Automotive Backup Rollover Prevention System Requirements

Rayshawn Holbrook, Erin Hoffman, & Camille Welcher
Michigan State University

February 19, 2015

The proposed system will aid vehicle operators in the ability to detect nearby objects while operating the vehicle in reverse. The field of view is dangerously limited while backing up. Thus, the risk of collision with nearby objects is dramatically increased. Such collisions can cause considerable property and liability damages. More importantly, serious injury (often death) can occur when the vehicle comes in contact with humans. This system will take advantage of sonar parking sensors for detecting the distance of nearby objects, and provide in-vehicle audio alerts that vary in intensity based on the distance between the vehicle and the closest nearby object. In addition to the detection and alert functionality, a rear facing backup camera is included to provide additional visibility into the area behind the vehicle. This video feed is displayed via a rear-view mirror monitor, for easy observation. The Backup Rollover Prevention (BRP) system will be expected to be used in "normal" low-speed driving and parking situations. It will not be expected to function during operation over 15 km/h, nor will it be installed in vehicles used for activities such as racing. We also will not expect it to be used in fleet vehicles (police or fire) where reliable close-quarters operation can be critical.

Functional Requirements

Operating requirements and performance requirements dictate that components be consistent with existing automotive architecture, so the various controllers are therefore required to be Electronic Control Units (ECUs) connected over a Controller Area Network (CAN) bus. ECUs are embedded computers within modern automobiles (Her et al. 2007). They are essentially microcontrollers connected with inputs and outputs. ECUs broadcast messages over the CAN, bus, which will serve as the network in our system. For the sake of simplicity, the controller associated with each sensor or output will be referred to as an individual ECU.

1. Proximity Alert System
    a. A gear shift ECU to sense when the vehicle is in reverse and broadcast a message
    b. A rear-facing sensor using sonar or similar technology to detect objects in a known field of view
        i. If one sensor is insufficient, multiple sensors are used
        ii. The field of view is bounded by the defined ranges
    c. An ECU to control the sensor (1.b) and process inputs
        i. Listens for a message from the gear shift ECU (1.a) that the vehicle is in reverse
        ii. If the vehicle is detected to be in reverse, the sensor (1.b) should be turned on; else, it should be turned off

   iii. When the sensor (1.b) is on, compute the distance to the nearest object and place it into one of ranges 1, 2, 3, 4, or 5
   iv. If the sensor indicates range 1,2,3, or 4, broadcast a message indicating the stereo system to mute and a message for the audio alert system ECU (1d.) telling what range level was detected
   v. If the sensor indicates range level 5, broadcast a message for the stereo system to resume previous volume and for the alert system to cease sounding
   vi. If the gear shift ECU (1.a) indicates the vehicle is no longer in reverse, repeat the behavior of 1.a.v

d. An audio alert system to produce sounds (using existing alert system)
e. Audio alert system ECU
   i. Should listen for updates from the backup proximity sensor ECU (1.c)
   ii. If 1.c sends a range 1 message, sound the alert continuously
   iii. If 1.c sends a range 2 message, sound an alert for 0.2 seconds every 0.4 seconds
   iv. If 1.c sends a range 3 message, sound an alert for 0.2 seconds every 0.8 seconds
   v. If 1.c sends a range 4 message, sound an alert for 0.2 seconds every 1.0 seconds
   vi. The ECU shall contain an interval timer so that the sound pattern will not restart when a duplicate range message is received
f. A stereo system (if available)
g. A stereo system ECU
   i. Should listen for updates from the backup proximity sensor ECU (1.c)
   ii. If this ECU receives a mute message, it should store the current volume and reduce the volume to 0
   iii. If this ECU receives a resume message, it should restore the volume to its previously stored level
   iv. This this ECU receives a resume message and is not currently muted, it should ignore it

2. Camera System
   a. A camera sensor, consisting of a digital video camera, facing the rear, viewing ranges 1 to 4
   b. A camera sensor ECU
      i. The camera sensor ECU should listen for a message from the gear shift ECU (1.a) indicating the vehicle is in reverse
      ii. If the vehicle is in reverse, the camera should be initiated
      iii. The video information should be converted to the appropriate packet format and streamed across the CAN bus
      iv. When the vehicle is not in reverse (1.a), the camera should be turned off
   c. A video display, integrated into the rear-view mirror
   d. A video display ECU
      i. The ECU should listen for a message from the gear shift ECU (1.a) that the vehicle is in reverse
      ii. If the vehicle is in reverse, the display should be initiated, the this ECU should begin listening for data from the camera sensor ECU (2.b.iii)
      iii. When video packets are received, convert them to the proper display format and put them on the screen
      iv. When the vehicle is not in reverse, turn the display off

Nonfunctional Requirements

We choose 4 meters as our maximum distance (3.iv) based on the results of Paine and Henderson (Paine et al. 2001). A false positive is when the system sounds an alert with no obstacle in range. A false negative is when the system fails to sound an alert when an obstacle is anywhere with the alert range. With reversing shown to be a considerable risk to pedestrians, it is important that these systems be fault tolerant, but also that they operate with reasonable and understood limitations. False negatives are unacceptable, but we still aim to reduce false positives in an effort to avoid drivers adapting to alert messages and ignoring them (see 3.e).

It is important that we expect a reasonable level of efficacy, and not give operators the impression that their proximity sensors are fool-proof. Experimentation showed that at 8kph, the speeds at which most backup collisions occur (Young, Eberhard, and Moffa 1995), most sonar systems designed for parking could only be expected to prevent 25% of collisions (Glazduri 2005). Given the age of this study, and that the sensors were placed for parking and not pedestrian detection, we require our system to achieve a 50% prevent rate under the same laboratory conditions (3.g). While this will be an improvement over the previously tested systems, the still-low level of efficacy supports our also including rear cameras.

3. Ranges and tolerances for the Proximity Alert System (1)
    a. Ranges are measured from the rear bumper of the car, facing backward, perpendicular to the bumper
        i. Range 1 shall be distance 0 to 1 meter
        ii. Range 2 shall be distance 1 to 2 meters
        iii. Range 3 shall be distance 2 to 3 meters
        iv. Range 4 shall be distance 3 to 4 meters
        v. Range 5 shall be distances beyond 4 meters
    b. Ranges can be transmitted over network with less than 0.1 seconds of delay
    c. All states emitted by the proximity ECU (1.c) shall be subject to error correcting codes
    d. Any message received by the alert system ECU (1.e) which is outside of the acceptable ranges shall result in a dashboard error notification
    e. Any message received by the alert system ECU (1.e) in range 1 or 2 shall result in an alert, regardless of error state
    f. Proximity sensor response times shall be less than 350ms, as dictated by ISO standards (Standardization 2002).
    g. Proximity sensor collision prevention probability shall be at least 0.5 under laboratory conditions

An important consideration for the camera system is the acceptable lag between shifting into reverse and activation of the view-screen. Manufacturer comments during NHTSA proceedings suggest reasonable times of 1 to 3 seconds ((NHTSA) 2007) (4.a).

4. Tolerances for the camera system
    a. We require a maximum 1 second delay between shifting and view-screen activation
    b. Minimum average mean time between failures for camera subsystem activation shall be 3 years in a well-functioning system

References

Glazduri, Viliam. 2005. "An Investigation of the Potential Safety Benefits of Vehicle Backup Proximity Sensors." In *Proceedings of the International Technical Conference on Enhanced Safety Vehicles*, 1:2. http://www-nrd.nhtsa.dot.gov/Pdf/nrd-01/ESV/esv19/05-0408-W.pdf.

Her, Jin Sun, Si Won Choi, Du Wan Cheun, Jeong Seop Bae, and Soo Dong Kim. 2007. "A Component-Based Process for Developing Automotive ECU Software." In *Proceedings of the 8th International Conference on Product-Focused Software Process Improvement*, 358–373. PROFES'07. Berlin, Heidelberg: Springer-Verlag. http://dl.acm.org/citation.cfm?id=2394450.2394490.

(NHTSA), Department of Transportation (DOT). National Highway Traffic Safety Administration. 2007. "Federal Motor Vehicle Safety Standard, Rearview Mirrors; Federal Motor Vehicle Safety Standard, Low-Speed Vehicles."

Paine, Michael, Michael Henderson, New South Wales, and Motor Accidents Authority. 2001. *Devices to Reduce the Risk to Young Pedestrians from Reversing Motor Vehicles*. Motor Accidents Authority of NSW New South Wales. http://www.kidsandcars.org/userfiles/dangers/backovers/studies/2001-devices-reduce-risk-study.pdf.

Standardization, International Organization for. 2002. "Transport Information and Control Systems – Maneuvering Aids for Low Speed Operation (MALSO) – Performance Requirements and Test Procedures." *Draft ISO/DIS 17386*.

Young, Stephen K., Carol A. Eberhard, and Philip J. Moffa. 1995. "Development of Performance Specifications for Collision Avoidance Systems for Lane Change, Merging and Backing, Task 2 Interim Report, Functional Goals Establishment." *US Department of Transportation, National Highway Traffic Safety Administration*. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.41.1409&rep=rep1&type=pdf.