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Combined list:

1. Based on the description, the following are a few testable requirements for back-over prevention system:

1. Detection Range:
   The vehicle's system will detect pedestrians within a 10-meter radius of the vehicle while backing up at less than 8kmph. Sensors like motion sensors will be used to detect movement. A backup camera will be added so the driver can see blind spots. The camera field of view must include the area of critical risk. The display for the camera feed should be of adequate quality. We suggest a refresh rate of at least 45 Hz and a display resolution of at least 480p. An object with a height (30 inches or 0.762 meters) must be visible in the area of critical risk at a light level of 0.01 lux [3]. To test this requirement, we can place dummies of heights ranging from 1 inch to 30 inches in varying ranges of under 10 meters to verify detection.
2. Response time:
   The system will issue an alert and apply brakes automatically within 0.5 seconds of detecting an object within 3 meters of the vehicle. A maximum of 2 seconds delay between shifting the vehicle into reverse and the display of the feed from the rearview camera, as suggested by General Motors and Gentex. An entity that appears in front of the rearview camera should appear on the display in real-time. We suggest a maximum lag time of 0.25 seconds. To test it, we can simulate pedestrian entry into the detection zone and measure the response time of the alert system.
3. Environmental robustness:
   The system has to be operational during rain, snow, fog, or any scenario where the visibility is >= 10m and low light conditions. The camera sensor must be functioning under a large range of weather conditions (-20F to 120F). Simulating the scenarios with weather chambers and low light conditions like heavy snow or rainy days is required to test the detection accuracy.
4. Pedestrian Classification:
   The system should be able to distinguish pedestrians from inanimate objects with more than 95% accuracy. To test this, we can use labeled datasets of pedestrians and objects like bicycles, cars, animals, or infants to evaluate classification performance.
5. False Alarm rate:
   The system has to maintain a false positive rate of less than 5% in scenarios with nonpedestrian objects like traffic cones, trash cans, etc. Test this would require deploying
   non-pedestrian objects in controlled environments and recording false alarms, for example, a person walking towards but is at a safe distance when the car is backing up. In such scenarios, the car shouldn't be abruptly braking or alerting.
6. Driver Alert Prioritization:
   The system should give audio alerts and visual alerts when a pedestrian is detected in the rear of the car. One thing we need to test for is the decibel level of the audio alert and the response time of the visual alert.
7. Power Constraints:

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The system should operate within the vehicle’s 12V power supply exceeding a 5A current draw. We can test the current during system operation.

2. The 3 global invariants of the system other than “prevent injuries” are:

1. System Availability:

The system has to be active when the vehicle is in reverse gear. The driver should be able to deactivate the system in case he wants full control and there is no imminent danger.

2. System Interference:

The system cannot impede the driver’s control of the car unless an impact is about to happen and within 5 meters away from the object.

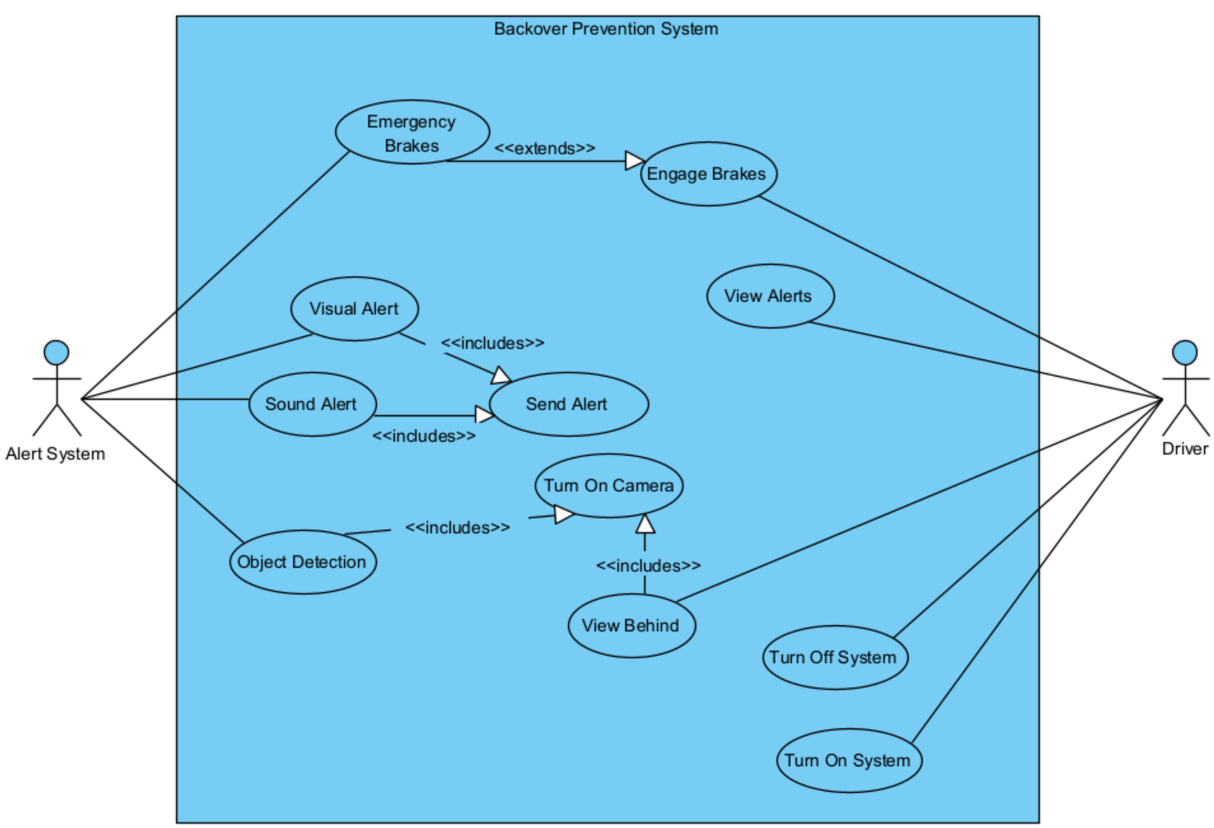
3. Sensor Integrity:

The system has to have updated sensor health information and alert the driver in the case of sensor degradation. If the sensors are not available, then the system will not be functional. Also, the system should have an average uptime of 99.9% over the average lifespan of a car, around 200,000 miles driven.

Process of including and excluding requirements:

There were no new requirements added, we only added details to existing requirements. We used Arman’s list of requirements as the foundation and integrated the requirements from both lists from there. There were a lot of similarities in requirements, so we made Arman’s requirements more detailed by integrating some details from the requirements in Simon’s list.

Assignment 2 & 3)



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Assignment 4)

Use Case:	View Behind
Actors:	Driver
Description:	The Driver must be able to view the rearview video for visibility.
Type:	Primary and essential
Includes:	Turn On Camera
Cross-refs	1.1

Use Case:	Sound Alert
Actors:	Alert System
Description:	The Alert System will send a sound alert, to indicate
Type:	Primary
Includes:	Send Alert
Cross-refs	1.6

Use Case:	Engage Brakes
Actors:	Driver
Description:	The Driver should always be able to engage the breaks.
Type:	Primary
Cross-refs	2.2

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Use Case:	Emergency Brakes
Actors:	Alert System
Description:	If the Driver turns on the automatic breaking system, the Alert System can engage the breaks. If the Driver turns off the automatic breaking system, the Alert System cannot engage the breaks.
Type:	Primary and essential
Extends:	Engage Breaks
Cross-refs	1.2, 1.5

Use Case:	Visual Alert
Actors:	Alert System
Description:	A red border would be shown around the display for the camera feed to alert the driver of danger.
Type:	Secondary
Includes:	Send Alert
Cross-refs	1.6

Use Case:	Send Alert
Actors:	Alert System
Description:	This would send an alert to *View Alerts* for the driver to be alerted about warnings about detected objects, system unavailability due to weather, power failure, and sensor health.
Type:	Primary
Cross-refs	1.5, 1.6, 1.7, 2.3
Use Cases	The alert system will send the sound alert and the visual alert.

Use Case:	Object Detection
Actors:	Alert System
Description:	The Alert System will initiate the *Object Detection* module through the *View Behind*. Alert System will use this to locate objects of importance through using the sensors available like camera and motion sensors.
Type:	Secondary
Cross-refs	1.2, 1.3, 1.4, 1.5, 1.7, 2.3
Use Cases	*Object Detection* must be done before the Alert System can engage *Emergency Brakes*.

Use Case:	View Alerts
Actors:	Driver
Description:	The send alert will send the alerts to view alerts where it would display and sound the different alerts in the vehicle
Type:	Primary
Cross-refs	1.5, 1.6, 1.7, 2.3
Use Cases	*Send Alert* has to send the alert first for the *view alert* to alert the driver.

Use Case:	Turn On Camera
Actors:	Driver, Alert System
Description:	The camera will become operational when requested by the Driver or the Alert System. It will also turn on when the car is in reverse.
Type:	Primary
Cross-refs	1.1
Use Cases	*Turn On Camera* must be done before *Object Detection* to function.

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Use Case:	Turn Off System
Actors:	Driver
Description:	The Driver can turn off the system if the Driver wants full control of the vehicle.
Type:	Secondary
Cross-refs	2.1

Use Case:	Turn On System
Actors:	Driver
Description:	The driver can turn on the system if the system is turned off.
Type:	Primary
Cross-refs	2.1
Use Cases	The system has to be turned off to be able to turn it on as the default state of the system will be on. *Turn On System* must be done before the Alert System can interact with the system with the following uses: *Object Detection, Visual Alert, Sound Alert,* and *Emergency Brakes*. The Driver will still be able to view the camera.

Assignment 6)
The following lists are the requirements of each member after taking into account the feedback given by Dr. Cheng.

Arman's list:

Back-overs are a serious issue that are caused by the drivers backing out of their garage or mall parking. Even the most careful of drivers cannot avoid it sometimes due to the car having so many blind spots. There are many examples of pedestrian deaths, most toddlers and children deaths, for example, the daughter of Rachel and David Clemens who got hit by their car when David was backing over. Due to blind spots in the car and not having a back camera, he didn't see the his daughter standing behind. This is just one of many incidents that have occurred due to not having blind spot cameras. The following is a framework for car backing up system.

Based on the description, the following are a few testable requirements for back-over prevention system:

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1. Detection Range:
   The vehicle's system will detect pedestrians within a 10-meter radius of the vehicle while backing up at less than 8kmph. Sensors like motion sensors will be used to detect movement. A backup camera will be added so the driver can see blind spots. To test this requirement, we can place dummies in varying ranges of under 10 meters to verify detection.
2. Response time:
   The system will issue an alert and apply brakes automatically within 0.5 seconds of detecting an object and within 3 meters of the vehicle. To test it, we can simulate pedestrian entry into the detection zone and measure the response time of the alert system.
3. Environmental robustness:
   The system has to be operational during rain, snow, fog, or any scenario where the visibility is >= 10m and low light conditions. Simulating the scenarios with weather chambers and low light conditions like heavy snow or rainy days is required to test the detection accuracy.
4. Pedestrian Classification:
   The system should be able to distinguish pedestrians from inanimate objects with more than 95% accuracy. To test this, we can use labeled datasets of pedestrians and objects like bicycles, cars, animals, or infants to evaluate classification performance.
5. False Alarm rate:
   The system has to maintain a false positive rate of less than 5% in scenarios with nonpedestrian objects like traffic cones, trash cans, etc. Test this would require deploying
   non-pedestrian objects in controlled environments and recording false alarms, for example, a person walking towards but is at a safe distance when the car is backing up. In such scenarios, the car shouldn't be abruptly braking or alerting.
6. Driver Alert Prioritization:
   The system should give audio alerts and visual alerts when a pedestrian is detected in the rear of the car. One thing we need to test for is the decibel level of the audio alert and the response time of the visual alert.
7. Power Constraints:
   The system should operate within the vehicle's 12V power supply exceeding a 5A current draw. We can test the current during system operation.

The 3 global invariants of the system other than "prevent injuries" are:

1. System Availability:
   The system has to be active when the vehicle is in reverse gear. The driver should be able to deactivate the system in case he wants full control and there is no imminent danger.
2. System Interference:
   The system cannot impede the driver's control on the car unless an impact is about to happen and within 5 meters away from the object.
3. Sensor Integrity:

The system has to have updated sensor health information and alert the driver in the case of a sensor degradation. If the sensors are not available, then the system would not be functional.

The 3 sources of uncertainty and their impacts on the system are listed below:

1. Sensor limitations in bad weather:
   The heavy rain, snow or fog may reduce the radar or camera accuracy, leading to false alarms or missed detections. One way to mitigate this is to use multiple different sensors and combine their data to increase accuracy at such occasions. For example, thermal Cameras.
2. Unpredictable pedestrian movement:
   One such unpredictable pedestrian movement could be a toddler darting on the vehicle's path, exceeding the system's reaction time. This could, however, be mitigated by a predictive algorithm that can predict based on an object's trajectory if it is going to impact the car or the driver or a wide sensor domain.
3. Electromagnetic Interference:
   Interference may occur with nearby electromagnetic devices which would cause the sensors to disrupt. The obvious mitigation would be sensor shields on the motion sensors. One other way could be to add error-checking protocols.

Bibliography

[1] N. News, "Lives shattered in driveway backover accidents," NBC News, Jun. 24, 2007. https://www.nbcnews.com/health/health-news/lives-shattered-driveway-backover-accidentsflna1c9471576 (accessed Feb. 08, 2025).
[2] "Federal Register :: Request Access," unblock.federalregister.gov. https://www.federalregister.gov/documents/2019/10/10/2019-22036/federal-motor-vehiclesafety-standard-no-111-rear-visibility

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Simon's list after accounting for feedback:

Based on findings from the National Highway Traffic Safety Administration (NHTSA), combined multi-technology systems such as using a camera with ultrasonic sensors, has been observed to be less effective in aiding the driver for avoiding backover accidents as using camera technology alone [1]. From this, we propose to use a single camera system for improving rearview visibility of passenger cars.

Definitions

- Area of critical risk: An area behind a vehicle that must be visible to the driver during a backing maneuver [1]. Based on simulations done by NHTSA and published in their Advance Notice of Proposed Rulemaking (ANPRM) for expanding requirements of passenger cars, the following measurements define the size and shape of the area: Starting with a width of 10 feet (3.048 meters) at the rear bumper and linearly widening symmetrically to 20 feet (6.096 meters) at a distance of 6 feet (1.8288 meters) from the rear bumper [1]. We simplify this suggestion by defining the area by a field of view of 120 degrees, centered at the rear bumper of the car, and extending outwards until 20 feet (6.096 meters).

- Entities: These are subjects that we want the system to prioritize avoiding collisions with, such as people, vehicles, and animals.

Global Invariants

1. The system should be reliably functional so that drivers can rely on the system to avoid back-over accidents.
2. The system must be able to see potential sources of collisions, so the camera field of view must include the area of critical risk and secondary sensors must be able to detect and alert the driver about incoming vehicles or pedestrians that the camera cannot see.
3. The driver should be able to use the system to promptly react to entities within the critical area and incoming entities.

Requirements

1. Rearview visibility
    a. Camera field of view must include the area of critical risk.
    b. The display for the camera feed should be of adequate quality. We suggest a refresh rate of at least 45 Hz and display resolution of at least 480p.
    c. An object with the height (30 inches or 0.762 meters) must be visible in the area of critical risk at a light level of 0.01 lux [3].
2. The system should have an average uptime of 99.9% over the average lifespan of a car, around 200,000 miles driven [2].
3. Response time
    a. A maximum of 2 seconds delay between the shifting the vehicle into reverse and the display of the feed from the rear view camera, as suggested by General Motors and Gentex [1].
    b. An entity that appears in front of the rear view camera should appear on the display in real time. We suggest a maximum lag time of 0.25 seconds.
4. Environmental Robustness
    a. The camera sensor must be functioning under a large range of weather conditions (-20F to 120F).

[1] “NHTSA,” *NHTSA*, 2022. https://www.nhtsa.gov/document/notice-proposed-rulemaking-federal-motor-vehicles-safety-standard-rearview-mirrors (accessed Feb. 02, 2025).

[2] “How Many Miles Can a Car Last?,” *www.progressive.com*. https://www.progressive.com/answers/how-many-miles-does-a-car-last/

[3] S. Store, “What is LUX?,” *Supervisor Store*, 2018. https://supervisor.store/blog/f/what-is-lux (accessed Feb. 15, 2025).

Assignment 7)

None of the requirements were discarded as all of them seemed necessary for a safe system. All them were intersecting each other so we combined them for more specific details of the requirements.