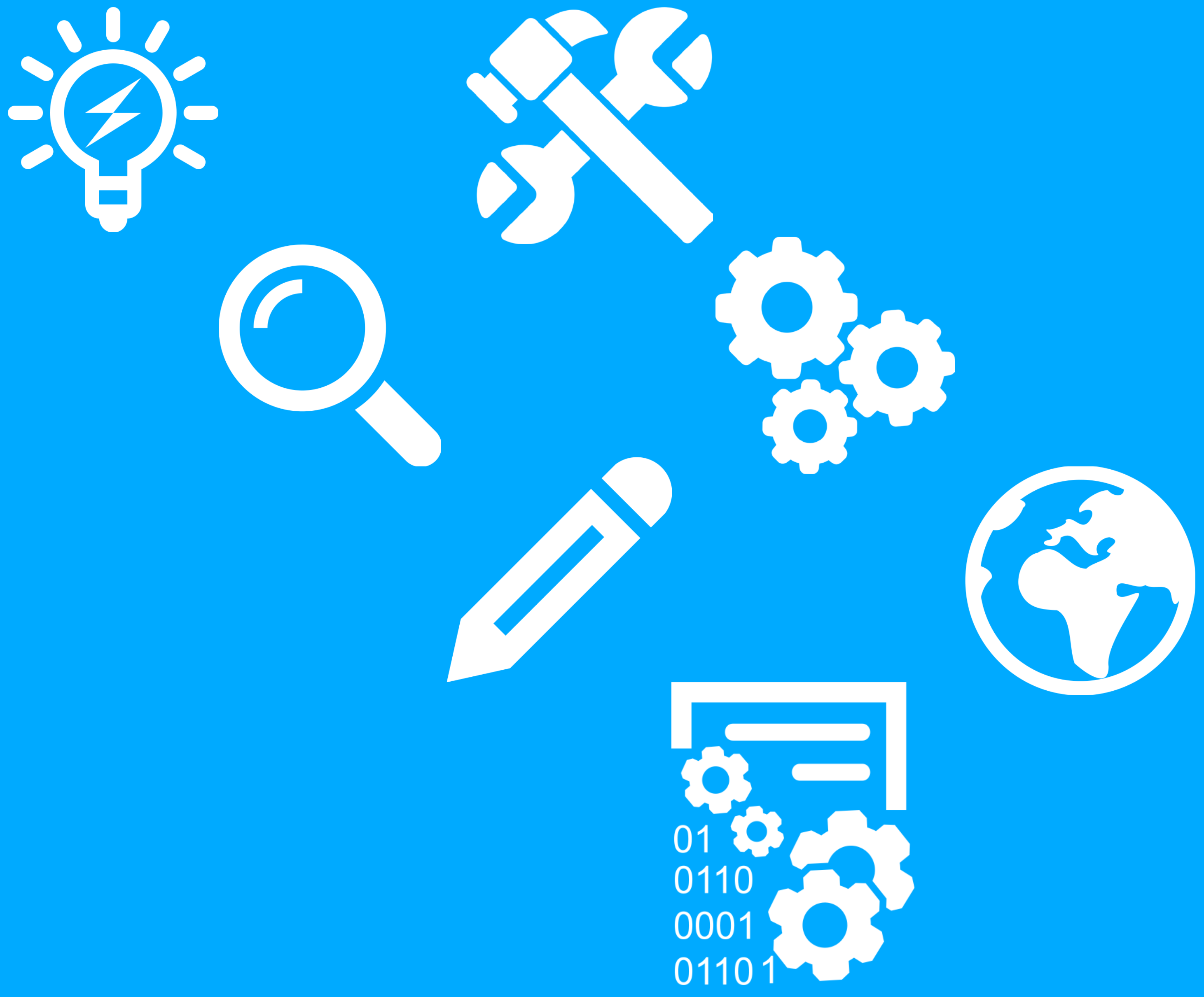

Noah Ingham
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IPS

Idea

Dickson College's Engineering and Robotics classes make heavy use of autonomous vehicles with GPS navigation. During rainy and cold seasons, however, testing these systems becomes difficult and impractical.

Instead of using satellites, an Indoor Positioning System (IPS) relies on nearby *nodes*, with pre-calculated positions. IPSs work by detecting (or being detect by) vehicles using optics, radio or acoustics. Comercial IPSs, such as Vicon motion capture cameras, cost up to $500 000 for a full system.

In response to these problems, Dickson College is setting up an optical-based Indoors Positioning System. The goal of the project is to create a system capable of detecting vehicles in areas where GPS is not available, for a setup and maintenance cost affordable to any interested school or university. In comparison to the products in the current market, our final outcome will be easy to setup up and highly available.

Research

Having analysed the available products on the market, the determined solution was to develop a new system using widely available technology, combining it in new ways in order to come up with a cheap and effective way. Various solutions and technologies were examined and evaluated.

The technology considered used extremely recent advancements, allowing for a state of the art product. In particular, this section will examine the technology available to be used for the nodes, i.e. the sensors capable of detecting object identifiers. The different methods were being evaluated by the price, the performance speed, time to aquire/set-up, the convinience of programming and configuring and the range/field of fiew of the sensor.

The four nodes that were investigated were the Pixy camera, the Raspberry Pi Camera Module, the Wii Remote and Sonar.

Pixy Camera

Pixy is a vision sensor that is Arduino compatible. The advantages of the Pixy are it's ability to learn new vehicles easily. To differentiate between different vehicles of similar composition, colour coding would be required. Because the Pixy has already been programmed to detect objects, there would be no computer-vision programming involved. At the time of starting the IPS, the Pixy was not yet commercially available.

Raspberry Pi Camera Module

Raspberry Pis are cheap credit-card-sized computers. The Raspberry Pi Camera Board, equally as inexpensive, can record 1080p video at 30 frames per second. The setup could be used an optical sensor for the IPS, allowing for a highly configurable system.

Infrared Sensors

Wii Remotes, the controllers of the Nintendo gaming console, use infra-red light to determine position. An IPS using these controllers would rely on inexpensive equipment. It would be difficult to set up and mount, but the results would be fairly accurate.

Sound

Simar to the sonar systems used underwater, using sound to detect objects would require minimal hardware. With only three or four nodes required, the principal advantage would be the simple setup. It would, however, require a lot of high-accuracy sensors, thorough tuning and high-speed programming, all of which would depend of costly hardware.

To evaluate the four options, each technology was scored in six weighted categories.

Table 1. Weighted Concept Results

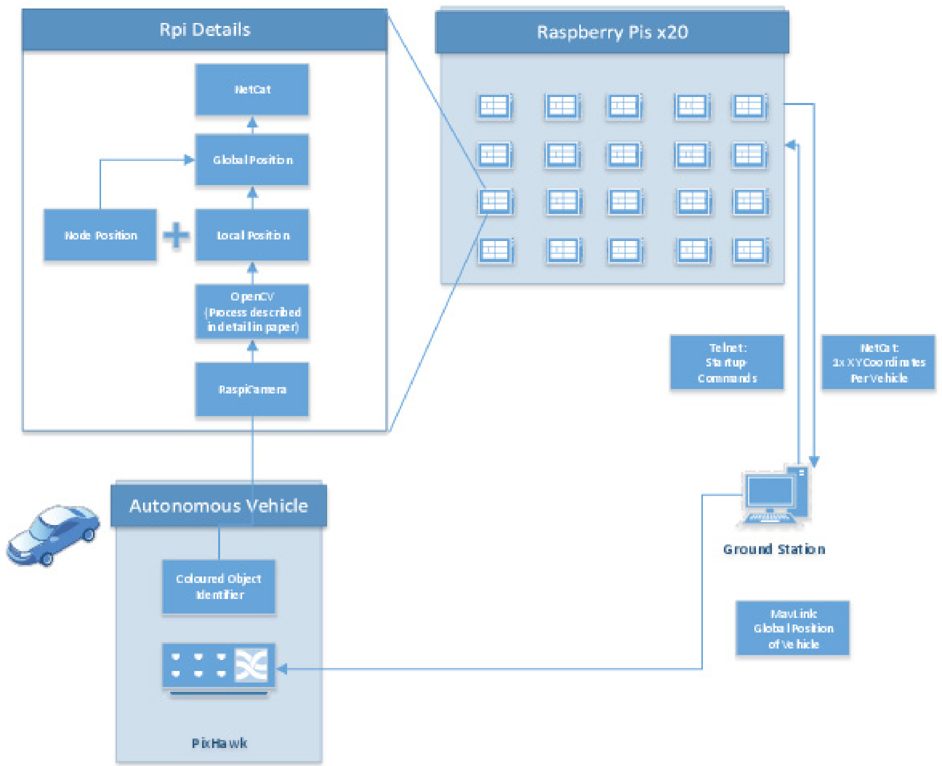
Node	Price	Performance	Convenience	Time	FoV	Range	Total
(Weighting)	0.5	0.8	0.5	0.8	0	0	
Pixie	3	1	1	4	75°-47°	7.62m*	6
RasPi	3	3	2	1	53°-40°	5m	5.7
Wii	1	2	4	3	42°-32°	10m	6.5
Sonar	3	3	4	4	>180°	>10m	9.1

Based on this evaluation, the Raspberry Pi setup was determined to be the best option for a Positioning System.

System

Concepts

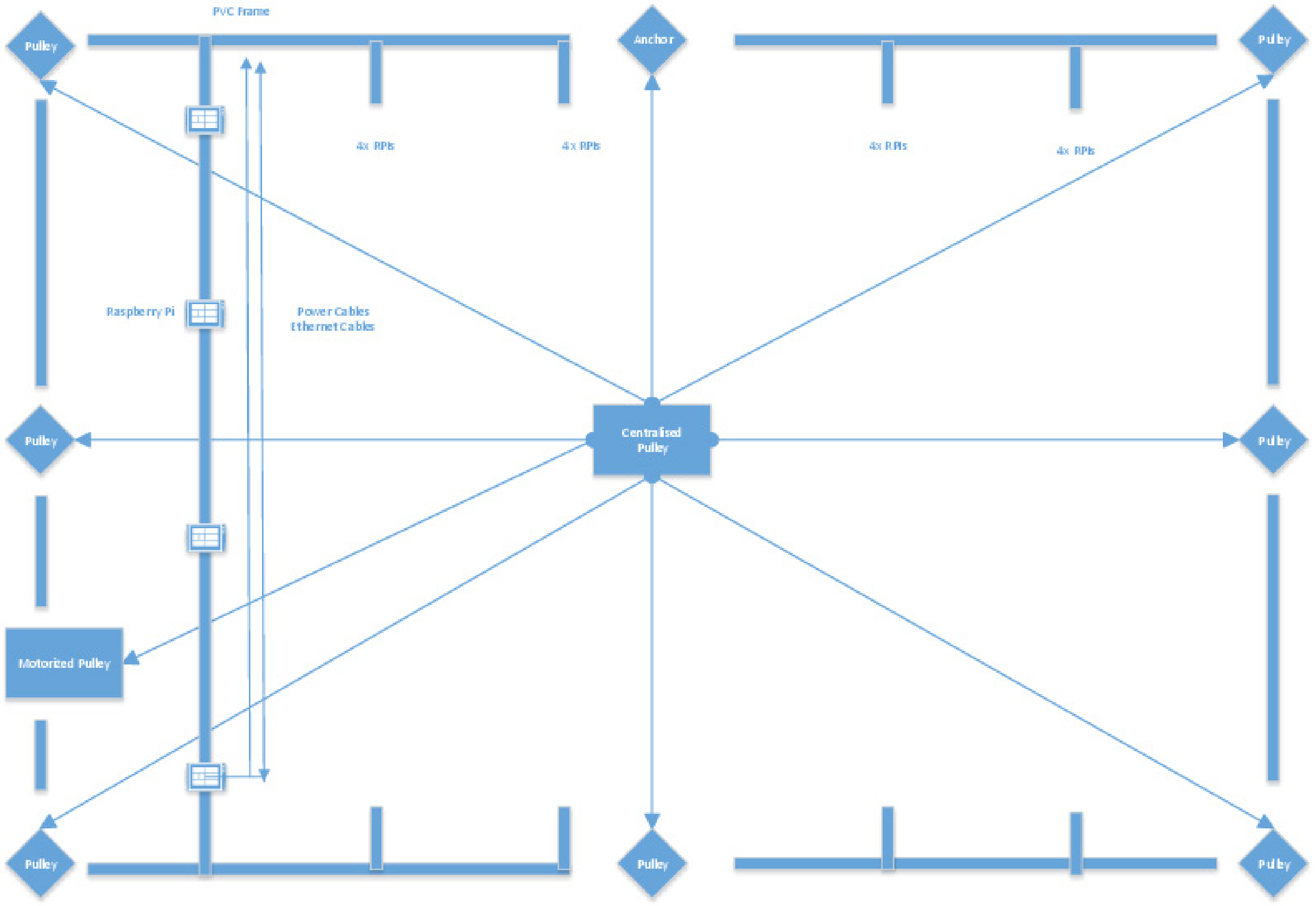
After deciding on the technology for each positioning node, concepts were developed for the setup of the entire system. In particular, the mounting and networking setups were experiment with. Three different System Diagrams representing physical and logistical hierarchies were developed (using Microsoft Visio).

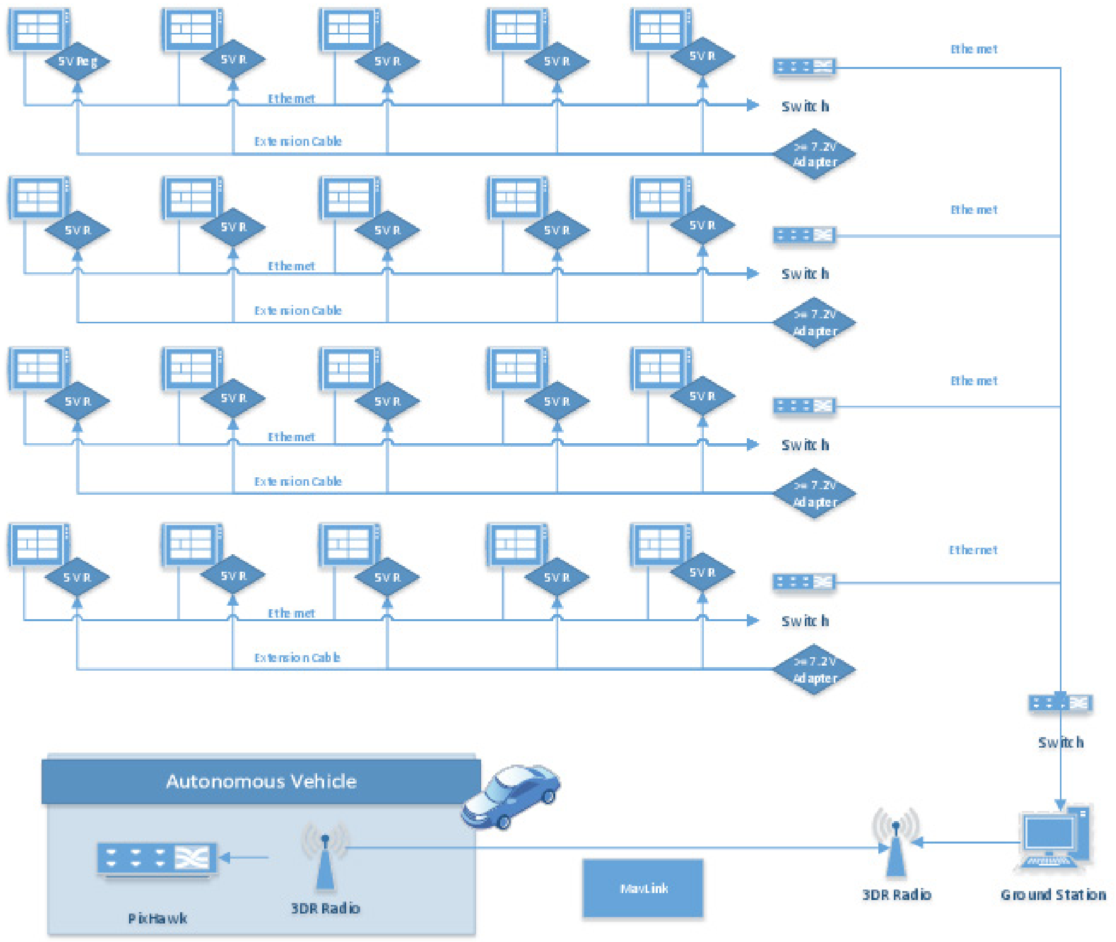


Whole System Diagram

The diagram below demonstrates the plan for mounting the the IPS in the school hall. The setup will form a grid of Raspberry Pi nodes, raised using a pulley system.

Mounting Diagram





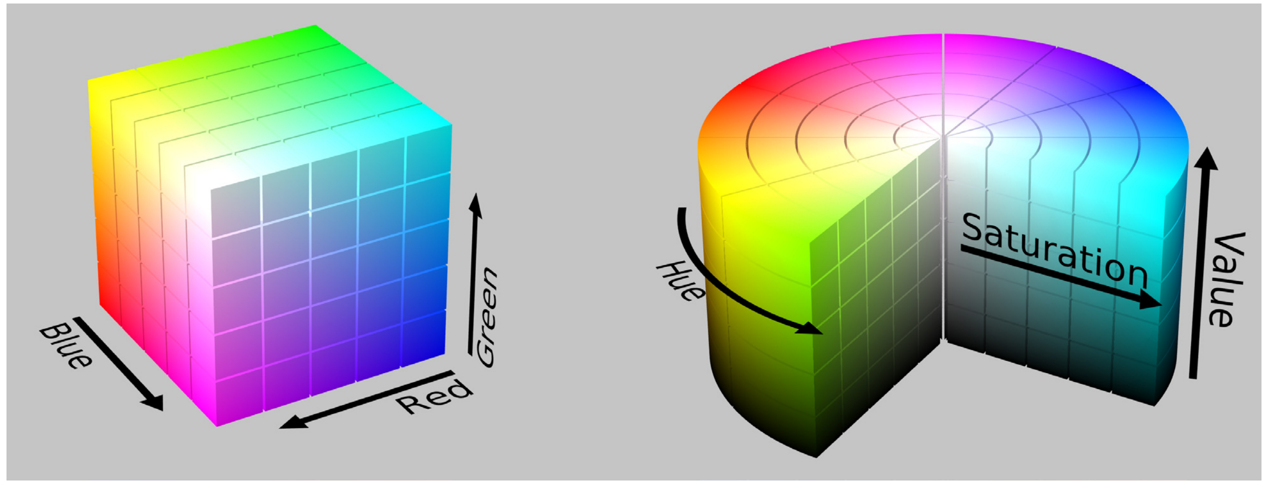
Networking Diagram

The diagram above shows the data and networking link between each component.

Software

The software aspect of the IPS has been split up into two sections. the IPS-Node software runs on each Raspberry Pi, recognizing vehicles and returning a pixel offset; the IPS-Server software runs on a single computer, receiving pixel offsets of each vehicle, converting them into a GPS coordinates and sending it to the vehicles.

The Raspberry Pis, each connected to a Raspberry Pi camera module, make use of the open source OpenCV computer vision library to ease the task of detecting vehicles. After receiving a frame from the camera, the Pi first con-

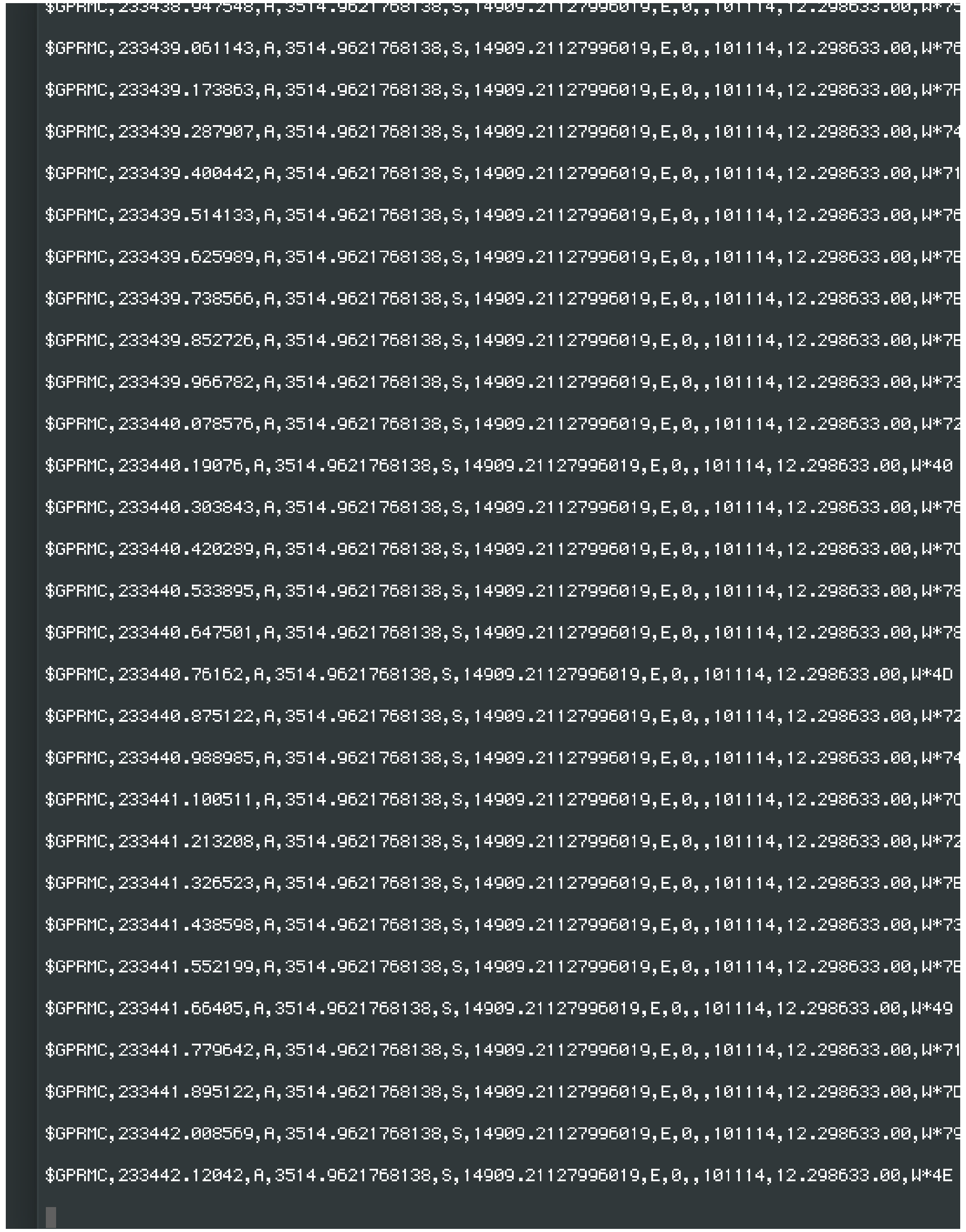


verts the data from the RGB (red,green,blue) (left) to the HSV (hue, saturation, brightness) (right) colourspace. By using a polar coordinate system rather than a three dimensional Cartesian coordinate system, HSV makes it easier to categorize colours by angles. For each vehicle in the field, the image is transformed into a 1-bit image containing only the colour of a marker on the vehicle.
After detecting the pixel offset of the vehicle, the data is send to the ground server.

The ground server, upon receiving the pixel offset of a vehicle, combines it with the latitude and longitude of the relevant node to find the global position. Using the NMEA 0183 specification, defined by the National Marine Electronics Foundation, the server converts the position into a format readable by the onboard autopilot. Using an xBee radio module, the server send the NMEA sentence to the autopilot, at a rate of approximately 9Hz.

The software on the autopilot and ground station of an autonomous system do not need to be modified to make use of the IPS. The only hardware modifications required for each vehicle is the replacement of the GPS module with an xBee radio module. This involves simply disconnecting one from the autopilot and connecting the other.

Example of NMEA sentences being sent to Pixhawk autopilot.



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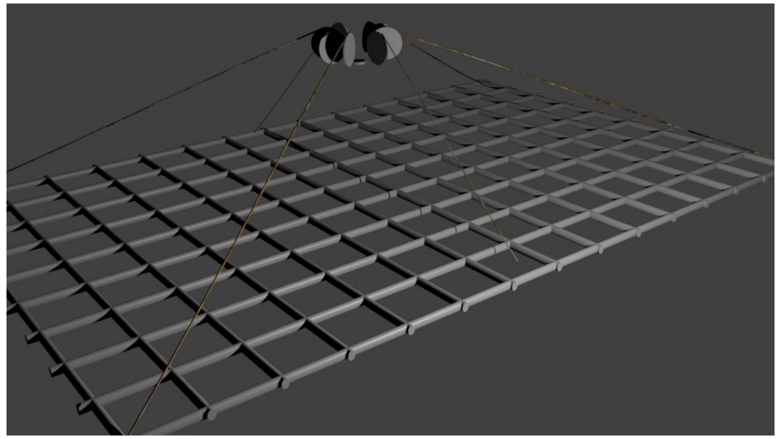
Hardware

Indoor Positioning System's mounting has a few important requirements:

1. Cheap components
2. Quick to set up/take down
3. Strong

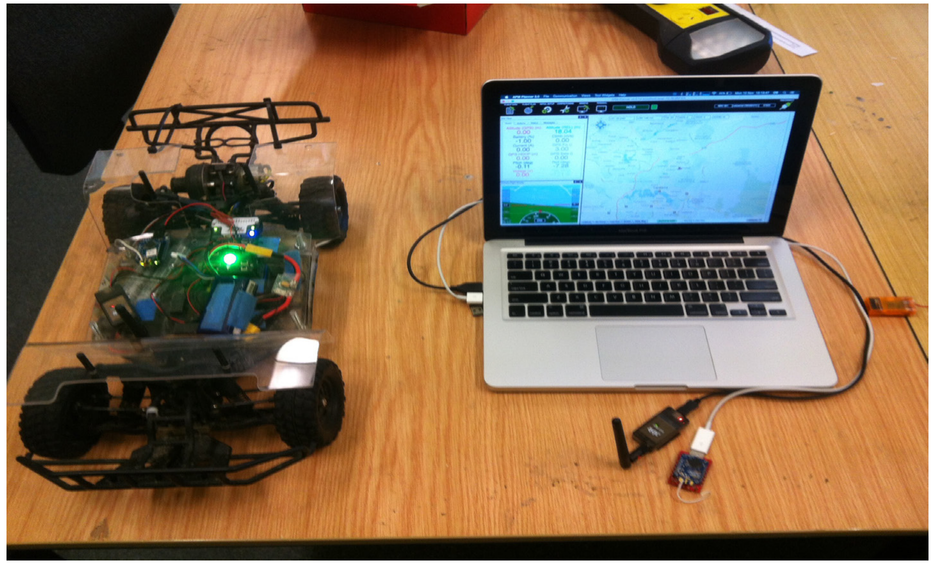
To meet each requirement, a system involving a PVC grid was designed, raised using four corner pulleys connected to a central pulley. Designed using cheap pipes and 3D-printed connectors, the setup up is cheap and easy to construct. The setup can be disassembled and reassembled in a very short time. The pulley system allows the IPS to be mounted in any kind of room, ranging from school halls to small classrooms.

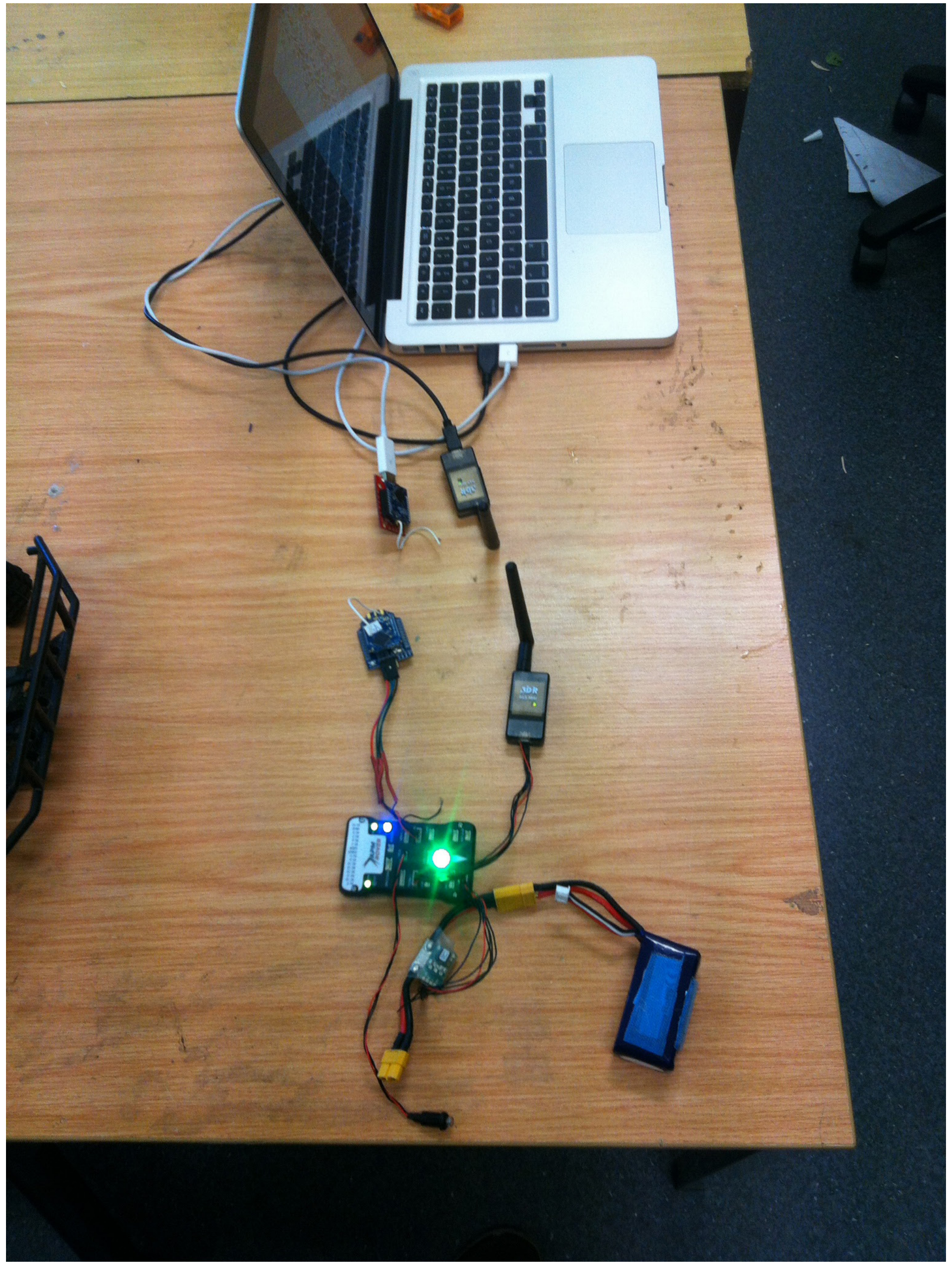


System

After coming up with concepts and designs for each component of the project, a prototype has been setup in a classroom, using four nodes in series. The setup uses a small autonomous Rover controlled by a Pixhawk autopilot, a groud station running both the IPS-Server software and APM Mission Planner and the four Raspberry Pi’s runing the IPS-Node software. The prototype has been used to succesfully control the autopilot, setting different Waypoints around the classroom.

After setting up the IPS, the only equipment to use it is an autonomous vehicle and a ground station (right image).





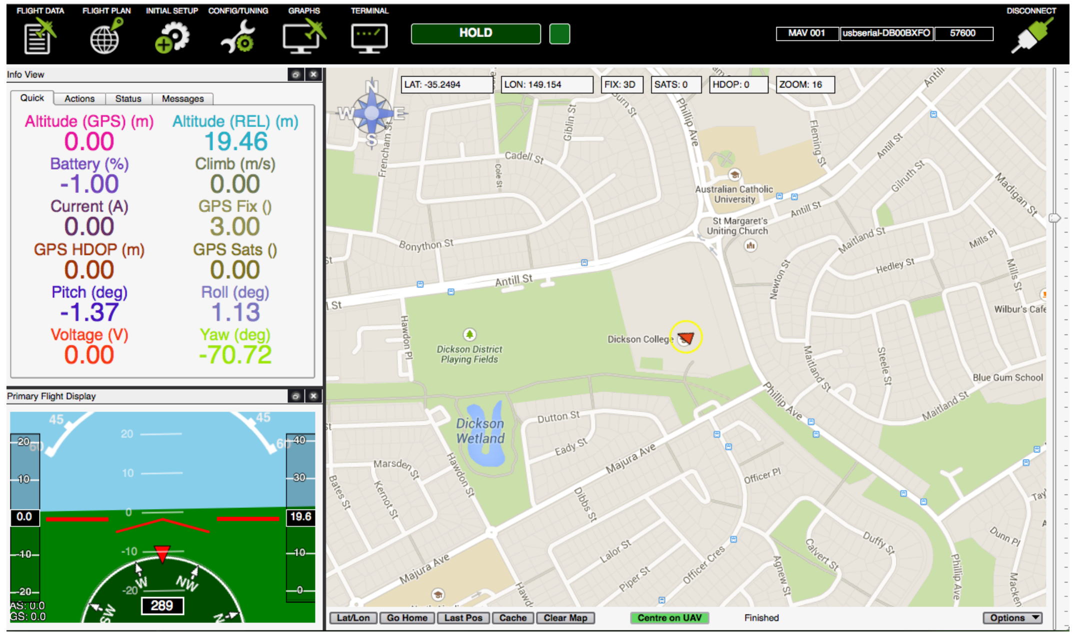
The left image shows the connections going to the Vehicle. The right wireless link, through two Telemetry transceivers, is the connection to the Mission Planner.

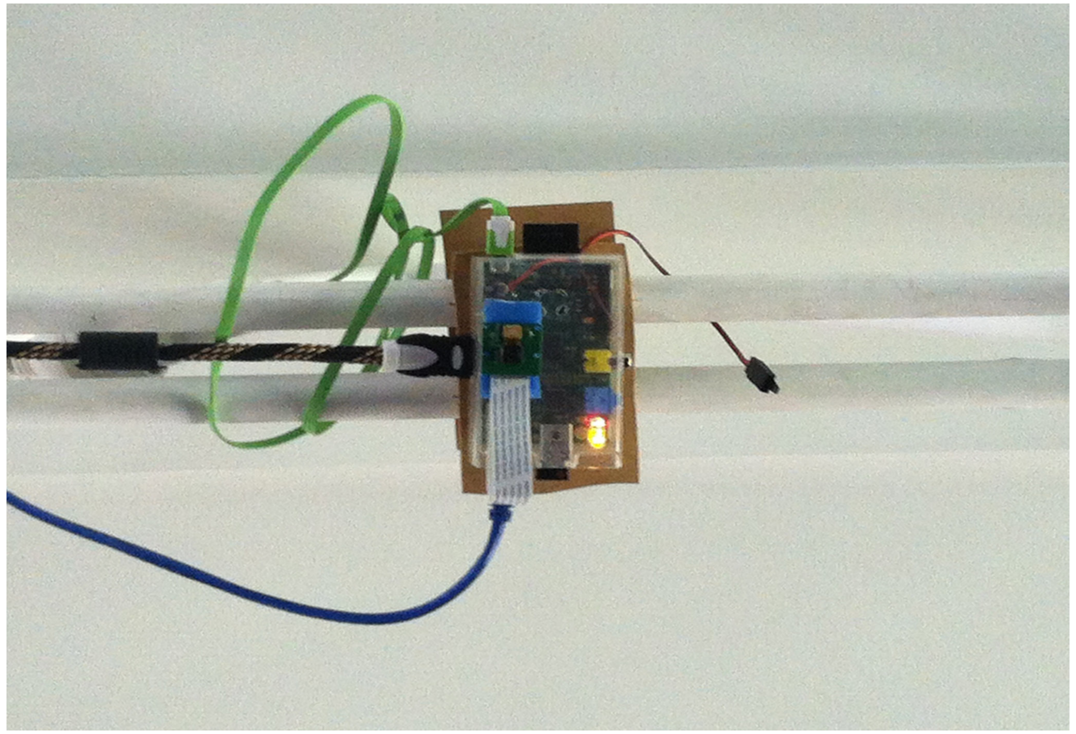
The left connection, using two xBee radios, is the connection to the IPS-Server.

The Raspberry Pis are connected to the school network through a switch and Cat 5 cables.

The ground station is connected to the same network. This is done wirelessly, but a wired link to the switch can be used instead.

The top image demonstrates the APM Planner receivinga GPS signal (GPS Fix of 3) from the IPS. The GPS The base/starting location can be any where in the world. The Raspberry Pi (bottom) is shown mounted to the roof. The image shows three cables running to it. The Cat 5 cable (blue) connects the computer to the IPS-Server. The green USB cable provides power. The black HDMI cable, used for prototyping, will not be required in the final IPS.





Next Step

After completin and evaluating Dickson College's Indoor Positioning System, the school plans on making the technology available and cheap to schools worldwide.

By using crowd-funding services online, the project will introduce students to real-world project management, strengthening financial and comunication skills.

The Positioning system is also planned to be extended to cover other uses, including physical movement-based Augmented / Virtual Reality.

The system will be used in 2015 to run various quadcopter and rover based events and competitions. In the 2014 UAV Outback Challenge, the Dickson team repurposed the IPS-Node software to detect symbols in a grass field.