Situational Awareness Fault-finder Extension

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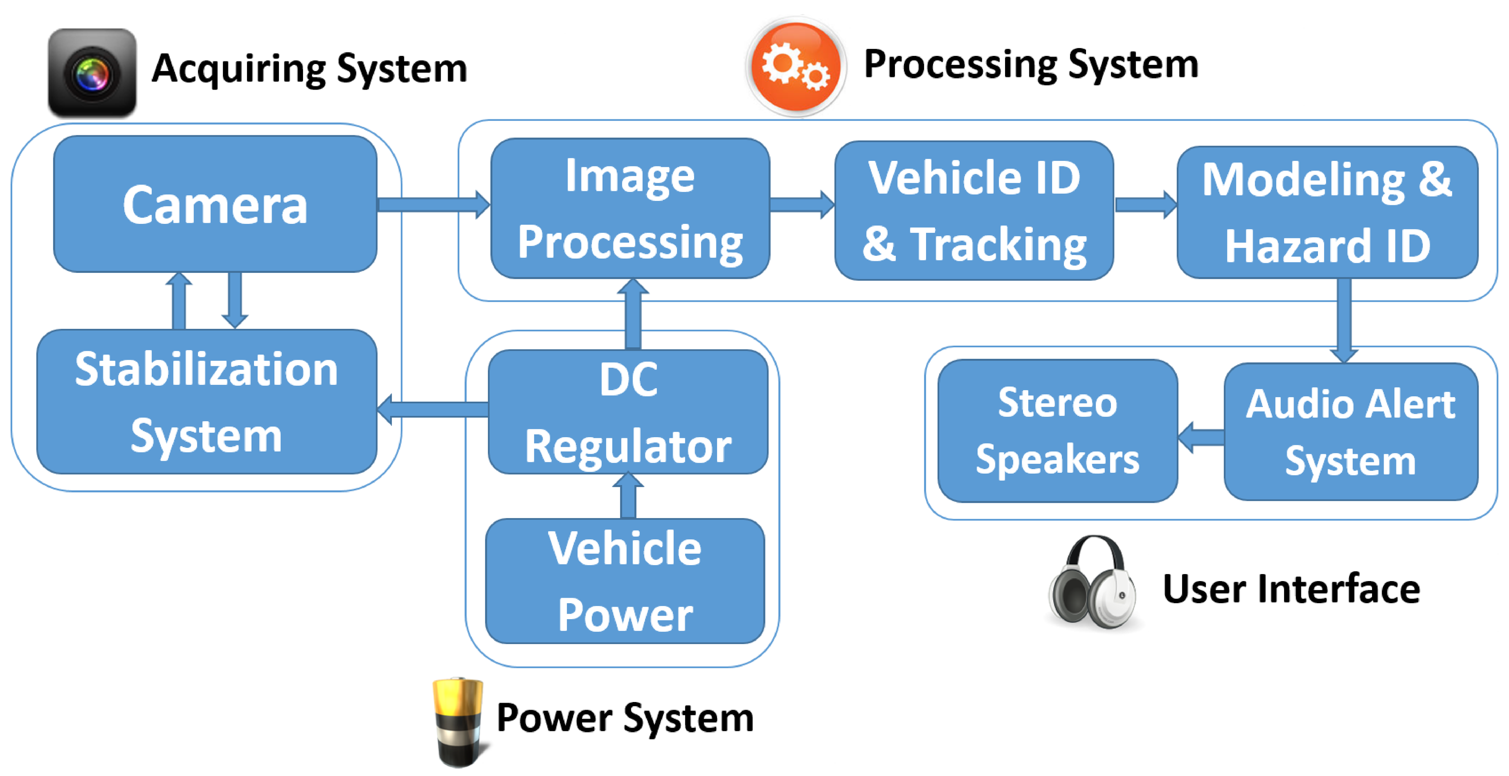
*In 2011, 81,000 motorcyclists were injured in accidents on U.S. roads. Of those casualties, 4,612 were fatal. Motorcyclists and scooters are more vulnerable on the road than other drivers. A majority of motorcycle accidents are the result of other vehicles failing to detect the presence of the motorcyclist. Currently there is no commercial product supporting vehicle collision avoidance from behind. We have worked on creating an affordable and intelligent system, **Situational Awareness Fault-Finder Extension (SAFE)**, which monitors rearward and alerts the driver audibly in case of imminent danger from behind. We believe this enhances the operator's awareness and so will prevent forward collisions as well.*

1. Introduction

SAFE is designed for either automobiles, motorbikes, or bicycles. **SAFE** is able to track posterior vehicles, monitor their relative speed, position, and direction, and provide auditory alerts using tempo, amplitude, and stereo cues to indicate position, speed, and danger from tracked vehicles.

2. System overview

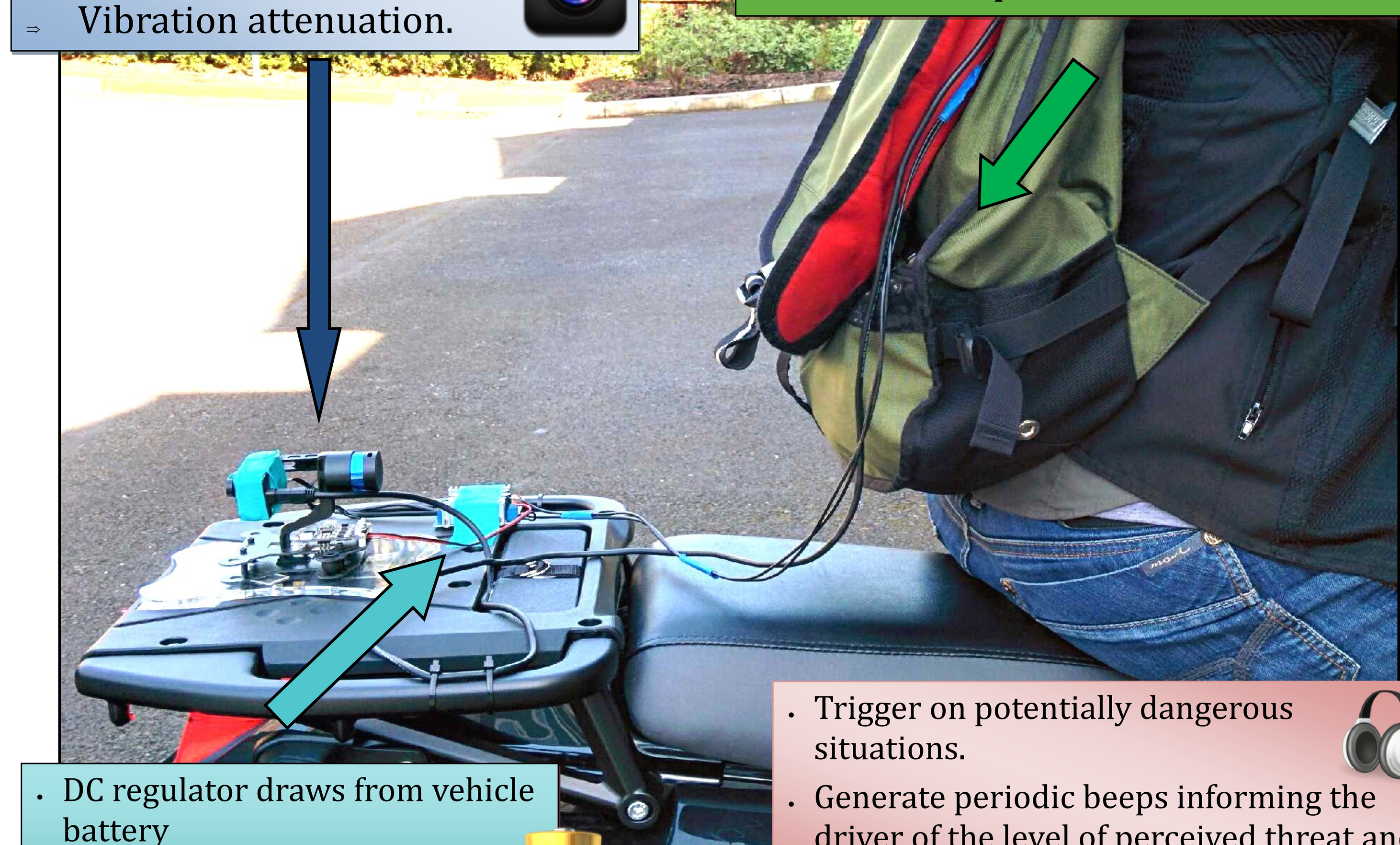


First, an image of the scene behind the user is acquired by a single camera mounted on a stabilization unit. The image is then processed to detect vehicles in the scene. Next, the detected vehicles are assigned a unique ID for tracking and for modeling their potential hazard. Whenever a vehicle is determined to be a dangerous object to the user, **SAFE** will send an audio signal to the stereo speakers to alert the user. A single power system using the vehicle's own generated power provides for both the acquisition and processing system.

3. Hardware

- CMOS camera with global shutter.
- 640x480 resolution pixels.
- 60 frames per second.
- Tarot T-2D gimbal
  - Roll stabilization
  - Vibration attenuation.

- Intel Atom processor running the Lubuntu OS with custom C++ software.
- Perform object recognition, position and velocity tracking, hazard detection, and generating audible alerts.
- A production solution would be much smaller, fitting inside the vehicle's internal compartments.

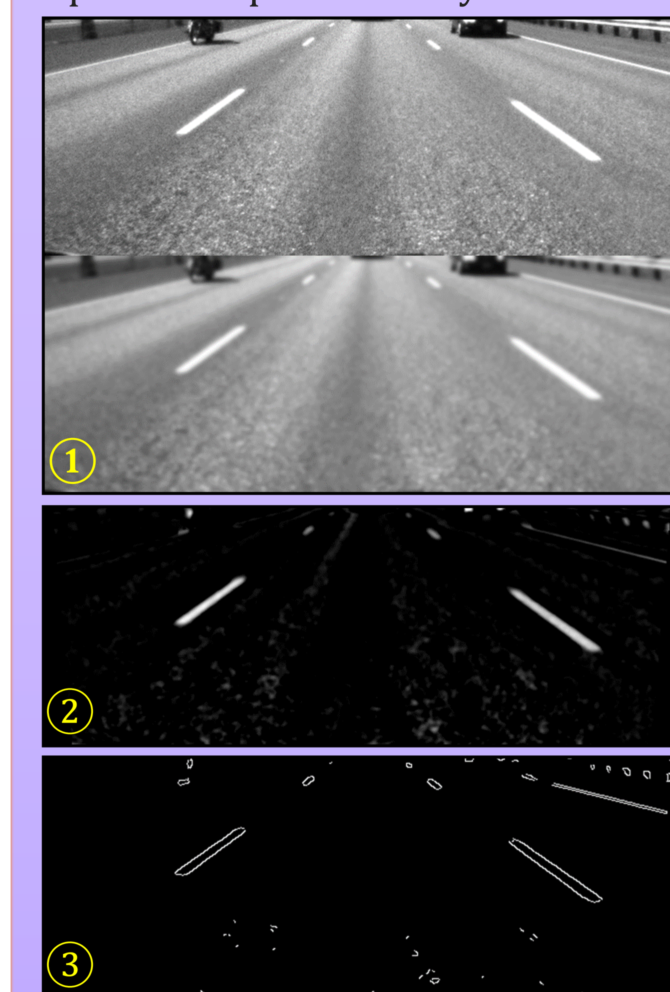


- DC regulator draws from vehicle battery
- Powers camera, gimbal, and processing system.

- Trigger on potentially dangerous situations.
- Generate periodic beeps informing the driver of the level of perceived threat and the position of the hazardous vehicle.

4. Software

The heart of **SAFE** is custom image processing software, which identifies and tracks objects from frame to frame. This software was written in the C++ programming language, and uses the OpenCV computer vision library. This open source library provides optimized matrix math and commonly used image proccessing algorithms. The code executes on a 1.6 GHz Intel Atom based embedded system running the Lubuntu operating system. The process is based upon work presented by Marcos Nieto et al. [1].

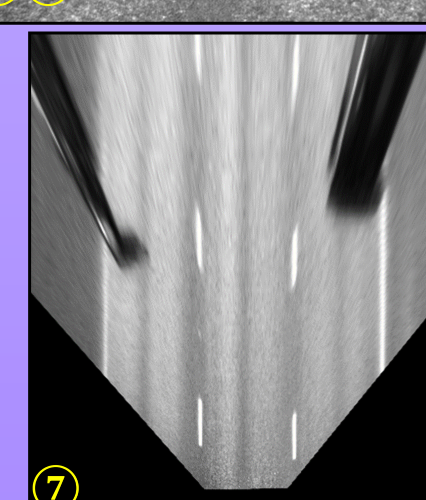


① Blurring
Only the bottom half of captured image used. Noise is removed using Gaussian blurring. This acts as a low-pass filter, reducing rapid gradients between neighboring pixels.

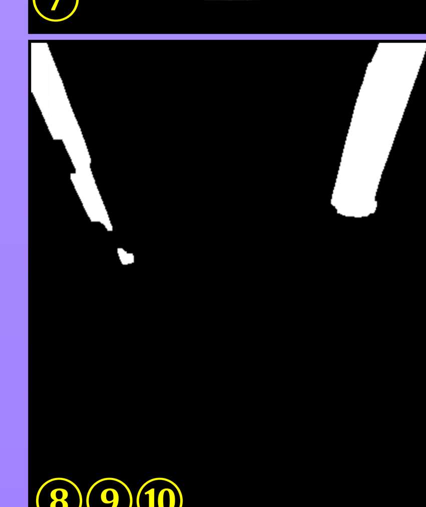
② Lane Marker Detection
Lane markings are bright pulses bounded by homogeneous darker areas. A one dimensional filter is applied which responds strongly to this criteria.

③ Edge Detection
The edges of the lane markings are found using the Canny edge detector algorithm.

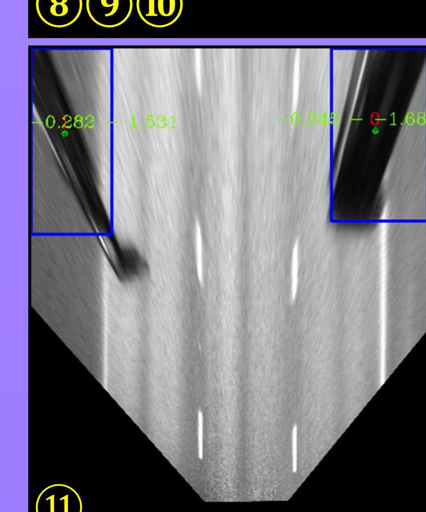
④⑤⑥ Line Detection, Intersection, Filter
A line detector obtains the line segments representing the original edges. We use a RANdom SAmple and Consensus (RANSAC) algorithm to find the intersection of the lines, providing the vanishing point of the image. A Kalman filter is used to smooth its movement.



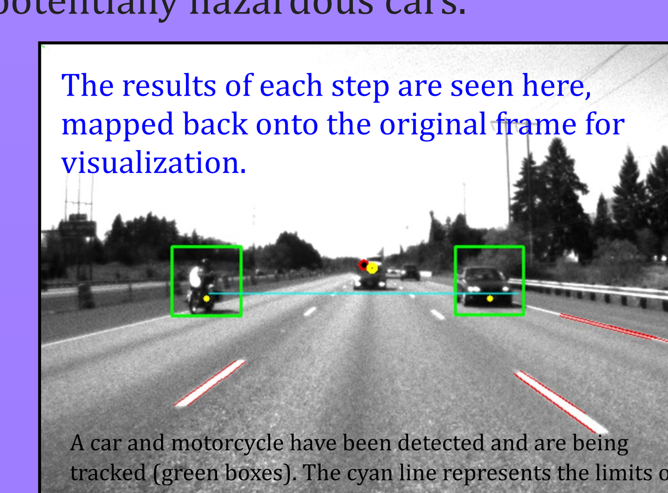
⑦ Top Down Transformation
Since the camera has a no roll angle, the vanishing point gives us enough information to know the road plane. We can then change perspectives to look top down. This is called a plane-to-plane homography.



⑧⑨⑩ Estimation, Segmentation, Morphology
The pixels are classified into object and non-objects, a step called Bayesian segmentation. The parameters for this classification are estimated using the expectation-maximization (EM) algorithm. The object-pixels are then filtered to connect close blobs and remove isolated ones.



⑪ Blob Detection
A blob detector is applied to find vehicles. It finds the center of each object, and these are matched between frames for tracking. The velocity is extracted and used to model potentially hazardous cars.



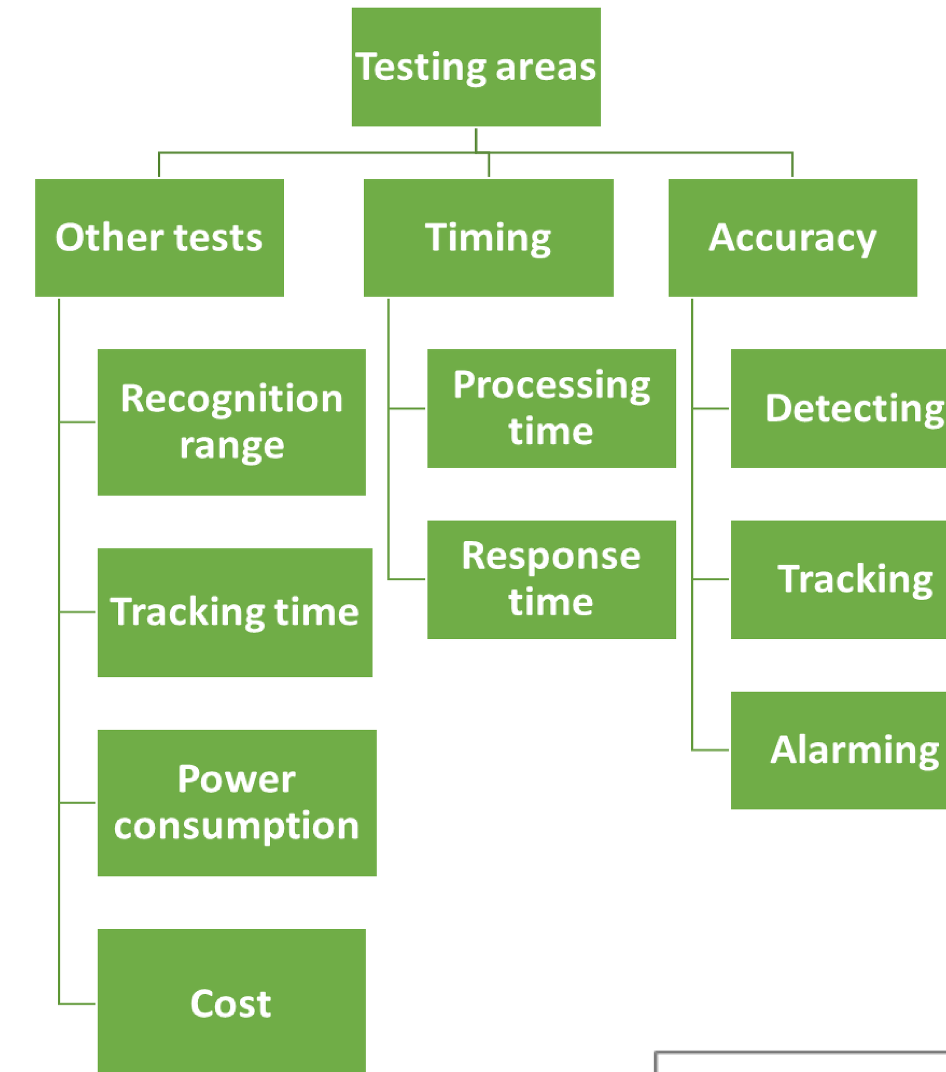
The results of each step are seen here, mapped back onto the original frame for visualization.

A car and motorcycle have been detected and are being tracked (green boxes). The cyan line represents the limits of the homography view.

[1] M. Nieto et al., "Road environment modeling using robust perspective analysis and recursive Bayesian segmentation," *Machine Vision and Applications*, vol. 22, no. 6, pp. 926-945, Nov. 2011.

5. Performance

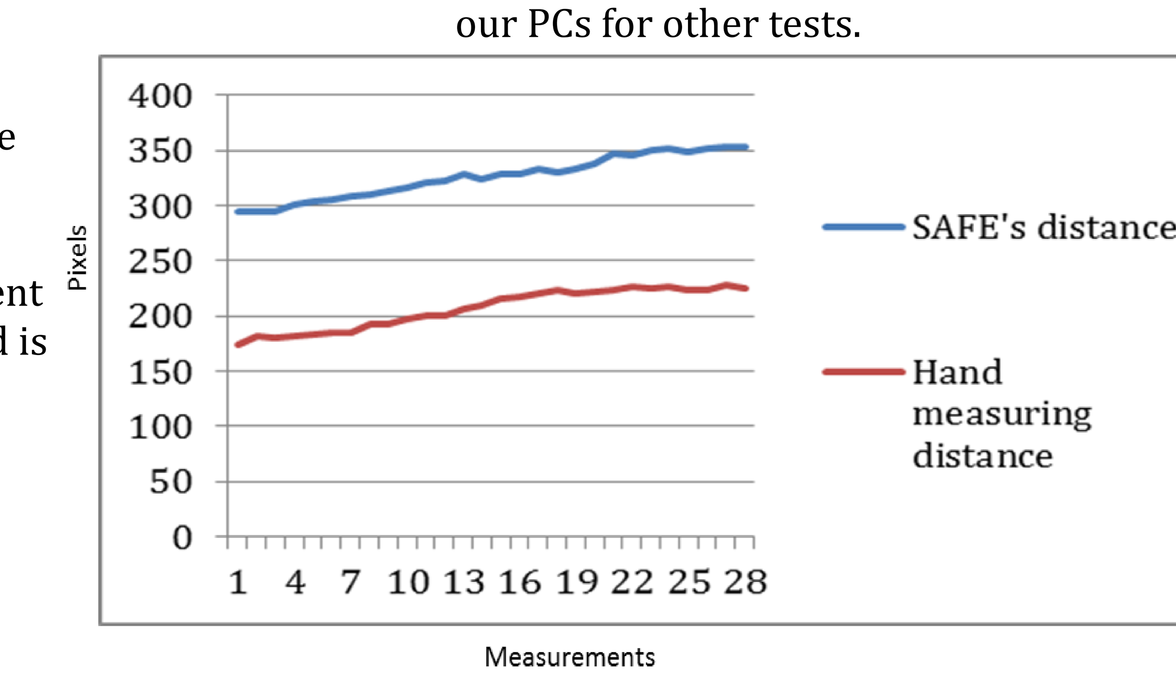
We developed tests based on the requirements of the device, which focus on three main areas: timing, accuracy, and other tests. In detail, the diagram above lists all individual test we conducted.



The CMOS camera was mounted along with its stabilization system on the back of a motorbike. We then drove it on highways and surface streets to record many 5 minute videos at a rate of 30 frames per second. Next, the footage was processed with our software on the Atom board for timing and power tests, and on our PCs for other tests.

The **SAFE** estimated distance was compared to the hand-measured distance.

The constant offset is inherent to our detection method and is later compensated for in tracking.

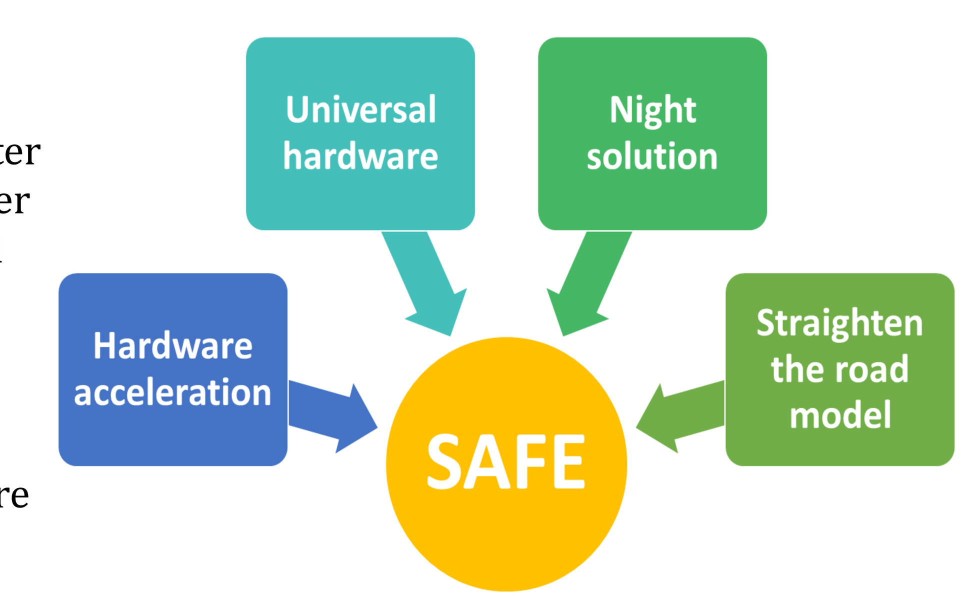


Requirements:	Achievements:	Notes
Precision and sensitivity of 80%	69.7% precision and ***83.8% sensitivity***	✓
Real time processing, less than 100ms per frame	***Processing time of 55ms***	✓
Maximum response time of 1 second	***Response time of 0.825s***	✓
Audio alarm	***Success audio alarm***	✓
Portable, able to work on a car or a motorbike	***Portable, 16.7 Watt***	✓
Maximum range of 100 feet	***Maximum range of 110 feet***	✓
Affordable, cost less than $500	***$477 without development board***	✓

In summary, the **SAFE** device meets almost all of the original requirements, except for precision. Strategy to improve this performance will be mention on the next steps session.

6. Next steps

We need to continue to optimize the algorithm we currently use. We need to better model the road, straightening curves in order to better detect objects. We believe we need to design a more robust, fully-custom prototype using a permanent, dedicated vehicle. We would design a new algorithm dedicated to use in night situations. Our algorithms would be accelerated in hardware to ensure optimum performance of our software algorithms.



7. Acknowledgments

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