Smart Traffic

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Comments:

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Summary

We realised that the world's road networks are on a verge of a revolution. However, we also realised, that this revolution can not happen without the introduction of a new communication standard. This communication would merge different elements of the network such as the roads, cars, junctions, crossings, pedestrians, motorbike, bicycles, trains, vans, trucks, motorbikes, car parks, and buses into a cooperating, efficient, and safer system. This system would be "Smart Traffic". This is is helped by several technologies that, to a high degree, are operational today. These technologies include:

- LIDARs for ultra resolution 3D real-time maps of the entire road network.
- Centimetre accuracy GPS systems for highly precise location of each and every vehicle
- Wireless network for quick and efficient communication between every element of the transport network.
- Intelligent roads and pavements that know where each moving element of the transport network is and are able to prevent crashes before they even happen
- Smart vehicles that are informed of the road conditions in real - time and know about their surroundings.

Main advantages of implementing such a system include:

- A more efficient road network which can communicate to eliminate traffic congestions and work around issues such as accidents and road works.
- A smarter, safer road network which can substantially reduce accidents by eliminating the accidents caused by human error and weather problems.
- Elimination of car theft due to cars being smart because of them always being connected to the smart traffic network - allowing for control of the car to be taken over by the system at any time., and an array of connectivity options along with constant GPS tracking.

- A greener environment due to having a road network that can be self sufficient in power, by being paved in solar panels, as well as being able to generate excess power.

In our system, the key to everything working well together, is to have quick and efficient communication of the relevant information between every element of the smart traffic system. As the system itself is so vast and requires so many advanced technologies to function. There are inherent obstacles such as cost, the colossal amount of work required for implementation, and the legislation required to make it all work.

We decided to demonstrate Smart Traffic using a scaled down version of our system. We took the various elements of the Smart Traffic system and scaled them down as much as possible. For example, GPS became a set of ultrasonic sensors and colour detectors, while the cars used small stepper motors for movement and servo motors for steering. This gave us ultra precise control of our cars as both motors allowed for adjustment degree by degree. Communication was done by wireless transceivers. All these components were to be controlled by various arduino boards - Pro Minis for the cars, and a Mega for controlling the cars and the sensors.

Once we had chosen the components, we proceeded to search for the components online at a price our budget could afford. We found a Chinese wholesale site, DX.com and an English site, HobbyComponents.com, and ordered the parts required. As we waited for the parts to arrive, we continued to work on the software side of our system and getting the mechanical parts and the main body of the car printed with our 3D printer (RIP). Unfortunately the parts took quite a while to get here. Once they did we were able to finalize the design for the car and begin printing the finalised components, unfortunately by the time we got to the mechanics of our first full car prototype, our 3D printer ceased to function. This coupled with the fact that we only had enough power supplies for one car, as the rest were damaged in transit. This meant we would only be able to have one car running for our demonstration. We could not order replacements because they would take too long to arrive. Due to our underestimation of the amount of time required to build the whole system software,we worked towards having one car drive around a simple route while being controlled by a base station. This would allow us to demonstrate the self driving and some of the communication aspects of our car.

We believe that Smart Traffic is the future of our transport and urge governments and private companies to fund development of the technologies required for such a system. Research could be continued by building small pioneer cities outfitted with the system as a complete proof of concept. We firmly believe this is the future of our road networks.

Introduction

As our transport networks expand in size and complexity we humans are really beginning to have trouble travelling quickly and efficiently, reliance on GPS navigation is increasing and now with more and more cars getting on the road people look at new technologies to alleviate traffic problems. The most promising technology so far is that of Self Driving cars.

The concept of self driving cars is pretty self explanatory (it's in the name) and has been around for quite some time. Many high profile companies such as Google, Tesla, Audi, and Mercedes have been working on the creation and integration of self driving cars for many years. Google has already managed to make a fully functional self driving car, which we can see is at an almost consumer ready stage, being in road test trials throughout California.

The three of us have noticed, that pretty much all of the self driving technology in development is a form of driver assistance, i.e. it is not truly self driving. This is due to the immense complexity of a real self driving car. The Mercedes technology is simply a lane changing cruise control. Tesla's cars simply follow road markings, read speed signs, or park themselves in your garage.

We also noticed, that, while Google's technology is, in our interpretation, a true self driving car, it still consists of independent units; they are not part of a larger system of traffic. Each car maps out its surroundings in real time, processes its data itself, recognises objects such as pedestrians, cyclists, cars, animals, or motorcyclists, but knows no more than their positions and does not share one bit of the valuable information it has gathered.

We believe that to really revolutionise our transport network, making it safer and more efficient, as well as bringing self driving cars closer to reality, traffic should be smart. Communication is the key to this. Cars should know relevant details about the routes of surrounding vehicles, be able to communicate with cars around them, the road itself, the junctions, the pavements, maybe even the cyclists and pedestrians. For true self driving, smart cars, we need smart traffic. Only with the data generated from such a system can we make a system where almost every single aspect of transport could be automated, smart, and safe. A system where traffic wouldn't need to stop.

Our aim for this project was to design such a system and showcase a basic version of it, to give people an idea of what it would take for truly smart traffic. Although a lot of our research was done online, a large part of it was talking to people we knew and asking them about such a system. Each person we talked to threw a different scenario at us, hoping to figure out a fatal flaw within such the system, but up until now we have been able to counter any argument thrown at us. One thing we all came upon during our research and talking to people about such a system is that not everyone is warm to the idea of their car driving itself. Therefore we have to create a system, where the cars do not need to be self driving, just only smart. This is not a problem, however, since the idea of a smart manual car is not contradicting itself. The smart traffic system would only take control of the "manual" cars during emergencies, and times of extremely heavy traffic, or at convenience, in an appropriate manner. Yet it would still share its relevant data in order to contribute to a safer traffic network.

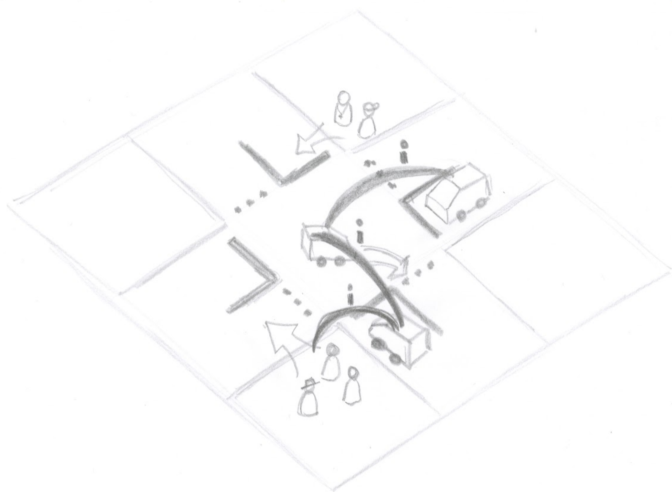
As the project continued, we began to realise that most of the technologies required for our system were already in development, but not as a single, standalone product. No one had yet thought to put them together. Which is why we decided to do this project and show the way towards truly smart traffic.

Demonstration

(Experimental methods)

We thought that to best demonstrate our idea, we should build a scale model that would incorporate as many of the elements of our system as possible and show them in action together.

First we needed to create a design for such a system. We decided in favour a road layout made up of four adjacent squares, as seen on the diagram beside. This would allow us to showcase the workings of a large junction, coordinated by the system. It would be complete with a pedestrian crossing on another part of the road system. As our ideas developed, we also planned to include a carpark. At a stage, we were also playing with the idea of a railroad junction.



After we had a design awaiting implementation, there were several technical difficulties we needed to overcome. We followed up leads on various technologies that looked potentially useful to realize our design.

Scaling down for demonstration was a hugely important step in this process. We understood, that in the RDS, we would have a limited amount of space available. As our project stand is 1200mm wide, we designed our demo board to be based on a 1200mm × 1200mm square, and we applied for an extra space allowance. Although that may seem like a large amount of space, this design was already incredibly compressed, as we planned on actually running several small cars on the track.

We settled on the use of the Arduino development boards and environment for our system as it is programmed using a variant of C that is familiar to both Aron and Akhil. The Arduino development environment is widely used for prototyping and is extremely flexible, compatible with a vast catalog of devices ranging from LCD touch screens to simple DC motors.

Once we settled on the Arduino development environment we had to choose what sensors we would use to represent our system in action. We needed to choose appropriate methods to represent the various elements of our system such as GPS, LIDAR, communication, roads and the cars themselves.

First we had to make decisions about the car itself. We had to compress it to the smallest size we possibly can. We used computer modelling and 3D printing technology to create the frame. This frame would go through several iterations of redesign and refinement. We decided to use 2 AA batteries as a power source, as it would be minimal in size, provide a decent voltage and store enough energy. The batteries' 3V added potential could be increased to the 5V required by the system components by a boost converter. For computation, we decided in favour of Arduino Pro Mini's, as they come in low price and small size, although we initially thought about Spark cores too. In early designs, propulsion would be done by DC motors, but we later changed this to a stepper motor because you can control how much it turns to a sub degree level. Steering would be managed utilizing a servo motor and a rack and pinion mechanism.

We carefully studied several options for communication. We knew, using the 2.4GHz band, especially a WiFi network would be dangerous, having experienced the overload of these frequencies in the RDS before. ZigBee-like networks, operating in the same band, however, do have a channel untouched by WiFi. In the end, the two main competitors were the more popular, 2.4GHz ZigBee-like XBees and the 434MHz HC11 wireless serial chips. In the end, we used the HC11s, partially due to financial reasons and to keep complexity low.

In the meanwhile, we needed to look at replacing GPS for our scaled model, as its accuracy is far from the size of our track. Lacking a better solution, we planned on using strategically placed ultrasonic sensors on the board to measure the position of the car. This system would be complemented by a series of colour sensors built in the road, which would identify the car being measured. As soon as a car passed above a colour sensor, the ultrasonic sensors would fire automatically and determine its position. In the meanwhile, the colour sensor would identify the colourful sheet stuck at the bottom of the car. This, way, the position of each car could be measured with a small delay (around 100ms), which could be accounted for. However, that delay would still be there and this system would also need a vast amount of sensors, which increase both cost and complexity.

We also had a temporary plan to include accelerometers and gyroscopes in the cars, and calculate our speed and position with their help. Unfortunately, after some research, this turned out to be incredibly inaccurate{1}.

Looking for a better replacement for the GPS, we had the idea to use a QR code based system. A phone, fixed at the top, would scan the position, rotation, and identity of QR codes stuck to the roofs of the running cars. This data could be then forwarded to the Arduino base station. However, this proved to be unreliable and the latency was much too high. Eventually we realised, we do not need any sensors at all, if we swapped the DC motors originally planned to stepper motors. While DC motors just spin back and forth, a stepper motor turns in small, well defined steps. This makes them highly accurate in the angle and speed they turn at. Along with the 1° accuracy of the steering servos, position could be computed using simple geometry. We expected that the pro mini would find it difficult to steer, communicate and step the stepper motor at the same time, so we outsourced this to a smaller chip called an ATtiny that would be given the sole task of stepping the motor. The ATtiny would communicate with the Pro Mini through I^2C communication.

For the base station we chose to use an Arduino mega board as it was able to control up 4 cars through its 4 serial ports simultaneously and up to 50 different inputs and outputs - the most of any Arduino board. These inputs and outputs would be used to control the various sensors within the model roads.

Once all this planning was completed we proceeded to order our parts from two sites, one of which shipped from China. This proved to be a problem because the parts we ordered took over a month and a half to get here and some parts arrived broken, such as the voltage converters for the car power supply. Even though we managed to get some parts for up to four cars and our base station we couldn't build more than one car due to a lack of power supply and certain 3D printed parts. Our 3D printer gave us many inaccurate prints and we spent much time testing different designs and trying to print prototypes. Eventually we managed to print a few prototypes and 1 full car, but once we got to the steering assembly for the second car, our 3D printer ceased working{2} and that was the end of that.

Unfortunately due to our underestimation of time required for such a display and the problems mentioned above we were not able to get our demonstration model fully functional on either the software or hardware sides. Although we do have one car that is running to some level and is able to demonstrate the self driving and communication aspects of our system.

Smart Traffic

(Results)

Based on work done a list of elements we would incorporate in our system is as follows:

- ## LIDARs

The term LIDAR is a combination of the words light and radar. It is a remote sensing technology that works by using light in the form of a pulsed laser to measure ranges to the objects around it{3}, the ranges measured are then used to build something called a point cloud map, which are essentially ultra high resolution 3D maps{4} of the scanned area created from all the range points recorded by the LIDAR.

Currently LIDARs are used to create maps of the routes upon which self driving cars will travel (Google's) and then to map out the surrounding area of the car in real time, The real time map is then compared with the pre recorded one to detect any obstacles near to the car and act accordingly.

In our system LIDARs would be placed at regular intervals along the sides of roads and at each road corner/turn/junction within reason{5} The LIDARs at first would be used to map out the entire road network, then learn the habits of traffic, and finally be used to analyse the road network in real time and make sure there are cars where there should be cars.

The kind of analysis LIDARs would do would be to watch the movements of objects such as people, animals, and cyclists/motorcyclists{6}, detect obstacles, and the position of cars accurately. The data generated would be primarily used for accident prevention and making sure that cars stay on track.

- ## Wireless Networking

Wireless Networking technology is already an integral part of our lives and is most commonly seen in the forms of WiFI, Mobile networks and Bluetooth. Wireless networking is simply the sending and receiving of information via radio waves.

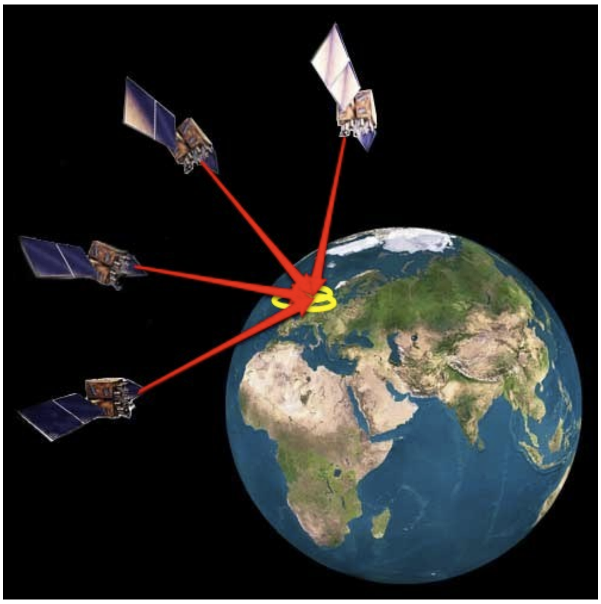
One of the many current use cases of wireless networking is A-GPS. That is, WiFi and mobile networks are used in smartphones to generate a coarse location[7] that helps GPS satellites locate the phone. Once the satellites lock on, an exact location can be generated. This speeds up the discovery time greatly, and accuracy can be improved. This technology is cheaply and readily available. It is also used in Google's self driving cars.

The more obvious use case for wireless networking is to upload and download content to and from network, i.e. communicating. Communication in this system would include other vehicles, roads, paths, junctions, or even regions. Relevant details about routes, position and speed, crossing permission and timing at a junction, suggested alternative routes, road construction, vehicle or system failures··· These are all examples of data that would be sent and received. It's kind of like an Internet of Things[8] for traffic. Some of these services already exist, such as Waze[9], where speed data is shared. Yet none of them are well integrated. We believe, this network should operate in an ad-hoc[10] manner, as such a network can tolerate the fault or loss of some components[11]. It should also be of course anonymous, and well encrypted[12]. Technologies required to implement such a network already exist, or can be modified for the system. For example, currently 3G and 4G network technologies are available, they can reach from small to larger distances, provide minimal delay and large throughput.

This second use case is the part, we believe, is missing from today's cars, self driving (Such as Google's solution) or not. Though many modern cars are already capable of connecting to the internet, they do not utilise this opportunity.

Cars could also use this capability to communicate with their owner in the event of a break in, or stream live in car footage to the web, and take pictures and upload them to the appropriate locations on the web in the event of an accident (of which we will hopefully have much less).

- ## A-GPS/Maps



GPS and maps are already an integral element of todays traffic network, with many modern cars having these features built in it is an obvious choice to include them within our system. GPS stands for Global Positioning System and does exactly what it says on the tin, GPS is used for finding the position of objects with GPS transceivers anywhere on the earth{13}. Maps refers to the maps of the road network that are available online via services such as Google Maps or Nokia Here maps.

Currently GPS and Maps are used together to to provide navigation assistance to human drivers, GPS works in the form of A-GPS where it is assisted by WiFI and mobile networks to place the user on a specific point on the earth. This location data is then fed to navigation software such as Google Maps which shows the user as a dot on the map. Based on the users location an appropriate route to the destination is highlighted. It is then up to the user to follow this route to reach their selected destination.

Currently GPS accuracy is not very precise as it always a few meters off, this inaccuracy is not of much disadvantage to humans as we can look at our position on the map, compare it to our surroundings and compensate for the error{14}, machines on the other hand would not be able to compensate for such an error unless it had human like AI. Instead of having to write complex algorithms to counteract this problem, we could just increase the accuracy of current gen GPS systems to the centimeter scale as this can be allowed for in our system{15}. Such a system is already under commercial deployment by Japan, who hope to have it fully operational by 2018{16}, another solution to this inaccuracy is called Quantum Positioning{17} which is said to be 1000 more accurate than current gen GPS systems.. Quantum positioning is expected to go into military land trials this year which means that it could be many years yet before we see it in commercial use.

Current gen maps already provide an impressive level of accuracy and detail, street view by Google being such an example, but for our system the entire road network would need to be mapped out through LIDARs so that a car knows exactly where it is on the road and what to expect at any given time{18}.

Together GPS and LIDAR generated maps would give us unprecedented accuracy and allow cars to drive within a few centimetres of each other.

- ## The Roads and Pavements

Roads and pavements are currently made using asphalt and concrete, right now they have no other use than to be travelled upon.

We believe there is untapped potential in the surface area occupied by roads and pavements. Implementing a system such as ours would increase a nation's power demand quite a bit, as the data generated by our system would require the construction of vast data centres to process the information in real time, and a single data centre can use enough electricity to power 180000 homes[1], and fossil fuels are running out[2]. A simple way to solve this would be to build Solar/wind/tidal farms or even a few nuclear power stations, but these pose the issue of space to build them. A solution to this would be to replace our traditional roadways with solar paneled roadways, the same would work on pavements. A company situated in the USA{19} has completed fully working prototypes that even have LEDs in them, which adds a smart element to the road surface itself. These LEDs could be used to display information about the road ahead e.g. weather warnings. Special panels designed for Zebra Crossings can illuminate lights on the ground telling pedestrians where to stay while waiting for the cars to stop/slow down. Current prototypes are also heated and eliminate the snow/ice problem that is often responsible for fatal road accidents. Further features that could be incorporated within these roadways include data transmission cables and water piping allowing for a much easier to maintain water and data infrastructure due to the modular nature of solar roadways{20}. The cost of installing such a road system is sure to be substantial but over time these roadways will definitely pay themselves back due to the incredible amount of energy that is sure to be generated by them.

Another use for roads we came upon could be for the charging of electric cars throughout their journey through the use of induction coils embedded at intervals within the road. A prototype of such a system is already in use on a Milton Keynes bus route{21}. This would promote the use of electric cars further reducing the environmental footprint of our travel network.

An obvious element of making roadways smart could be to incorporate environmental sensors such as temperature and humidity to keep tabs on the weather conditions along the road. In this system we could{22} also incorporate ultrasonic sensors and primitive pressure sensors. These sensors could line along and on the road and supplement other road monitoring systems such as the LIDARs and Cameras by detecting objects on the road and also flagging them for the attention of the Cameras.

Also since the roadways are smart the design of the road marking could be changed based on the car to make them easily understandable to machines.

- ## Cameras

Cameras are already in wide use in current traffic management systems to monitor traffic on the road network as well as search for stolen cars.

In our system cameras could be programmed with algorithms similar to those used for Google's visual search{23} engine. The cameras primary function would be to supplement the LIDARs in recognising objects on and around the road. Cameras will also be used to assist in collecting traffic data.

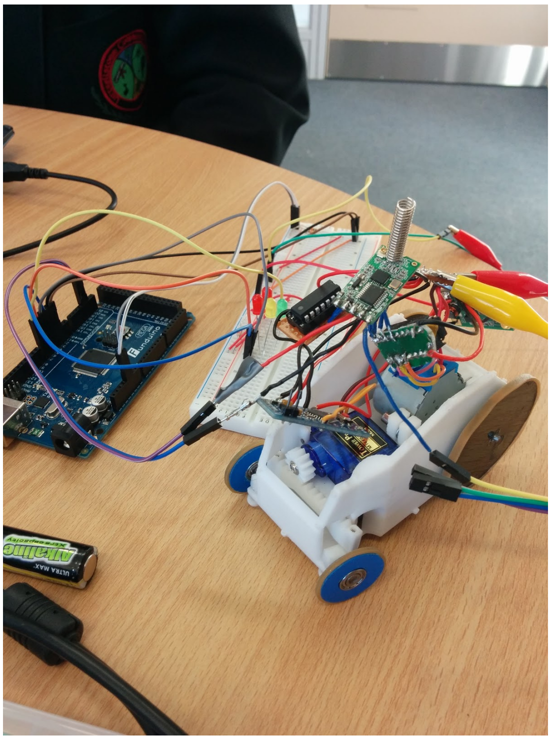
- ## Traffic data

Traffic data is something that is already very important within the travel network, internet connected navigation systems access it to check that the route to be recommended is not too congested, even people check on it just to make sure the road up ahead isn't too blocked.

In our system, the traffic data accumulated would be used to make intelligent sectors possible. These sectors would recommend optimal routes to enabled cars. This would allow for the most efficient traffic distribution possible. The optimal route would not have to be calculated on an individual basis, as it is be in today's world. Using data obtained, such as entry and exit points, timing, or even priority (eg. emergency/public vehicles)[24], intelligent sectors could compute routes for each vehicle, such that it would be optimal for the whole sector. Of course, these routes would be computed so, that they would not be too far from optimal for the individual vehicles either. Also, individual drivers would be given the freedom to disagree with and overwrite the suggested route at any time, even in self driving cars. The sectors would also communicate with each other, and help each other to optimise traffic distribution in the whole system.

It is worth noting that the traffic statistics accumulated could also help humans to design changes for a more efficient road network.

- ## The cars



The Cars are the most important part of our network as they are what it has been designed to serve in the first place. Obviously, to have smart traffic we need to have smart cars, Modern cars already have many of the systems cars operating in our system require such as, GPS/Maps, compass/gyroscopes, Internet access, proximity sensors, and onboard cameras.

For cars to work efficiently within our system their current capabilities would need to be extended. For example, proximity sensor accuracy would need to be increased to around 1 cm resolution (possible with current technology), as well as a more accurate GPS would be useful (work in progress). Cars would use these sensors to make sure they are on route and an appropriate distance away from objects and other cars[25]. On board cameras would be used for analyzing the surroundings much the same way the cameras on the roads would be used to help LIDARs.

Cars of our system would also incorporate a drive by wireless technology{26} to increase safety. As all of the car's controls would be electronic, the system could override them in moments of absolute emergency. Cars would be connected to the communication network that forms the core of our concept. They would process, receive and share relevant data, and communicate with other elements of the system in order to make travel safer and more efficient.

The system consisting of all the above elements would work together to achieve smart traffic, which will result in an intelligent road network that has a level of self awareness. This smart traffic system would work with any car that has the mentioned technology built in and would even be able to power itself. Such a system would vastly increase system would vastly increase the efficiency of our road network and along with it bring many benefits ranging from safety to environmental.

Conclusions and recommendations

From the work we have done on our concept{27}, we can conclude that there are numerous advantages and features that such a system could provide. These include:

- An intelligent road network that knows what's what and where what should be. A vehicle's position on the road is strongly suggested by the road itself based on current road conditions including weather, ~~grizzly bears~~ animals, routes of cars in the same sector, priority of the vehicle, and any obstacles on the road. Vehicles, self driving or manual, would be suggested routes optimised for both their preferences and system conditions. The driver, however, has the choice whether to accept that route or not, as, of course, we do not want people to feel limited in any way. The routes provided will be machine generated and the most optimal route followable, if every driver goes by their suggested routes we could have a road network where traffic never needs to stop and traffic is a thing of the past.

- A substantial decrease in accidents due to the constant monitoring and real time analysis of the road network, as well the built in smart traffic safety features that can even take control of any car in the event of a crash being imminent. Crashes involving self driving cars would be inherently low due to the sheer amount of sensors monitoring each one and the precise coordination of our system. Pedestrian related crashes should decrease too as the road network would be monitored. If any pedestrian is about to cross the road cars will be notified and slow down/stop as appropriate. Accidents caused by weather conditions such as ice and snow should also see a substantial decrease due to the roads being monitored and optionally heated. Accidents related to driver fatigue would also decrease due to cars being able to self drive in the event of driver incapacitation.

- Features of our system include intelligent junctions, regions and car parks. Intelligent junctions would be normal junctions outfitted with our systems. This would enable features such as a coordination of all vehicles travelling through this junction, so that the amount of stops required can be minimised., It could also give pedestrians a reasonable indication whether or not it is safe to cross. This would minimise the amount of time any one vehicle/pedestrian needs to wait in order to cross. Intelligent sectors would work to divide the road network in sectors. Cars would send their entry and exit points to the sector server, which would supply them with optimal routes based on current and predictable conditions of the sector it manages. This also helps load balancing. Inter-sector cooperation is also important to have the whole system in an optimal state (for example in cases where a sector is full and a neighbouring one has capacity left over). Intelligent car parks would eliminate the stress of finding a space in a crowded car park by guiding/driving your car to the free spot nearest to your selected entrance as soon as you enter the car park. A notable feature in Tesla's cars is the ability to park themselves in your home garage. This sounds similar, but is done on a much smaller scale and does not involve the communication part[3].

These are just some of the main benefits to having such a system in place, others include:

- A dramatic decrease in the 1.3 million traffic fatalities yearly as 90% of these are due to human error[4] - these are just accidents that occur during traffic.
- A huge creation of jobs and a surge in employment, implementing and maintaining such a system would require large amounts of manpower.
- A decrease in insurance costs as roads would become substantially safer and there will be minimal requirement for insurance.
- A greener environment as such a system would generate energy for itself and more, letting us ease off of our dependence on fossil fuels.
- Because each car is smart and always connected to and controllable over the network, car theft will become a thing of the past.

Based on these conclusions we recommend that research is to be actively and collaboratively funded by the governments and private companies of the world to further the development of the technologies required to make such a system work. We would like to see this system implemented around the world for safer and smarter roads.

While we understand that the resources required to build such a system are immense, we believe it is the future of travel. Implementing such a system all in one go would an impossibility, so the way forward would be to start building and implementing such a system stage by stage, as parts of the system come out of their research and prototyping stages. This would also give people time to get used to the system, and by the time it is fully functional they won't be overwhelmed. A simplified example of the stages such a system could be implemented in is as follows:

1. An ideal first step would be to make the cars smart. We could include drive-by-wire capabilities and some sensors. This would also mean that we could introduce a small level of self driving, for example when parking, driving on highways, and deserted roads, similar to Tesla's features.
2. A second step could be to introduce communication amongst cars themselves. They would share and receive relevant data and make simple decisions on their own, helping the driver.
3. The next step could be to start the use of LIDARs to map the road network and allowing for the use of next generation GPS in cars, letting them take more complex routes by themselves
4. Using these, traffic data and existing camera systems could be improved and the road could begin to communicate directly with the cars.
5. Next the final communication and sensory system could begin implementation, The system can now become fully operational.
6. During this the revamp of the road and pavements and transformation into smart solar roadways could begin.

This is just an example roadmap within which each stage would take many years to complete. The sooner research is started and the more funding it gets, the quicker we can have such a system. Testing the system on a smaller scale could also serve proof of concept, give further insight and quicken advancements. This system could revolutionise our road networks that have been the same for decades.

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- Steven Harris (TY Student)

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A list of general articles about self driving cars, which broadened our understanding of self driving cars and gave us information about certain systems we would use in our system:

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Appendix

(Also a selection of puns by Aron Hoffmann)

{1} = Aron created an app that would dump accelerometer data to the screen and we found that small movements would trigger large spikes of data that would completely throw off the readings being taken.

{2} = The print head of our 3D printer unfortunately became engulfed in a ball of flame and suffered a fiery death.

{3} = As the LIDAR rotates and sense laser pulses it measures the time it takes for the laser to bounce back and uses that to calculate range.

{4} = A point cloud map is created using the points generated from the LIDAR measuring ranges, currently the point cloud maps used in Google's self driving car are calculated at 1.3million points a second.

{5} = Depending on the size and average traffic of a corner/turn/junction a LIDAR or a group of them would be placed there.

{6} = Cyclists and Motorcyclists would be guided along a safe route through each sector by LEDs that follow them throughout their journey telling them where they should be on the road.

{7} = A coarse location is generated by measuring the signal strength of a device from networks of a known location such a cell tower or a WiFi network. Usually 3 readings are taken and the triangulation method is used. Distance from each tower is estimated based on the signal strength.

{8} = Internet of Things refers to everything being connected to and accessible over the internet from washing machines to smart locks.

{9} = Waze is a crowdsourced travel network data map in which its users submit data such as speed and the direction they are travelling, Additional data such as road incidents seen by the user are also sent in. This data is available to other users who can use it to plan their journeys efficiently.

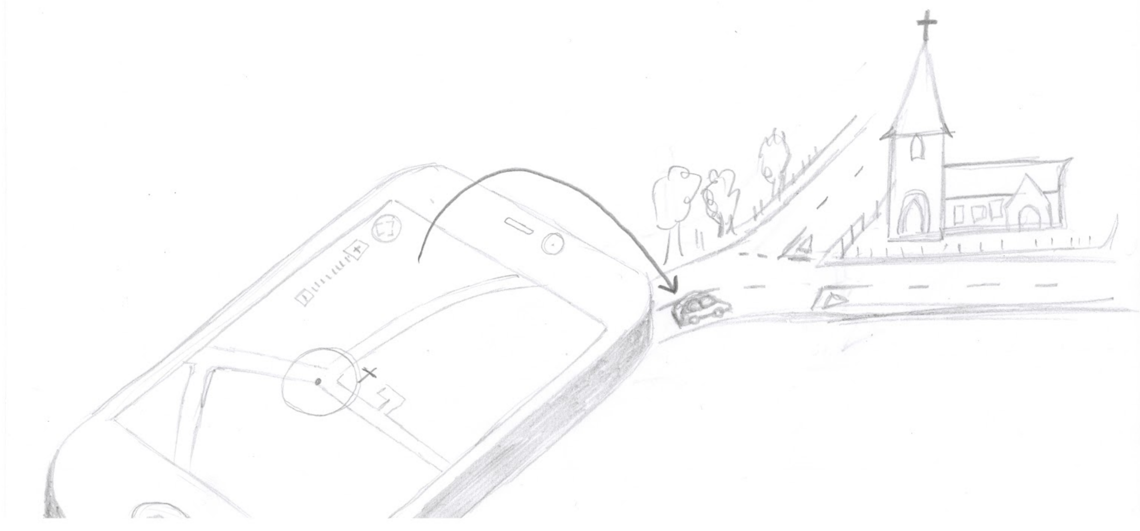
{10} = An ad-hoc network is decentralized and relies on the nodes within it to pass on information to one another until it reaches its destination, which nodes pass on data is based on the connectivity of the node.

{11} = As an ad hoc network passes information through itself without the use of routers or central exchanges if a part fails the network will simply skip it and send it to the next node.

{12} = Encryption means to scramble data using a key that is made up of random numbers and letters and then using another key to unscramble the data.

{13} = GPS satellites in view of the transceiver send signals down to the transceiver and if the transceiver receives the signal it sends one back to confirm.

{14} = In the navigation software, the user is automatically assumed to be on the road compensating for the sideways error, but the location along the road is not compensated for by the software. So the user compares the map to their surroundings and compensates accordingly.



{15} = If the location is off by about 5-6 centimetres then cars will always be told to keep a 30 CM gap between each other for safety.

{16} = Japan has designed a system made up of 1200 reference stations and seven satellites. The first satellite was launched in 2010 and the remaining six are expected to be in space by 2018.

{17} = Quantum positioning works by cooling a cloud of atoms to just above absolute zero once they are trapped by lasers. At such a low temperature the atoms reach a quantum state that is particularly sensitive to outside forces such as movement. The changes in the atom can be measured using a laser and based on this location can be calculated from the last known position.

{18} = After the LIDAR maps out a part of the road while it is empty the empty map can be constantly compared with the live map and this information can be relayed to the car telling it what to expect.

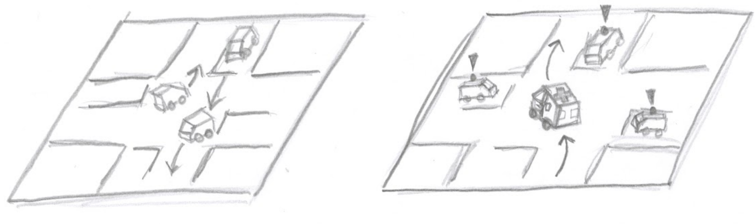
{19} = A company called Solar roadways has built a small parking lot built out of working Solar roadway.

{20} = Current Solar roadway prototypes are made using replaceable hexagonal plates that can easily be replaced and modified.

{21} = Route number 7 in Milton Keynes is 25 km long and has induction chargers for the electric buses that run it at every stop. While the bus is stopped it is charged.

{22} = When we say "could" we are referring to something that is not required but would be ideal.

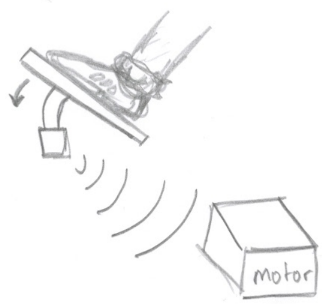
{23} = Google's visual search engine recognises objects in an image and runs a search on them.



{24} = One such feature would be that emergency vehicles are automatically given priority over all other vehicles and any cars up ahead will automatically move out of the way or stop so the emergency vehicles can quickly and easily pass. A future feature could be to introduce a priority system where users can buy priority miles and use those to be given a slightly quicker route for a certain distance.

{25} = If a car was set to be 30CM away from another car it would use these sensors to do so.

{26} = “Drive by Wireless” is an evolution of the “Drive by Wire” system. Mechanical linkages, inside a car, that link the controls to their various functions are replaced with wireless transmitters and actuators e.g. the driver presses the accelerator pedal - it sends a signal to a transmitter connected to an actuator which controls the accelerator and the car accelerates.



{27} = Scientists don't show off biceps, they show off concepts!