Situation-Aware Stop Signal

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***Abstract* — Advancements in technology made in the last two decades have made possible the rethinking and redefinition of traffic control at small intersections. Using new and more affordable LiDAR and RADAR technology, the Situation-Aware Stop Signal is aimed to reduce the number of accidents that occur on the smaller roads of our communities and, ultimately, save lives. A sustainable, solar-powered design allows the stop signal to be deployed and maintained for a low cost while eliminating its need for area utilities.**

***Index Terms* — Embedded software, microcontrollers, millimeter wave radar, road transportation, solar energy, sustainable development, traffic control.**

I. Introduction

At the crossroads of one small neighborhood in Orlando lies a small memorial at the corner of a four-way stop. It stands in remembrance of someone's loved one – a neighbor – who lost their life in a fatal accident in that very same place. Every year, in our community and in others, there are a multitude of accidents that occur at small, residential intersections controlled by stop signs. A 2002 study by the Insurance Institute for Highway Safety found that one third of all intersection crashes in the United States, and over 40% of those fatal, took place at intersections where these were the primary traffic control device [1]. Accidents of this kind are often the result of drivers running stop signs due to visual distraction, the influence of alcohol, and other forms of carelessness. Stop signs have long been important tools for controlling traffic at small intersections, but they are becoming less effective in an age when both traffic and distractions are more present than ever on the road.

Since the first stop sign was installed in Detroit in the year 1915, the approach for managing traffic at small intersections has not changed by a great amount. The need for change, however, has never been greater. Living in an age dominated by small, bright screens and various forms of handheld or otherwise easily-accessible entertainment, there is more potential for accidents to occur today than in any other time in history. These new distractions introduce complex issues into the realm of roadway safety and pose a serious threat to drivers if not mitigated.

A concern for the safety of others, paired with an admiration of current technology, has led us to rethink traffic control at the enforced stops of our community. The culmination of this thought is the Situation-Aware Stop Signal. Where conventional stop signs are insufficient, the Situation-Aware Stop Signal is intended to draw greater attention to the roadway and be a catalyst for safer crossings at small intersections. Influenced by technology found in existing traffic lights and autonomous cars, this intelligent system is designed to be a modern and more effective replacement for the stop sign. Using advanced sensors and real-time computing, the Situation-Aware Stop Signal is able to monitor the intersection for traffic and provide intuitive warnings to drivers.

II. Objectives

A. Prevention of Threat

A threat exists when a driver does not slow down as he or she approaches the intersection. This may be due to some form of a distraction, such as the use of smartphones while driving, or could be the result of driving under the influence of alcohol or other impairing drugs. For this situation, the stop signal was designed to alert the driver to slow down and to come to a complete and safe stop.

By triggering the driver's senses, particularly sight, the stop signal is able to help him or her maintain his or her eyes on the road ahead. Implementing this required a need to understand human psychology and the behavior people tend to exhibit while driving. Throughout our study, we observed that people seem to respect traffic lights more than stop signs. This observation was fundamental in exploring our method of redirecting the driver's attention.

To capture attention and prevent a driver from driving through the intersection, the stop signal indeed acts similar to existing traffic lights. Until a vehicle comes to complete stop, the signal provides a solid red light as an indicator that the driver must stop. This was decided due to people's familiarity with the stops of larger traffic control systems and their association of these with the consequences of violating such stops. When a vehicle has remained stationary for a period of time at the stop bar, the signal gives a flashing yellow light to indicate that the driver may proceed with caution. It was decided against using a green light to 1) invite the driver to be aware of other vehicles even while crossing and 2) provide a distinguishable experience from that of larger traffic control systems.

B. Protection from Threat

$$v = \sqrt{2 * range * \mu * g} \quad (1)$$

Should a driver constitute a threat and not slow down as he or she is entering the intersection, it is of critical importance to alert all other drivers at the intersection and keep them immobilized until the threat has passed. In such a situation, the traffic control system must attempt to keep everyone safe. This situation is given the highest priority amongst all other situations that may occur at the intersection.

A threat must be detected and classified well before it reaches the intersection. Here, a study of car velocity, driver reaction time, and safe stopping distance was required to properly identify danger. These factors were considered in the interpretation of sensor data and the primary function of the algorithms that were written in the project software. This ability to process data was directly dependent on the speed at which it could be captured. This second consideration, a need for real-time situational awareness, was the principal consideration of the embedded software design.

The Situation-Aware Stop Signal uses mmWave RADAR to track vehicles as they approach the intersection. As RADAR tracks a vehicle, it continuously compares its speed to that which it considers safe given its distance from the intersection. This analysis is represented in (1). Once RADAR detects a threat, the system immediately enters an emergency mode. In this mode, all lights are turned red, preventing any other vehicles stopped at or approaching the intersection from crossing. The stop signal continuously checks all sides until no threat remains. Once the intersection is determined to be safe, the signal exits the emergency mode and resumes normal operation.

C. Scheduling of Traffic

Oftentimes, drivers stop at the intersection at the same time and do not proceed for concern of incorrectly assuming or yielding the right of way. When this occurs, not only is traffic flow constrained, but a new threat to safety may be presented. By implementing basic scheduling with the stop signal, we took an opportunity to correct this issue.

We acknowledged current traffic laws and designed our system to direct traffic in a manner that is consistent with the behavior they dictate. We aimed to recognize all combinations of driver presence at the intersection and understand the order by which traffic should proceed in every unique case. A study of driver behavior and arrival times at small intersections was necessary to sufficiently consider timing when scheduling traffic. Although this was likely to vary greatly between drivers and locations, an average or more probable pattern of traffic flow and management was defined.

To implement fair scheduling of vehicles at the intersection, we designed the stop signal to operate using a simple FIFO queue. Simply put, the first vehicle to arrive is the first vehicle to be scheduled. The management of this queue performed by software running on a 48MHz processor allows the stop signal to capture vehicles when they arrive – whether they be hours, minutes, seconds, or microseconds apart. Current traffic laws indicate that should two vehicles arrive at the same, the one on the left should yield to the one on the right. With the Situation-Aware Stop Signal, virtually no vehicles are found to arrive at the very same time. There is always a “winner”: the one who is found to arrive first.

III. Self-sustainability

The Situation-Aware Stop Signal was designed to be self-sustaining. Although its manufacturing cost was acknowledged to be greater than conventional stop signs, it was determined that it should *not* imply a significant operational cost. Current traffic control systems at larger intersections require connections to area utilities and are either dependent on existing infrastructure or demand its extension. Such investment and continuing operational costs can lead to a great expense for the governments or private industries that manage them. Contrarily, the stop signal was created to reduce these costs and be deployable in diverse locations where area utilities may not reach.

To be independent of local power grids, the stop signal operates on solar power. A 28-inch by 28-inch solar panel rests overhead of the main control box and generates over 80W of power using 25 solar cells at 0.6V at 6A each. These solar cells were produced by Sunpower, which are currently the industry leader for consumer level solar cell production. These cells are a monocrystalline design which means that it is pure slices of silicon rather than melting smaller pieces of silicon into a single cell. Because these cells have less imperfections than its competitors, it allows them to be more efficient.

A solar charge controller manages power generated by the solar panel and regulates its storage in an on-board 12V lithium ion battery. While the solar panel is producing more than the device’s operating voltage, the charge controller will regulate the voltage going into the device to the desired 12V. To optimize the storage of the power generated via the solar panel, a MPPT (maximum power point tracking) charge controller was used. The MPPT charge controller similar technology as PWM (pulse width modulation) charge controller; however, these charger controllers can retain more of the generated power. With other PWM charge controllers as well as single stage charge controllers, excess voltage will be lost upon supply to the battery. With an MPPT charge controller, excess voltage can be converted into additional current. Using MPPT charge controllers will allow for larger solar panels which may be to maximize usable solar panel space.

By providing over 80 watts to our battery while only consuming about 12, our device stays low power. The additional power consumed during sunshine hours will be used to charge the battery. Florida produces about six solar hours a day, so the solar panel needed to produce at least four times the devices demand to say sustainable. This would account for the continuous operation of running 24 hours in a day. The battery that was chosen for this project has a capacity of 20Ah. Given our design operates at under 1A draw, our device will be able to operate for a day without any sunlight hours. Having the battery backup allows for days that have small amount of sun hours.

IV. MODULARITY

Modularity is vital to provide easy means of adjusting the signal to meet the needs of any intersection. While the goal of this project was to design a signal intended to replace stop signs at smaller intersections, the product was designed modularly with the ability to be expanded to larger roadways and eventually be used to replace traffic lights. Modularity appears throughout the device; where there is hardware modularity, there is also software modularity that conveys the design's robustness.

The physical design is where most of the modularity is seen. The use of 3D printed mounting brackets for both the RADAR and LiDAR sensors, allows the user to adjust the angle of the sensor to meet the needs of any intersection.** Additionally, with so many different types of intersections out there, the addition of removable side modules allows the user to add to take off any of the sides to suit the intersection more accurately. While our design only has two side modules on currently, more modules can easily be added in the future thanks to the use of the connectors on the back of the center module. As mentioned previously, testing the device with ease was another aspect in our design. Accessing the hardware inside each module was necessary to debug and ensure that all the components of the design were working together correctly. This was achieved by adding sliding hinges to the modules. This allows the owner to see the inside of the module and spot issues more easily. These additions to the physical design improved the quality of testing and highlight the easily adjustable nature of this unique stop signal.

Modularity also exists in the software. With the ability to add or remove more sides to the signal, comes the ability to adjust the software to the size of the current intersection. With just a simple numerical entry of the number of required sides, the software can detect cars from as many sides as the user requires and pull from the appropriate number of sensors. This can help improve efficiency and save power. If some users only require one modular side, the sensors in the remaining sides will be off and not be collecting unnecessary data, thus improving efficiency. Additionally, an ample amount of power is saved by not turning on extra lights and sensors.

Power is the final aspect of the modularity in this design. Because a requirement of this device was self-sustainability, the main source of power for this project is the solar panel. While this may provide the required amount of power, the majority of the time, when there is little to no natural sunlight, the device still needs to be functional. To achieve this, the addition of the battery introduces an additional power source for the device. While the sun is out, the device can be directly powered from the solar panel, however, on a cloudy day, the power gathered from the panel which is stored in the battery can be used to keep the signal functional. This second power source creates additional modularity for the system to ensure this device will be constantly operational.

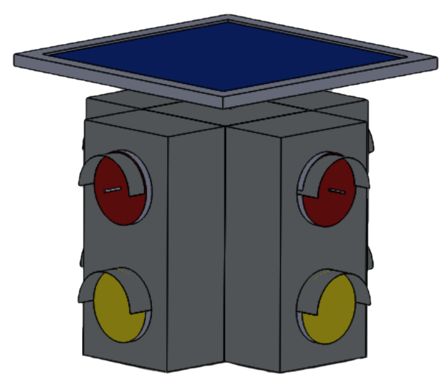

Fig. 1. 3D rendering of S.A.S.S. This rendering shows what the device would look like if implemented for a 4-way intersection.

V. STANDARDS

The design goal of this device was to mimic the look of a current stoplight that is seen on an everyday intersection. For this reason, we closely followed the Manual for Uniform Traffic Control Devices. All box dimensions, light sizes, and height have been in accordance with the Department of Transportation's standards.

Indicated in Figure 4D-4 in the Manual for Uniform Traffic Control Devices, the standard for the 12-inch lights presents a maximum of 180 feet from stop line to signal face. The standard for 8-inch signal indications is 120 feet from signal face to stop line.

The Manual on Uniform Traffic Control Devices states that traffic signals should determine who has the right of way by using priority control. Priority control is used by the signal to select the driver with the right of way by allowing whichever driver who stopped at the intersection first, to proceed through the signal first.

In addition to the traffic standards that were followed when creating this project, there were many hardware standards and testing standards that allowed the project to be completed correctly. While we are only dealing with low power electronics, it is still vital that the power supply and delivery standards be followed correctly. These efficiency standards for power supplies provide tests for the worst-case scenario of the circuit and require certain minimum and maximum power outputs in any scenario.

VI. Hardware

The one major focus of the hardware design was to save power. This engineering requirement played an important role in both choosing hardware, such as sensors as well as how designing the PCB. Another goal of the hardware was to create redundancy and ensure the safety of all drivers. To achieve this, two different types of sensors were included in the stop signal: RADAR and LiDAR. These sensors, along with the PCB makeup the hardware electronics.

The PCB was able to be designed without a maximum size requirement while keeping in mind an efficient output. Because this system will operate in real time and need to rapidly control lights, minimizing unnecessary components and trace lengths helped improve the functionality. Additionally, because the device will be operating outside, eliminating excess heat was achieved by swapping out a large linear regulator with a switching regulator. While the linear regulator helps eliminate noise, it loses a lot of power through heat dissipation. Because this board does not contain any major high frequency elements, saving power was more important than eliminating noise, which is why the switching regulator was used for the 12V to 5V step down. While power efficiency was a large concern, testing was another one. As a result, the PCB was designed with testing in mind. Signal LEDs and test pins were incorporated throughout the PCB to ensure that the regulators and other major components could easily be tested. This helped to easily identify and correct any major issues with the PCB.

At the heart of the PCB is the TI MSP432P401R microcontroller. Not only do we need a design that is power efficient, we need a design that can also perform adequately to read and interpret sensor data provided by the RADAR and LiDAR modules. This processor was chosen due to its extra memory, large number of GPIO pins, and compatibility with RTOS. This MCU also provided a quick and efficient means of flashing code, testing, and debugging the software. Because the MSP432P401R evaluation board was provided to us by the TI lab for testing the MCU, we were able to also use this evaluation board to flash our board with the designed software. This made testing both easy and efficient.

Accuracy was another major requirement of this project. In order to monitor and control traffic, creating redundancy allowed for us to ensure the safety of drivers who cross the intersection. This redundancy was achieved by sensor fusion or the use of both RADAR and LiDAR sensors to detect oncoming traffic. While the LiDAR and RADAR are being used in different ways to detect traffic, together they will provide more accurate readings of the way that traffic is behaving.

The RADAR module chosen uses mmWave sensors to detect objects with a frequency of over 100 GHz, the smaller wave size provides a more accurate and speedy result when detecting objects. This module includes an evaluation board that helps process the data gathered from the RADAR. As a result, this module will be placed inside the signal. The focus of the RADAR board is to gather the position and velocity of all oncoming cars. It will also detect and alert our PCB of any potential threats to the intersection.

Like the RADAR, the LiDAR is a time of flight sensor that uses a laser to detect objects within a thin beam width. While the LiDAR does not include an evaluation module, it includes a durable weather resistant casing, which allows the sensor to be placed outside the module. The main job of this LiDAR module is to initially detect any car approaching the signal. This sensor will be alerting the PCB if an object is detected and stopped at the stop signal. Then, unless a threat is detected by the RADAR, the LiDAR will alert the PCB that there is an object and, after the appropriate amount of time, allow that car to proceed through the intersection safely. The use of two different types of sensors that cover different ranges allows for more data and the redundancy required to provide a safe means of controlling traffic.

In addition to the hardware electronics, comes the power hardware. In order to make our device both power and cost efficient, a solar panel was chosen to be the main source of power for this device. This decision was made not only to save the user the cost of tying this device to the power grid, but also to increase ease of installation. While some components of this device are relatively more expensive than the traffic lights, the total cost saved from using solar power versus grid power makes up for the more expensive sensors used in the project. Also, the use of the solar panel can reduce the installation time drastically and allow this device can placed nearly anywhere, regardless of whether there are power lines near or not.

Because the solar panel was designed and created by us, we were able to focus on purchasing the most efficient solar cells possible to improve the overall power gathered from the panel. For example, since monocrystalline solar cells can generally produce more power than polycrystalline cells, these were chosen for the solar panel. While these cells were a bit more costly, it was worth the additional power gained to use them. Also, building a solar panel allowed for additional savings.

While the solar panel provides a lot of power, there is still a need to power the device in overcast or cloudy conditions. To do this successfully, a battery was chosen as an additional power source to allow the device to still work when there is not enough sunlight to power the solar panel. The battery chosen to do the job was the GTK 3S Lithium Ion battery. These batteries store more power and charge faster than lead acid batteries. The battery chosen was also much lighter than alternatives. This helped lower the overall weight of the traffic signal.

To ensure reliability and efficiency of the design, an MPPT charge controller was added to supply a constant voltage from the battery even while to device is charging. We decided to use an MPPT style charge controller over a PWM charge controller. MPPT charge controllers offer efficiencies over 95%, and the one we decided on has a max efficiency of 98%. By utilizing a charge controller, the lifespan of the battery can be improved. Charge controllers improve the lifespan of the battery by trickle charging after the battery is nearing maximum capacity as well as providing protection against overcharging. The charge controller will be placed between the battery, solar panel, and PCB. For our application, our solar panel will produce 15 volts during operation. Our charge controller is rated to be able to step this down to 12 volts during operation which is a key feature of this device. The charge controller also includes a display that will show the status of both the battery and charge controller. With the addition of the charge controller, the voltage that the PCB receives can now be limited and regulated to a near constant value.

VII. Software

The software of the system is broken down into four components which are:

1) Low-Level Hardware Abstraction
2) Object Detection
3) Object Classification
4) Traffic and Light Control

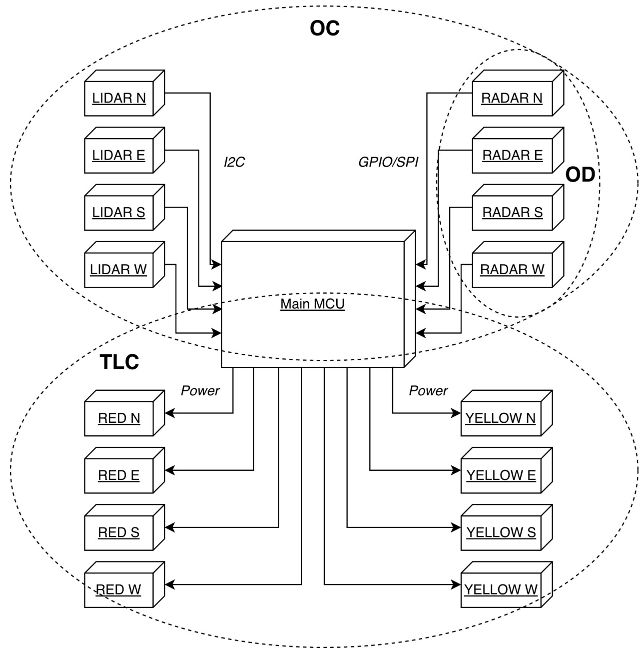

Fig. 2. Deployment diagram depicting three of the four software components used in the Situation-Aware Stop Signal: Object Detection (OD), Object Classification (OC), and Traffic and Light Control (TLC).

A. Low-Level Hardware Abstraction (LLHA)

The LLHA component is responsible for abstracting out the hardware that we used to prototype the design. Since we want this system to be modular and adaptable, it was essential that we design a common API-based system to perform all of the hardware-based functionality of our system. Doing this also simplified the design of the higher-level logic that we were to use in the rest of the system.

Currently, the LLHA component controls the lower-level settings for the LED lights, the I2C communication for the LiDAR, and the SPI communication for the mmWave device. This is done so that we can abstract out the hardware required for each side of the device in a modular way. The device could theoretically have 4 sides, so the software is designed to accommodate those sides through the settings within the LLHA submodule.

B. Object Detection (OD)

The OD component is responsible for detecting objects that the system can then respond to. This module relies on both the mmWave RADAR sensor and the LIDAR-Lite v3HP LiDAR sensor to detect vehicles that are entering the intersection. Object detection mainly takes place on the mmWave device since it is more capable of sensing vehicles that are moving towards the intersection. Then, once the vehicles are approaching the stop bar, the LiDAR device takes over and provides added information as to when the vehicle stops at its specified location.

C. Object Classification (OC)

The OC component is responsible for determining if each oncoming vehicle is considered safe or unsafe based on (1). Similar to the OD module, OC is started on the mmWave device which monitors the oncoming vehicle to constantly check if the vehicle is safe or not. Once a vehicle is determined unsafe, the mmWave device then triggers a hardware interrupt that will then force the system into emergency mode.

Alternatively, if the vehicle is determined to be safe then the system will operate normally, resulting in the device monitoring the LiDAR sensor for a vehicle that stops at the specified location for that side of the intersection.

Once the vehicle is in the proper location, the OC module is responsible for verifying that the vehicle is also still located in the intersection at that location. After validating that information, then the OC sends the vehicle object to the queue managed by the TLC submodule.

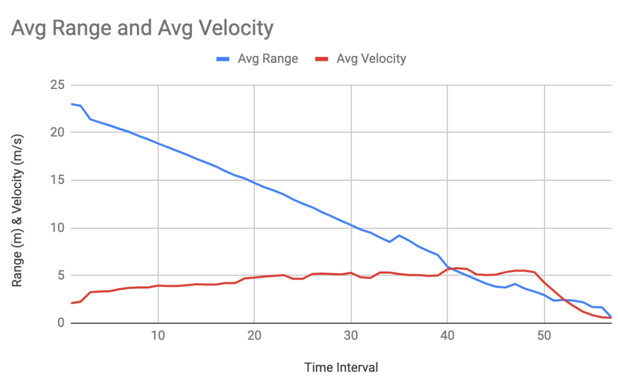

Fig. 3. Noise-reduced model of time vs range and velocity data gathered by the mmWave RADAR sensor (from captured logs).

D. Traffic and Light Control (TLC)

The TLC component is responsible for monitoring the state of the device and scheduling vehicles as they arrive in the intersection. This is achieved by inserting a new vehicle object into a queue. Doing this allows us to monitor each vehicle that arrives in the intersection while also keeping track of which side the vehicle has approached from. By doing this, we allow the TLC submodule to understand the state of the entire system, without knowing the implementation of the rest of the system. This is perfect for a traffic control device like this as it allows the scheduling mechanism to be updated and changed independently of the rest of the system and could then be optimized to allow for higher throughput.

The TLC is the perceived heart of the system as it is the only module that directly affects the external world. If the TLC does not work, then the entire system is a failure since it is the management system for all of the lights and traffic control. Currently, the TLC and the rest of our system abide by all of the standards and regulations defined in the Manual on Uniform Traffic Control Devices (MUTCD) and, accordingly, the system has a failsafe mode so that the system can deal with software and hardware failures as necessary.

E. Emergency Mode

As briefly noted, on detection of an unsafe vehicle, we trigger a hardware interrupt to force the system into an emergency state. We decided to use an interrupt-based approach because this would ensure that our system responds to the thread regardless of the thread that is currently running.

While in emergency mode, we rely on the mmWave sensor on each side to report back through the GPIO pin the status of the vehicles that are in view. While checking the status of each vehicle, we keep all lights on the system set to red to indicate that no vehicle is allowed to enter the intersection as there is a possible threat. Based on our implementation, as long as there is a vehicle that is detected that is considered a threat, the system will stay in this mode.

F. Failure Mode

Since drivers rely on traffic control devices to determine their actions when driving, it is important to ensure that our system is reliable and safe. Because of this, we included a default error-catching utility using a software interrupt that forces the system into a permanent failure state until the system is reset. In this mode, the system follows common traffic laws outlined in the Manual on Uniform Traffic Control Devices and the system will blink red approximately sixty times per minute to ensure that operation of the intersection defaults to that of a typical 4-way stop. Errors that could cause this are deadline failures, LiDAR sensor failures, and control failures. This ultimately gives the system a reliable way to fail without causing any sort of accident.

Since the software interrupt handles the LiDAR sensor failures, we still need another way to handle the mmWave sensor failures in case that sensor fails. If the sensor were to fail, it would never trigger that interrupt and in this case, that results in normal operation for the device, without the emergency detection feature.

For a more robust approach, this interrupt driven approach could be adapted to include more features such as self-reset and/or external LTE communication out to let a central control center know that the system is down. For us this was not within scope of the project in the time frame that we have, but it would be something that is important for a real production level system that is within the intersection.

G. Real-Time Operation using TI-RTOS

It was determined early on in the design of the Situation-Aware Stop Signal that the system should operate quickly, reliably, and *deterministically* due to its safety-critical nature. For this reason, it was decided that the software should be managed by a real-time operating system (RTOS). TI-RTOS, Texas Instruments' own RTOS product, was selected as the operating system to power the stop signal software because of its open-source nature and extensive support for both the MSP432 microcontroller and C++ programming language.

Multithreading support in TI-RTOS allows the stop signal software to run multiple threads of execution. Because the MSP432 microcontroller has one core, these threads are scheduled so execution time is shared in a fair and deterministic manner. The Situation-Aware Stop Signal software makes use of priority scheduling and three unique types of threads provided by TI-RTOS: tasks, software interrupts (SWI), and hardware interrupts (HWI). SWI inherently have greater priority than tasks, and HWI greater priority than SWI. Tasks are used for code pertaining to regular, safe operation. SWI are used to trigger system failure should any hardware or software issues exist. HWI are used to trigger the emergency mode when a threat is detected, exhibiting the highest priority to ensure the safety of drivers at the intersection.

VIII. Future Use

Currently, the Situation-Aware Stop Signal is designed for an intersection with stop signs, but that does not mean that this technology or our methods are not adaptable to more complex intersections. With RADAR and LiDAR technologies becoming more affordable within the last decade and advancements in low-power computer vision-based systems, it is much more likely that traffic systems will start being updated to do exactly what we have done with small intersections.

Computer vision is typically expensive and power-hungry but with new systems like the Nvidia Jetson and mmWave Radar sensor it is possible to replace the timer-and induction-based systems with RADAR, LiDAR, and computer vision systems. Doing this is currently not cost-efficient, but over the next few years it could be within reach to start replacing those systems to include smarter technologies to detect threats, increase throughput, decrease waiting time, and catch criminals.

One additional and needed feature for updated systems like S.A.S.S. would be an ability to catch and ticket drivers for not abiding by the laws of the road. This is because this is a large source of income for the states. Many systems do this already, but this would enhance that functionality and also bring it to smaller intersections that are more likely to have accidents.

Another possible use case for systems like this is exactly the use case that we addressed with S.A.S.S. We currently solved the problem for small intersections, but with more time, money, and equipment it is completely possible to increase the efficiency of the software and to enhance its functionality by allowing the system to monitor larger areas and accommodate different types of detected objects such as pedestrians, bicyclists, and animals. Doing this would allow a traffic management system to monitor the safety of drivers and pedestrians in a proper manner and could easily prevent accidents in high-traffic, inner-city roads.

With that in place, it is also possible to increase throughput of all vehicle and pedestrian traffic by allowing the system to control each component of the system and determine the optimum timings to allow for maximum throughput using machine learning. Some systems already do this using computer vision and sensors within the roadways, but this could give a more robust solution that relies less on sensors embedded in roadways.

While the device is already somewhat modular, in the future, even more modularity could be incorporated in the signal. While the device can detect bicyclists, a crosswalk or pedestrian crossing is very common in most intersections. The ability to detect pedestrians and alert the drivers by turning all the lights red could improve upon the goal of saving people's lives. While we originally wanted to be able to mount the solar panel on top of the device and have the ability to be rotated depending on the sunlight. A rotating solar panel would increase the amount of sunlight the solar panel could use and, as a result, provide more power to the device in a shorter time. With more money, resources, and time, a movable solar panel bracket could greatly improve the self-sustainability aspect of this device.

Also, because the device itself required more power than originally expected, in the future, a larger battery with more capacity would be used to reach the goal of being self-sustainable for two days without sunlight. Because there is still a lot more space in the device, a larger battery would not affect the physical design.

IX. Conclusion

The Situation-Aware Stop Signal demonstrates the effectiveness of modern technology working in concurrence with outdated traffic units. While following MUTCD traffic laws, this device built upon current traffic control units which relied on timed algorithms. Using LiDAR and RADAR sensors, this device is able to detect where cars are within an intersection and use this data to more safely and effectively control traffic.

A major requirement of the Situation-Aware Stop Signal is to keep drivers safe and prevent car accidents. With this in mind, the design challenge became how to orient this device so that it does not distract or confuse drivers. The solution to this challenge was to design the device so it resembled a traffic light, the difference being that our device does not have a green light. This decision was made as a result of our implementation directed towards smaller intersections. Rather than giving the drivers the “go” signal, this device tells drivers to “proceed with caution.” Proceed with caution better fit the scenario for the traffic device which was being replaced.

While the idea is expandable to larger intersections, the goal of this project was to focus on smaller intersections that currently have stop signs. Technology such as robust as RADAR and LiDAR are scalable to larger applications. Applying this idea to larger areas could reduce the amount of traffic incidents, increase the flow of traffic in dynamically changing traffic patterns, and provide lower cost traffic control to modern, adapting areas.

Ultimately, the Situation-Aware Stop Signal will be self-sufficient and able to easily be integrated into society because of its stop-light-like appearance. We hope this project improves traffic on low volume roads while reducing both traffic accidents and waiting time for cars. This idea opens up further opportunities to expand and build upon the idea of a smart, intuitive traffic signal.

Acknowledgement

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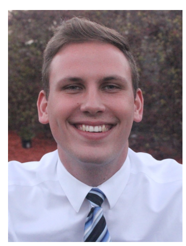
Finally, the authors wish to acknowledge the families of those individuals who have lost their lives in motor vehicle accidents at small intersections and at all crossroads of their communities.

Authors

Jon Ling is an electrical engineer from Merritt Island, Florida. Jon worked primarily on the power system, mechanical design, and PCB of the Situation-Aware Stop Signal, focusing on the distribution of power from the solar panel and battery source to all electrical components in the system.

Annabelle Phinney is an electrical engineer from Jupiter, Florida. Annabelle worked primarily on designing the PCB of the Situation-Aware Stop Signal, architecting much of the printed-circuit design while researching and acquiring the necessary electrical components.



Trent Sellers is a computer engineer from Orlando, Florida. Trent worked primarily on the embedded software of the Situation-Aware Stop Signal, focusing on the programming of the PCB with a particular emphasis on multithreading and real-time applications.

Joseph Walters is a computer engineer from Orlando, Florida. Joseph worked primarily on the embedded software of the Situation-Aware Stop Signal, focusing on the programming of the TI mmWave RADAR module with a particular emphasis on algorithm development and communications.

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