprints. It should be noted that the required storage space is provided by a 2.5 inch Hard Disk to achieve good performance at low cost. Moving on to peripherals, a video camera and a Bluetooth dongle are connected to the Intel desktop board via USB and a kit of IR receiver modules are interfaced with several pins of the LPT port as shown in the following figure.



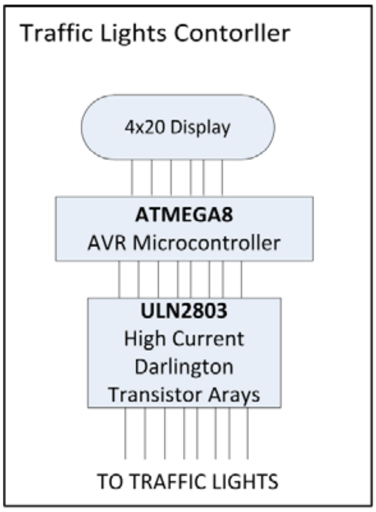
Subsystem 2 includes processing unit of NXT Mindstorm to handle specific sensors and few motors. A gyroscope sensor that is combined with an accelerometer (dIMU Inertial Motion Unit) together with and an array of IR transmitters (NXTLineLeader) are connected to NXT sensor interface. Lastly, three servo motors are attached to the unit with enables the vehicle simplest functionality; movement.

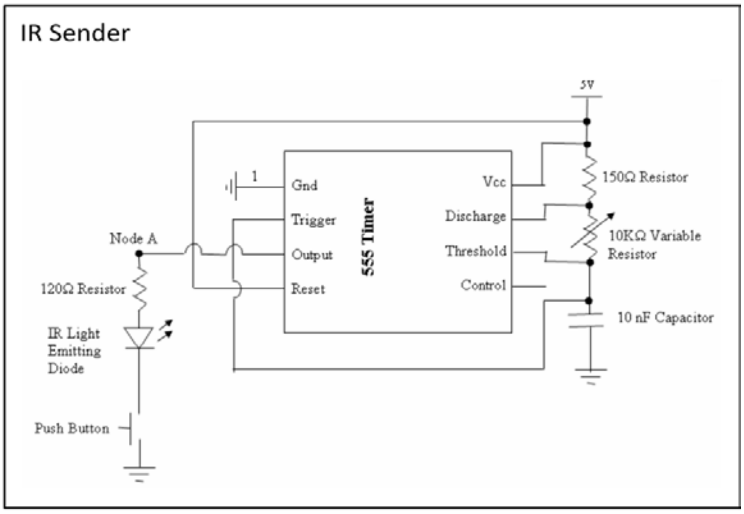
Simulated city

The simulated city is basically a scale model with Infrared senders to simulate BTS antennas and LEDs to simulate Traffic lights. The following figure shows what this simulated city might represent as a real city.



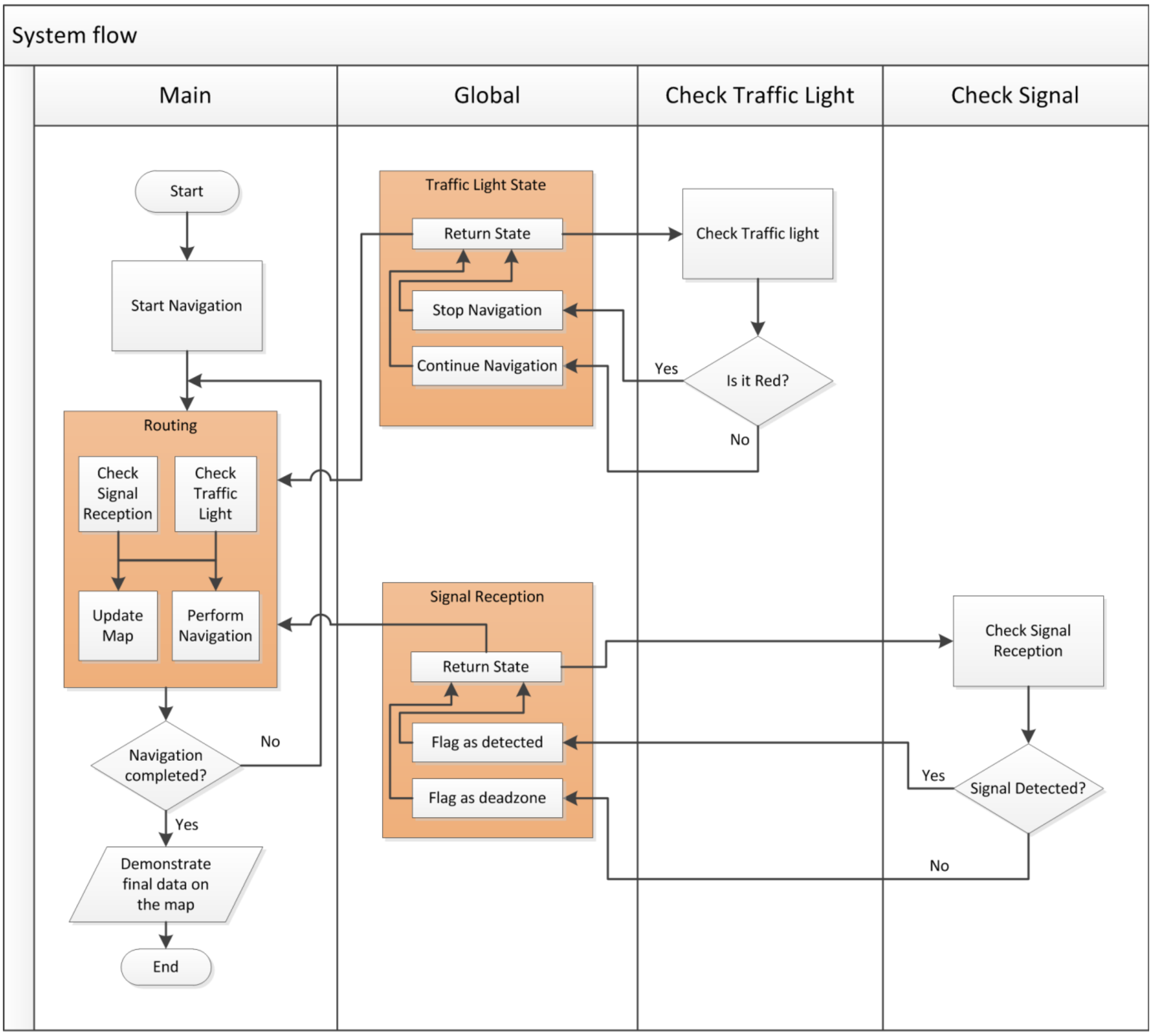
Infrared senders are modulated with NE555 ICs to have 38 KHz series of pulses in a semi-circular perimeter. It is important to know that different constructions and environments would have different level of signal receptions. Moreover, traffic lights states are managed centrally with a microcontroller system.





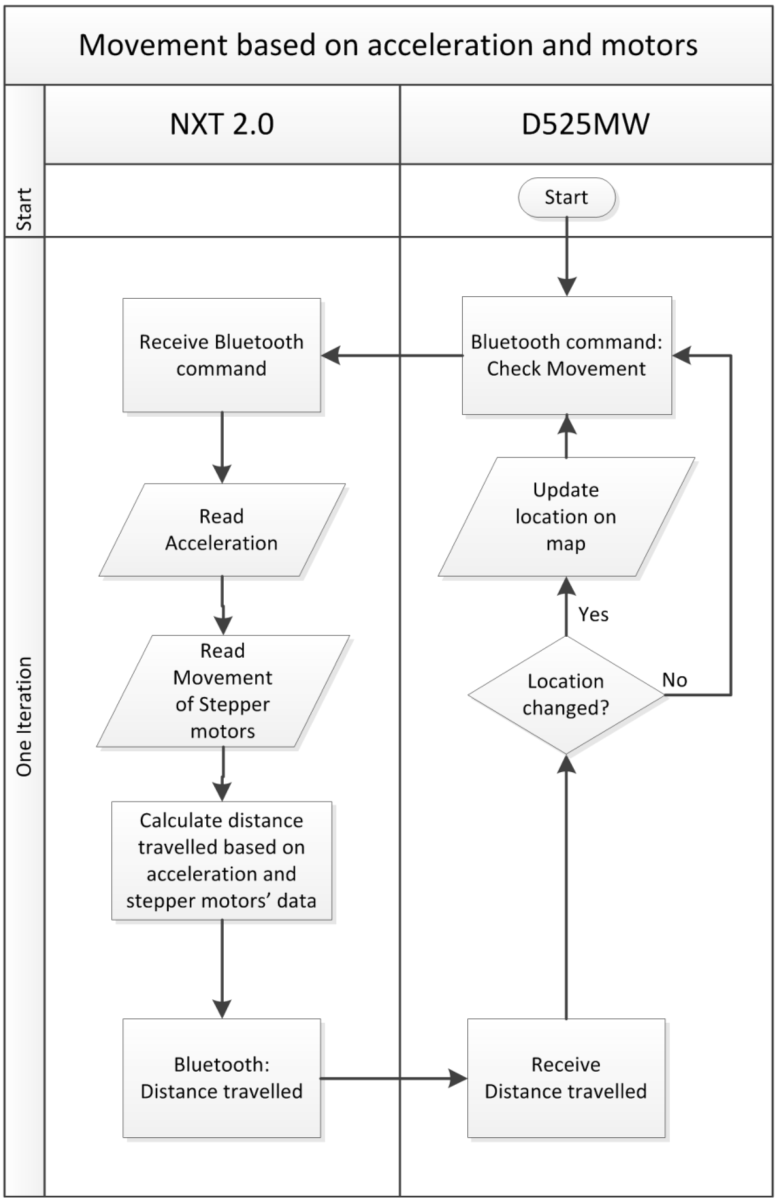
Software flow

The autonomous vehicle navigates on the scale model based on a given optimized route to drive over all streets. While navigation, the vehicle might face several traffic lights that affect the navigation decisions. Furthermore and most importantly, navigation on the city will end up to recognizing the signal reception of all areas of the simulated city. The collected data about the signal strength will be shown on the map of the city. The figure below shows an outlined flow of the system.



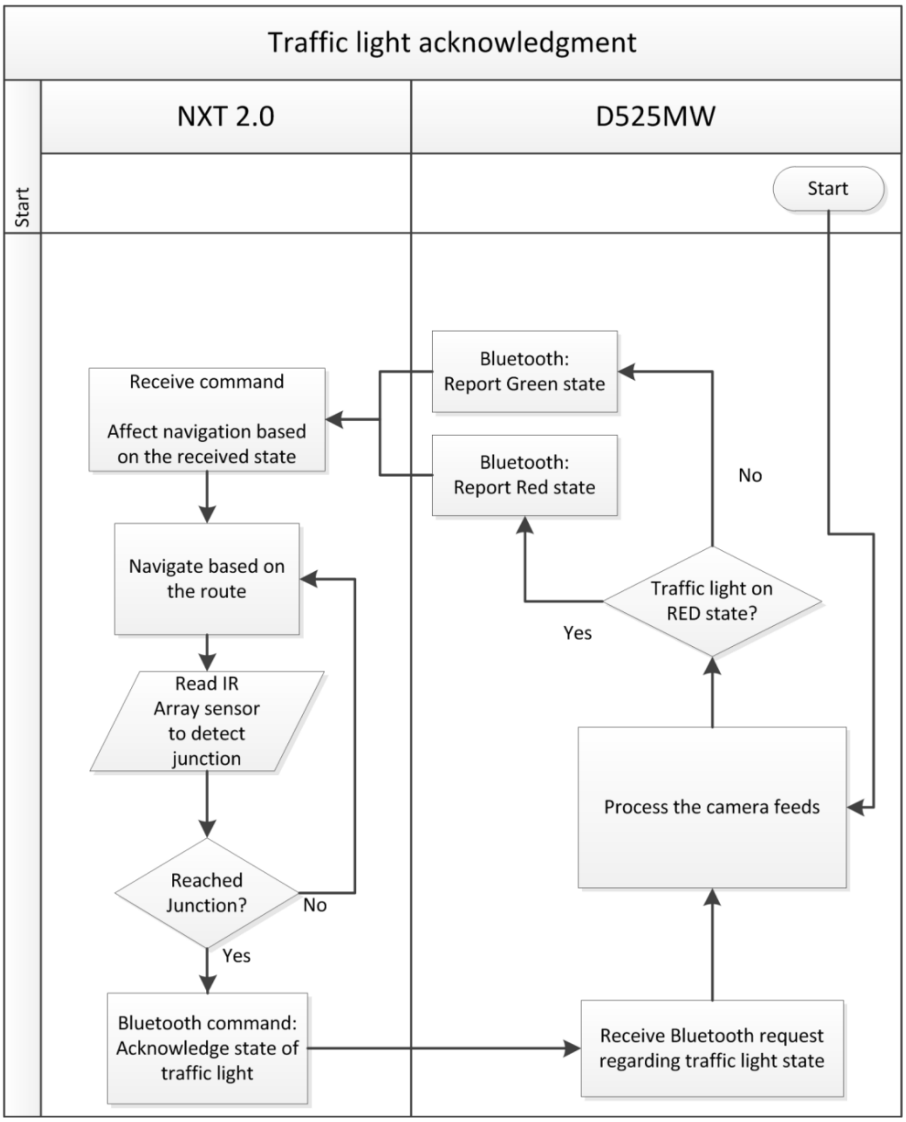
Movement based on acceleration and stepper motors

An accelerometer is connected to NXT unit and the data achieved from acceleration is used to estimate the location of the vehicle for navigation and for demonstration purposes. The location based on acceleration would have inaccuracy therefore the degree of rotation in stepper motors have been used to improve this accuracy. The location will be sent to Intel D525MW board using Bluetooth repeatedly based on a short interval. Flowchart of using acceleration and stepper motors rotation to estimate the location of vehicle on the map is shown below.



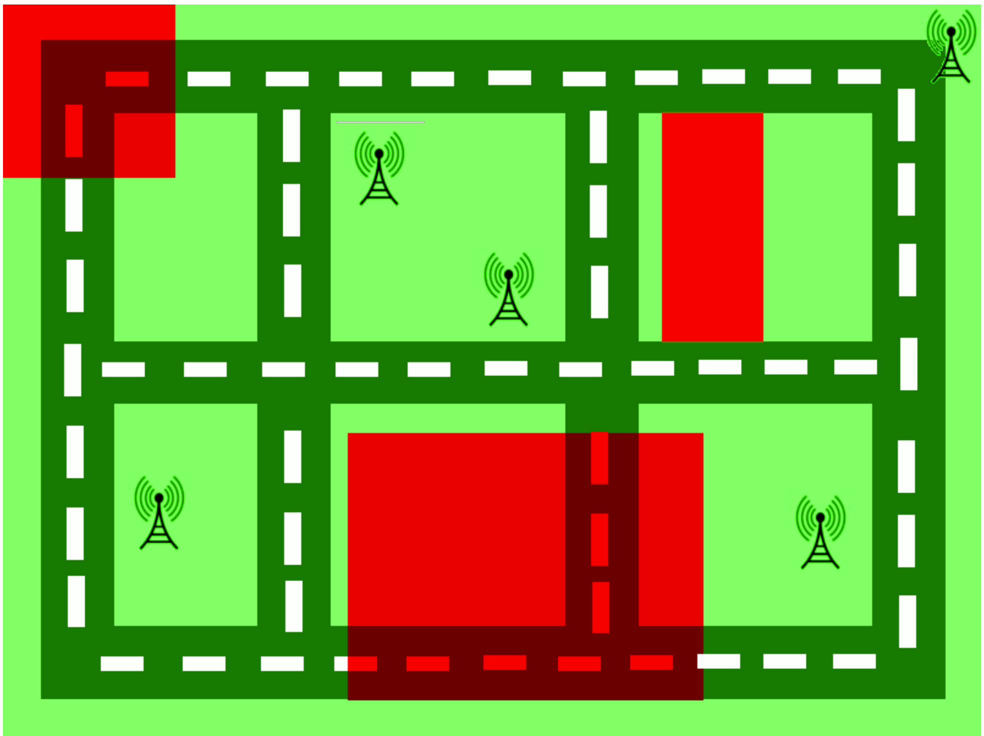
Traffic lights acknowledgment

The camera connected to the Intel board receives the video feeds and process them to determine state of traffic light once the vehicle has reached a junction. The state of traffic light will be sent over to the NXT unit using Bluetooth to affect navigation decisions. Steps involved in detecting the traffic light states and using this data for proper navigation are demonstrated on the following flowchart.



Signal strength demonstration

After navigating based on the route, the system generates a map of simulated city with strength of signal reception in different areas on it. This will be the final demonstration of how system had successfully checked entire model of a real city to obtain the signal strength on specific areas. A sample of how this demonstration would look like is as follows.



Results and Discussion

Generally there are a few advantages which make this project significantly unique. Before implementation of the project we were always looking for characteristics such as mobility, portability and flexibility in our project. Using outstanding features of the Intel's platform helped this project to have all these characteristics. Results of our implementation showed us:

• This system is fully automated or in other words, it is working without human's interference.

• The system performs all expected tasks (Collecting data about signal strength, moving across the simulated city with respecting traffic lights) very well under low power consumption.

• There is a good flexibility for working with different kinds of operating systems which made us free from implementation using low level programming language.

• This system is small and portable.

• This system is so flexible because there are a few numbers of I/O ports on the Intel's platform which make it easy to communicate with different system such as the NXT Mindstorm.

In this project we achieved all these advantages mostly due to the platform which we are using. Primarily, the Intel's board form-factor is small and also it has enough I/O ports which make our job easier. The platform allowed the system to be totally independent as well. Finally, the platform is compatible with all the Operating systems which made us free from implementation using low level programming languages.

It was also figured out that accelerometer does not return an accurate coordinate of the robot, utilizing the stepper motors in this system could help us to increase accuracy of returning coordinate of the system.

Conclusion

Network coverage analysis and diagnosis has always been a hassle for wireless service providers especially on metropolitan areas with rapid construction growth rates. This project introduced a compact system that automates the process of network coverage analysis by putting an unmanned vehicle in work instead of humans. The unmanned vehicle navigates through streets of a city and records data about network coverage to be demonstrated on a map later on. This solution not only reduces the costs of data collection, it also improves the timing and accuracy of tasks. Process of data collection may become a difficult task in near future due to population growth and this project can be utilized to overcome such concerns.