System Overview

While vehicles backing over pedestrians is completely preventable, it remains an issue that results in hundreds of deaths a year in the United States alone [1]. This is a problem that is not only present in the US, but a cause for concern globally. According to Transport Canada, approximately 900 pedestrians are struck and injured by reversing vehicles yearly [2]. This number also likely to be an underestimate due to many accidents occurring in private driveways and parking lots not being reported [3]. These numbers make a clear case for why vehicles need to be equipped with a system that aims at reducing the likelihood of an accident occurring while a vehicle is backing up. While similar safety systems have been proposed in the past [4], our’s aims extending this work to produce a more robust system.

The described Pedestrian Backup System (PBS) is an intended automotive cyber-physical system comprising of a network of sensors, electronic control units (ECUs), and visual and audio indicators that can be integrated with pre-existing automotive systems to prevent injury of both the driver and nearby pedestrians while the vehicle is in reverse. It is the goal of this system to promote safety by presenting the driver with enhanced information about the surroundings of the vehicle as well as alerting pedestrians of the approaching vehicle via an audible signal. In scenarios where a collision is calculated to occur, the impact will be mitigated by the PBS triggering the vehicle’s automatic braking system (ABS) and slowing the vehicle as much as possible. Idealistically, the braking will be sufficient enough to completely stop the vehicle before the collision occurs.

This system should provide the driver with maximal environmental information by incorporating data from multiple sensor systems and conveying it in an easily and quickly understood manner. While in reverse, a real-time video stream from the rear-view camera system will be sent to a LED screen built into the console of the vehicle. This video stream will also be processed by image recognition software present on an on-board ECU. Detected objects will be highlighted when displayed on the console screen. Distance to nearby objects will be calculated based off of a reading from a rear-mounted radar and displayed on the screen. Readings from side-facing radars or blind-spot detection systems will be monitored, allowing a warning to be given to the driver if objects are detected in close proximity to the vehicle, even if not captured on any of the rear-facing sensors. All information should be presented to the driver with intent to cause minimal distraction from the task of backing up.

To prevent physical harm to pedestrians present in the vicinity of the reversing vehicle, an audible alarm will sound when objects are detected within a threshold of the vehicle. This alarm should be not sounded continuously while the vehicle is in reverse, due to the nature of people tending to ignore constant signals. However, this alarm should sound abruptly only when an object is in potential danger of being struck by the reversing vehicle in a fashion designed to capture the attention of pedestrians. The PBS will also be directly integrated into the ABS system of the vehicle so that the speed of the vehicle can be greatly reduced or completely stopped before a collision occurs. This automatic braking should only occur if a collision is inevitable and the driver fails to react to previous warnings.

The PBS will have three different modes of operation when an obstacle is detected and the vehicle is in reverse corresponding to how close the obstacle is to the vehicle. If an obstacle is detected behind the vehicle and less than 20 feet away, the obstacle shall be highlighted on the console LED screen and a distance to that obstacle will be displayed. If the distance reduces to less than 10 feet a warning indicator light in the cabin of the vehicle will turn on, an audible warning signal will turn on, and the distance to the obstacle being displayed on the screen will be bolded or enlarged in text size. While in this mode of operation, the vehicles speed should be limited to no more than 5 mph. Lastly, if an obstacle is detected within 5 feet of
the vehicle, including the readings on the side facing radar or blind spot monitoring system, an audible warning shall be given to the driver, a visible warning will appear on the LED screen indicating which side of the vehicle the obstacle is being detected along with how far away the obstacle is, and the ABS should activate bringing the vehicle to a stop. After the vehicle has been brought to a stop, the driver must release the accelerator pedal and depress the brake to acknowledge the threat. When the driver has acknowledged the threat, they may continue in reverse at no more than 3 mph.

Functional Requirements:

Hardware

- Rear Camera
  - Mounted in the middle of the rear of vehicle
  - Has at least 160 degree field of view.
  - High resolution, atleast 720p.
  - Highlight moving objects in the screen via image recognition.
  - The camera should have a self cleaning mechanism.
- Radar Sensors
  - At least 3 radar sensors must be equipped on the vehicle. 1 on the rear of the vehicle and 1 on each side of the vehicle.
  - The orientation of the radar should provide maximal coverage of the area around the sides and back of the vehicle.
  - Radar should be of high resolution.
  - Radar must be able to detect obstacles accurately up to 30 feet away.
  - Radar must be able to perform in all weather and in temperature ranges from -35 to 110 degrees fahrenheit.
- Blind Spot detection system
  - If the vehicle has a blind spot detection system, the hardware from this system may be used to satisfy the side facing radar requirements if the sensors meet the quality requirements.
  - Trials will be needed to ensure that the blind spot detection system is capable of meeting sensing requirements and the field of view of the sensors does not leave gaps between the sides of rear of the vehicle.
- Console and cabin lights
  - Warning lights must be installed in either the console or cabin of the vehicle.
  - These lights need to be bright enough to capture the driver’s attention.
  - The lights shall have the ability to flash on and off at a medium frequency, around 2Hz.
- Cabin audio warning system
  - Audible warnings must in given to the driver.
  - These may be given over the car speaker system or through a separate device.
  - Audible warnings must be loud enough to be heard by the driver even in loud environments. If these warnings are being given through the vehicle's sound
system, any playing audio should be turned down to allow the warnings to be heard clearly.

- **External audio warning**
  - An external audio device must be able to be heard from a minimal of 20 feet away from the vehicle even in loud environments.
  - It is acceptable to use the vehicle’s horn if it meets the previous volume requirement.

- **Brakes**
  - The vehicle must have an ABS installed.
  - The ABS should adhere to industry standard.

- **System override button**
  - Allows the automatic braking, acceleration limitation, and audible warning features of the PBS to be turned off.

- **One or more PBS ECU(s)**
  - The ECU(s) of the system must be capable of monitoring the radar and rear camera.
  - The ECU(s) must be able to perform image processing on the video stream, detecting any obstacles. The type of obstacles need not to be categorized.
  - The ECU(s) must be able to relate a detected obstacle to a distance away from the vehicle based off of radar readings.
  - The ECU(s) must be able to stream output to the LED screen as well as be able to communicate with cabin lights, audible systems, and ABS of the vehicle.
  - The ECU(s) must be faster enough to accomplish all other listed requirements in real-time without a noticeable delay between input sensor readings and output.

**Software**

- Image Processing is to be active when the vehicle is in reverse.

- The software of the PBS will act in 3 different modes as described below and will be active while the vehicle is in reverse. Higher modes should take precedence over lower modes. Therefore, if an obstacle is detected at 9 feet, which satisfies the activation requirements for both mode 1 and mode 2, the system should be operating in only mode 2. Closer obstacles close take precedence. For example, if two obstacles are detected, 1 at 18 feet and 1 at 9 feet, the obstacle that is 9 feet away should be ruled as more important and the system should be operating in mode 2.
  - **Mode 1** is active when an obstacle is detected within 20 feet of the vehicle by the rear facing camera or radar.
    - The obstacle will be highlighted on the console LED screen.
    - The distance to the obstacle, as measured by the rear radar, will also be displayed on the screen.
  - **Mode 2** is active when an obstacle is detected within 10 feet of the vehicle by the rear facing camera or radar
    - An interior warning indicator will trigger, either a cabin or console light.
    - An interior audible warning will be issued.
The distance to the obstacle being displayed on the LED screen is bolded or increased in font size.

- The speed of the vehicle is limited to 5 mph.

- Mode 3 is active when an obstacle is detected with 5 feet of the vehicle by either the rear faces sensors (radar and camera), or the side facing sensors (either specific radars for this system or the existing blind spot detection system sensors).
  - An interior audible warning will be issued to the driver that is noticeable different than the warning given in mode 2.
  - A visible warning will be displayed on the console LED screen indicating where the obstacle is relative to the vehicle.
  - An exterior audible warning will be issued to nearby pedestrians.
  - The ABS will activate and break the vehicle to a stop.
  - The vehicle will not be allowed to move again until the driver releases the accelerator pedal and depresses the brake.
    - After the depression of the brake, the vehicle will be allowed to move again, but at speeds no higher than 3 mph.

Non-Functional Requirements:

- The orientation of the rear camera should be movable based on the vehicle’s direction.
- Resolution of the camera should be satisfactory so that the driver can identify objects clearly.
- Accuracy of moving object recognition should satisfy a given threshold.
- Console and cabin warning light should not be flashy and distracting.
- Cabin alarm should not be loud.
- External sound and light warning be overly loud such that they shock pedestrians.
- All the warning and actuators should work in real time.
- All audible signals are loud enough to be heard even in loud environments.
- Both audible and visual signals will be noticeable, but not overly distracting to the driver.
- Braking should be smooth.

References

   http://www.cse.msu.edu/~cse870/Homework/References/Truck-Accident-Prevention.pdf
   http://www.tc.gc.ca/roadsafety/menu.htm
   https://www.authorea.com/users/23901/articles/27506-software-requirements-spacecification-srs_pedestrian-backup-assist-system-pbs_/show_article