Electronic speed regulation system for materials handling vehicles

John Fielding
Prof. Adrian Keating
School of Mechanical and Chemical Engineering

Simon Chan
Remote Control Technologies Pty. Ltd.

Abstract

Commercial and industrial locations often need speed zones established for safety. For example in warehouses vehicles such as forklifts are often used to transport materials to various locations across the warehouse transiting areas of increased traffic of other vehicles and personnel. To safely traverse these distances the vehicle is required to pass through high traffic areas at lower speeds. While limits are marked in such locations automated solutions are preferred such that vehicles are forced to observe the speed limits. Existing speed limiters use GPS signals outdoors to locate the position of vehicles within zones and thus limit the vehicles speed via a speed controller. However indoors the options available are more limited with areas where GPS signals cannot be obtained and other option such as RFID being costly and disruptive in installation and maintenance. This projects primary objective is to prototype a new commercially viable solution based on colour identification (patent pending) that provides zone positioning data (thus speed limits) to a speed controller. The systems zones are indicated by using coloured areas on the floor. These areas indicate which speed zone the vehicle will be entering and the device will adjust the speed limits appropriately. Work continues on the prototype which has successfully completed several milestones and approaches completion.

1. Introduction

10% of all workplace accidents in Australia are related to materials handling vehicles. While often attributed to operator error, as much as 25% of accidents (Miller, 1998) can be avoided if additional safety measures are in place. The true cause is often traced back to lack of enforcement of safety regulations. Forklifts and other material handling vehicles while relatively slow, are capable of causing significant amounts of damage. From classical mechanics:

$$p = mv \tag{1}$$

The vehicles mass, typically 4.1 tonnes unloaded and upwards of 10 tonnes for loaded vehicles, enables momentum to build up quickly despite its limited top speed (typically 25 km/h). In comparison the standard cars' top speed is typically around 200-250 km/h and they weigh approximately 1 tonne. Worst-case scenario the forklift can be moving around the warehouse with $6.94 * 10^4$ kg m/s of momentum. As they often work in tight spaces a small loss in vehicle control can result in hundreds of thousands of dollars' worth of damage, not to mention the potential for fatalities and serious injuries to both the driver and pedestrians.

To properly assess the cost of an accident a number of factors need to be taken into account. The first of which being the direct costs, such as medical costs, fines, and the cost of replacing damaged equipment and products. The second accounts for indirect costs, meaning the cost associated with loss of production capacity, and the cost of hiring and training replacement workers. Finally there is an immeasurable cost; this is to account for the damage done to the company's reputation and the workers moral (Gavious, et al. 2009). Which is why speed limits are important to maintain in such environments. Typically the vehicles should never exceed 15 km/h and around heavy traffic areas it should be limited to 6-7 km/h (Lovested, 1977). Unfortunately these limits can often be ignored or overlooked by drivers and it is preferential for the speed to be limited automatically.

Remote Control Technologies (RCT) is an Australian company that specializes in providing safety and productivity solutions to many industries. The goal of this project is to produce a working prototype speed control system capable of automatically and unobtrusively limiting a vehicles top speed based on the surrounding risks. Based on a feasibility study conducted over January and February 2012 by Simon Chan and John Fielding for RCT, the project is to design a prototype sensor system that accepts input from a set of colour sensors, the sensor detects, and communicate with an existing speed controller product, manufactured by RCT.

Colour sensors often return information in the form of RGB colour space. This colour is based on the principle that every colour can be represented by a superposition of red, green and blue light at varying intensities. Unfortunately due to the Cartesian properties of this colour co-ordinate system it is very difficult to determine the observed objects colour just from this information. However if shifted to another co-ordinate system such as HSL (hue, saturation and luminance), it is possible to determine the colour simply from the hue. Converting the data between colour coordinate systems is a simple case. First the maximum (M) and minimum (m) of the red (R), green (G) and blue (B) values must be determined. Now the following equation can be used:

$$C = M - m \tag{2}$$

$$H = 60 * \begin{cases} undefined, & if\ C = 0 \\ \frac{G-B}{C} mod 6, & if\ M = R \\ \frac{B-R}{C} + 2, & if\ M = G \\ \frac{R-G}{C} + 4, & if\ M = B \end{cases} \tag{3}$$

Now that the hue value has been calculated it is possible to identify the colour of the object. Hue is measured in degrees and what is known as the colour wheel, is a well-defined circle with sections that correspond to specific colours. By relating the calculated hue value to the colour wheel it is possible to determine the corresponding colour.

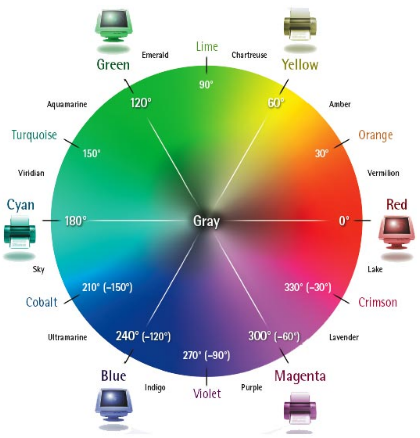

Figure 1: Standard colour wheel (McClelland, 2006)

This project builds on the results of the feasibility study. A prototype will be designed using the same sensor and also to be compatible with RCT's existing speed controller product. Speed zones will be indicated using hue values. In the feasibility study 4 colours were found to exhibit exceptional results. These will only need to be placed at zone boundaries. The other advantage to this solution is it also acts as a visual cue to both drivers and pedestrians, clearly marking the different zones.

2. Design Process

To effectively design the prototype an iterative methodology is adopted. This process involves rapidly developing a prototype, then testing and evaluating the prototype, and finally incorporating the information into the next iteration of design. This is repeated till the device performs at an acceptable standard (Dieli, 1989). While more common in human computer interface design, this methodology is also used for designing circuits where space and weight are not critical elements. The reason this design process is being used is that it allows a greater focus on critical issues facing the project; it is also makes it easier to assess the projects status and also provides proof of its status throughout the project lifecycle. Most of all it is a very reactive process, meaning that it is often easier to identify the sources of errors, this is due to the fact that the process often begins with a very simple design and each revision adds complexity making it easier to track when errors are introduced and allowing them to be fixed in the next iteration (Mantei, et al, 1988). To apply this method to the project all early circuit designs will be done on a copper strip board until the device is operating at a high level of accuracy, once this occurs the designs will form the basis of the PCB (printed circuit board) design.

3. Prototype Iterations

A number of laboratory and live test situations were devised to evaluate the capabilities of each prototype. The first few iterations of the prototype were too crude for live testing but underwent laboratory testing to identify and confirm the usefulness of selected parts. Initial designs used four colour sensors, 3 to detect red, green, and blue and the last sensor would use no colour filtering to measure total reflected light (Figure 4). The roles of each sensor could be changed in software resulting in different modes of operation. The layout however caused issues as the sensors were too far apart which lead to differing viewpoints. While testing the device by using various hue colours the colour wheels of different operational modes were plotted (Figure 3). By changing the order of the sensors no significant change in the colour wheel should be observed however large disparities were detected between a number of different configurations. It was realised that information gained from the sensor with no filter in place could be approximated by the sum of the RGB sensors. This led to a new layout with the three sensors side by side (Figure 4). 3 prototype testing units were constructed using the new layout, named and were tested by recording 15,000 consecutive hue readings of a single colour. The values were then averaged and the standard deviations were calculated (Table 1).

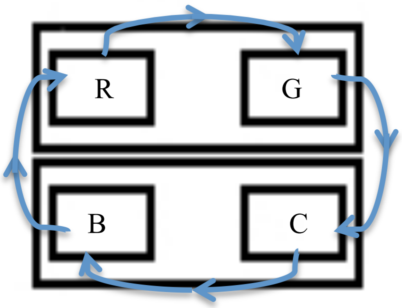

Figure 2: Initial 4 sensor configuration that allowed for sensors to switch to different modes of operation

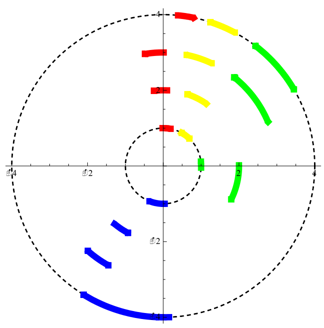

Figure 3: Experimentally determined colour wheels for 4 modes of operation for the 4 sensor configuration

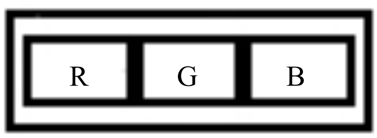

Figure 4: Revised 3 sensor configuration

	Prototype 1		Prototype 2		Prototype 3	
Colour	Avg. Hue	SD	Avg. Hue	SD	Avg. Hue	SD
Red	259.10	0.38	258.00	0.00	257.34	0.62
Green	6.00	0.00	8.57	0.49	9.58	0.13
Blue	54.87	0.31	47.87	0.85	56.31	0.00

Table 1: Comparison between the average hues (AH) given in degrees and standard deviations (SD) between the different prototype models.

When comparing statistical averages of hue values between the 3 prototype models the values remained consistent within degrees of each other and the standard deviations remains low indicating that the values are consistent over time. Thus confirming the previous issues had been resolved.

When testing the device outside reflected infrared radiation (IR) from the Sun was found to cause large fluctuations in the sensor readings. To eliminate the problem several IR filters were evaluated. This was achieved by taking intensity measurements in RGB space over a white surface, both inside a laboratory environment and outdoors in the Sun. The filters are designed to block out certain wavelengths of light however the materials used to make filters are imperfect, this causes the filter to partially block all wavelengths in the spectrum. Comparing the the two indoor cases it is possible to determine the signal loss caused by the use of the filter.

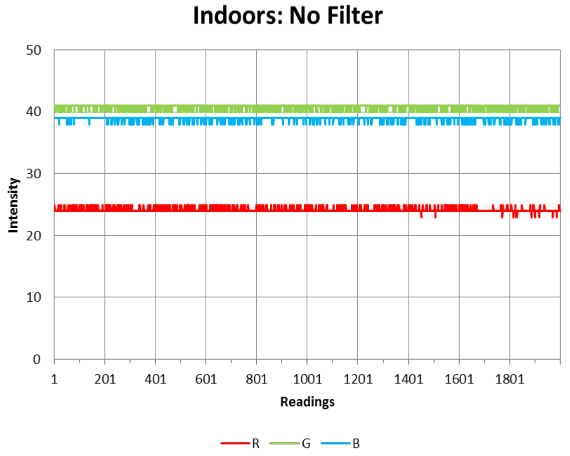

Figure 6: Intensity results for a sensor system indoors with no IR filter use

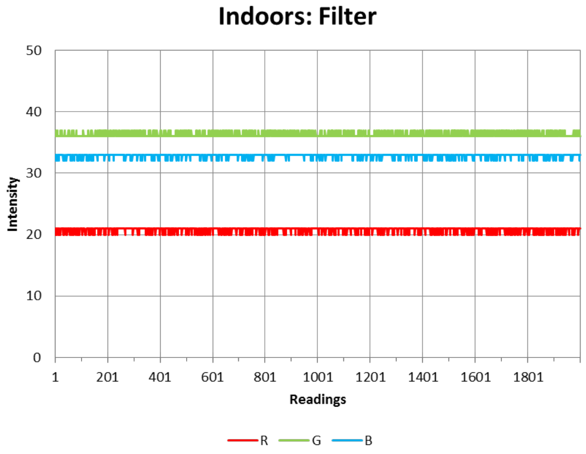

Figure 5: Intensity results for a sensor system indoors with IR filter use

For pure white light the red, green and blue intensity plots for a system with no filter would show each component colour in perfect balance. The disparity witnessed in Figure 4 is because of the different colours is due to the spectrum emitted by the light source. Comparing the plots in Figure 4 and Figure 5 the filter does not have a significant effect on the red, green and blue values which are clearly within the passband of the filter. While the intensity drops are approximately 10-20%, if the filter caused attenuation greater than 40-50% this would seriosly affect the performance of the device. For this particular filter though these effects can be mitigated by a white balance calibration.

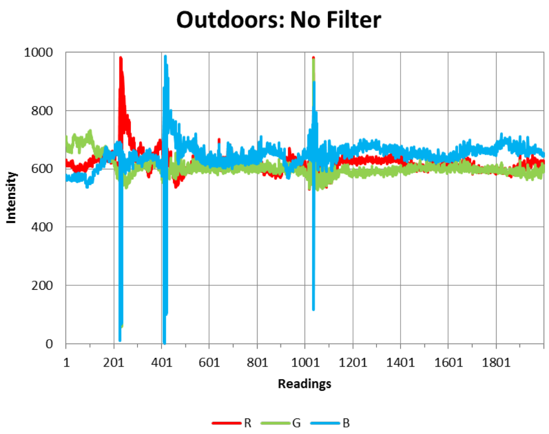

Figure 7: Intensity results for a sensor system outdoors with no IR filter use

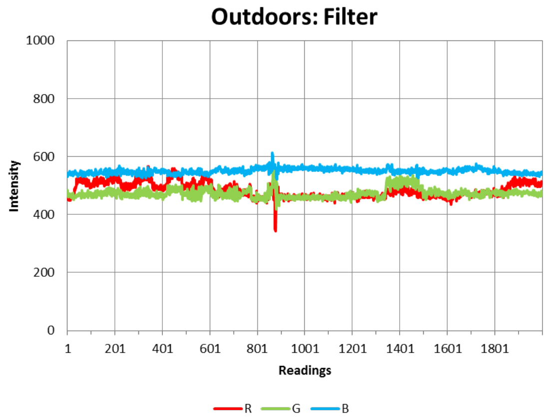

Figure 8: Intensity results for a sensor system outdoor with IR filter use

When taking the system outside the colour filters built into the sensor are sensitive to wavelengths outside of the visible spectum. Without the IR filter in place there is fluctuations in the signal at unpredictable periods (Figure 7). The signals could spike and double in magnitude but as this not a uniform rise or fall in the various signals, it is not something that can be adjusted for in software. When using this particular IR filter the signals from the sensors improved drastically, while still exhibiting some variation over time the signal is much more stable and using signal processing techniques like implementing a moving average it is possible to clean up the signal even more.

A number of algorithms were formulated to identify zones and zone changes. The algorithms were capable of identifying the difference between zones and brief flashes of colour with varying degrees of reliability. By modelling the algorithms in MATLAB and using RGB data collected from field testing the prototype it was possible to refine an algorithm to a highly reliable state. In this effort a number of debugging tools (logging, post processing, csv processing) were also developed for the project.

4. Conclusions and Future Work

Ultimately the prototype is shaping up to be a reliable system for colour detection with few drawbacks. It is capable of accurately and consistently changing colour zones and the colour transition works as an additional visual cue for the operator to know what speed zone the vehicle is entering. The system does have weaknesses that it is yet to overcome such as significant dirt and wear and tear on the zones, or significant changes to lighting condition can lead to incorrect colour recognition. Apart from working on these issues a PCB will also need to be designed for the system.

This project was more research based extending the concepts of the feasibility study (which provided proof of concept) to a much more robust prototype of the system. While this system shows significant promise to providing a low-cost indoors speed controller there is still work to be done before it's ready to be implemented as an industrial safety solution. Future work will focus on commercializing the solution and bringing it up to industry standards. Commercializing the solution involves designing a ruggedised version of the product, reducing the total cost of the device, and optimizing/improving the software for better usability and interfacing.

5. Acknowledgements

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6. References

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