Back-over Prevention System

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General Process of Selecting Requirements

To choose the requirements we went over each of our individual requirements and compared them to each other one by one. If we found a requirement on both lists that were similar, we merged them as they were requirements we agreed upon separately. If a requirement was not present on the other's list we discussed the reasoning for why they listed that requirement. This discussion gave us insight into how the other envisioned the system and what assumptions we had made about it.

After going through each of the requirements in our lists we streamlined the list by looking for redundancies, and deciding which requirements are essential. This revision step helped us to solidify our vision of the back-up prevention system and made the list more of a cohesive document.

Functional Requirements

1. Must have a rear-facing camera and display unit to display the area behind the vehicle also known as the rear blindspot. Resolution of the camera should be at least 720p.
    a. In compliance with FMVSS No. 111 rule [8], it needs to see a rectangular area that is 10 ft wide and 20 ft long directly behind the car.

2. The system must have LiDAR sensors (hardware constraint) at the back of the vehicle for detecting obstacles within a 6-feet radius of the vehicle.

3. The system must alert the driver through a beeping sound that is distinct from the other alarm sounds of the vehicle if an obstacle is detected by either the camera or the LiDAR sensors between 6-feet from the vehicle.

4. System should have ultrasonic sensors beneath the back bumper to detect obstacles that are closer than 1ft to the vehicle/directly underneath the vehicle. Should cover what the camera and LiDAR cannot see.

5. The system must allow the driver to temporarily turn off the current alarm in case of false positives.

6. The system must have collision detection sensors (force sensor) at the back of the vehicle to stop the vehicle as soon as collision is detected (In case the detection system fails to detect an obstacle and the vehicle collides with it, it has to stop before any further damage is done.)

7. (Since most injuries are caused by running over the body) The system must take over control from the driver and engage automatic emergency braking when an obstacle is less than 2-feet from the vehicle [1].

8. System should let the driver be able to gauge how far obstacles are from the rear of the vehicle by providing guidelines (3m line, 5m line).

Non-Functional Requirements

1. The system must be able to detect faulty sensors, disable emergency braking in case ⅔ of the sensor malfunction and alert the driver system isn't working properly.

2. The system must maintain more than 99.9% detection accuracy in different weather conditions. (To be more specific, false negatives must be nearly nonexistent to ensure that no pedestrian goes undetected and false positives must be < 5% to prevent driver desensitization to alarms.)

3. The system cameras and sensors must be installed at least 12 inches above the ground to avoid false positives [2].

4. Rear camera should be able to see an object that is 30.2 inches tall that is 1ft behind the vehicle. [6]

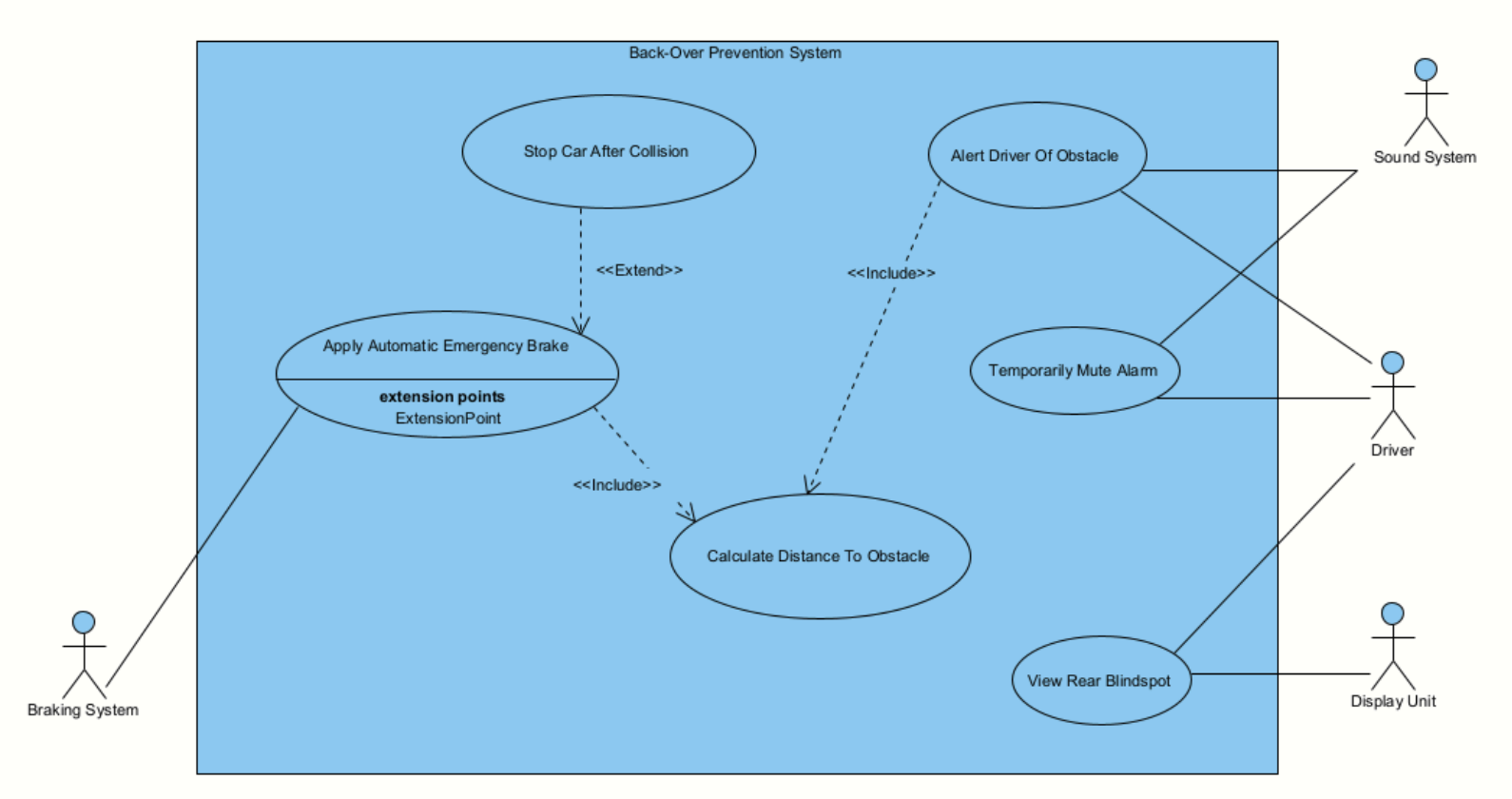
5. Emergency auto-brakes have to apply within 0.1 seconds of obstacle detection.

Global Invariants

1. The back-up system is only active when the vehicle is shifted into reverse.

2. The system must process sensor data with ≤100 milliseconds latency (hardware constraint) to ensure real-time detection.

Use Case Diagram



Use Case Descriptions

Legend

Fx = Functional Requirement x
NFx = Non-Functional Requirement x
GIx = Global Invariant x

Use Case	Alert Driver of Obstacle
Actors	Driver, Sound System
Description	Utilize the sensor suite consisting of LiDAR sensors, ultrasonic sensors, and rear camera to detect obstacles behind the vehicle. Must be able to detect obstacles in a rectangular area directly behind the vehicle that is 10 ft wide and 20 ft long. The system must be able to detect obstacles with near perfect recall (no false negatives) and sufficiently high precision (less than 5% false positive rate) Once an obstacle is detected, alert the driver through a beeping sound that is distinct from the other alarm sounds of the vehicle if an obstacle is detected by either the camera or the LiDAR sensors between 6-feet inches from the vehicle. Driver can push a button to temporarily mute the back-up system alarm in case of a false positive.
Type	Primary
Includes	Calculate Distance to Obstacle
Cross-refs	8 (F1, F2, F3, F4, F5, F7, NF1, NF2, NF3, NF4)
Use cases	*Calculate Distance to Obstacle* Knowing the distance to the obstacle allows the system to alert the driver when the obstacle is a certain distance from the vehicle.

Use Case	Calculate Distance to Obstacle
Actors	None
Description	Using data from sensors, the system must calculate the distance between the vehicle's rear. This information is then sent to the system, which can alert the driver or engage the emergency brake if needed.

Type	Secondary
Cross-refs	3 (F2, F3, F7)
Use cases	*Calculate DIstance to Obstacle, Apply Automatic Emergency Brakes* These two use case acti based on the calculated distance between the vehicle's rear and the obstacle.

Use Case	View Rear Blindspot
Actors	Driver, Display Unit
Description	While the driver is reversing their vehicle, they can view what the rear camera sees. Shows guidelines and obstacles detected by camera algorithms. Allows drivers to quickly gauge where obstacles are in relation to the rear of the vehicle.
Type	Secondary
Cross-refs	4 (F1, F8, NF4, NF5)
Use cases	*None*

Use Case	Apply Automatic Emergency Brakes
Actors	Braking System
Description	In the event that the driver fails to stop when an obstacle is detected within 1ft of the back of the vehicle, automatically apply the brakes to prevent injury.
Type	Primary
Includes	Calculate Distance to Obstacle
Cross-refs	3 (F7, NF1, NF5)
Use cases	*Calculate Distance to Obstacle* Knowing the distance to the obstacle allows the system to apply automatic emergency brakes when the obstacle is a certain distance from the vehicle.

Use Case	Stop Car After Collision
Actors	Braking System
Description	In the event the vehicle crashes into an unexpected obstacle, immediately apply the brakes to immobilise the car and prevent further

	back-over
Type	Secondary
Extends	*Apply Automatic Emergency Brakes*, as it is even more urgent in applying brakes, and does not involve the primary sensor suite.
Cross-refs	2 (F6, NF5)
Use cases	*None*

Back-over Prevention System (Individual Requirements)

Daniel Nguyen

Requirements that were included in the final requirements list are in green and the ones that were not included are in red.

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1 Desire

Primary Prevent Injury

Secondary Do not irritate driver with false alarms

2 Functional Requirements

fr1 Apply emergency auto-brakes if driver fails to stop when detecting an obstacle within 3 inches is behind vehicle.

Explanation: Ms. Rezaeimanesh and I had similar requirements for having a system that would take over the braking system. The only difference was when the system activated, and we decided on 2ft being more appropriate to account for various backing speeds. → F7

fr2 System should detect pedestrians and obstacles in view with 98% accuracy

Explanation: This honestly should not be a functional requirement. Was incorporated into a similar non-functional requirement with more specific details on false positive and false negative rate. → N2

fr3 Must have a rear camera and display unit to display area behind vehicle. Automatically displays on the vehicle's display unit when reversing.

fr4 Rear camera must be positioned to view a clear area behind vehicle and be able to see small obstacles behind vehicle. In compliance with FMVSS No. 111 rule, it needs see an area that is 10 ft wide and 20 ft long directly behind the car.

Explanation: For my fr3 and fr4, we both knew that a camera should be involved in this system. These ended up being incorporated into functional requirement 1 with more specific details on resolution and placement (non-functional requirement 3). → F1, N3

fr5 If an obstacle enters the rear camera's field of view while vehicle is reversing and is within 6 feet of the vehicle's rear, alert the driver with an audible alert.

Explanation: Both of our requirements had this requirement of an audible alert of an obstacle within the vehicle's rear. Our requirements differed on the distance it should be active. We decided to go with "less than 6 feet" as a decent distance for a human to react to a sudden obstacle appearing behind the vehicle. → F3

fr6 Rear camera should be able to see an object that is 30.2 inches tall that is 1ft behind vehicle

Explanation: The specific height is based on a study about a vehicle's rear blindspot where the purpose was to emulate the height of a small toddler. Ms Rezaeimanesh and I agreed this requirement was good and included it in the non-functional requirements as that was a better fit as it specified a system performance marker. → N4

fr7 System should have sensors beneath the back bumper to detect obstacles that are closer than 1ft to the vehicle. Should cover what the camera cannot see.

Explanation: This requirement was designed to prevent a situation of obstacles starting directly behind the vehicle's tire that evaded the other sensor's detection. Was incorporated with more specific details on type of sensor. → F4

fr8 Documentation provided about backup camera system operation in user manual.

Explanation: While probably useful, we felt that this requirement was not necessary for our software development.

3 Non-Functional Requirements

nfr1 Emergency auto-brakes has to apply within 0.1 seconds of detection.

nfr2 Rear view camera and sensors should be reliable in low visibility situations such as low light or heavy weather.

Explanation: Nfr1 was incorporated directly into non-functional requirements. Nfr2 was incorporated as well with more specific details on what should be reliable (2/3rd of sensors operable) → N1, N2

nfr3 Screen that driver views for rear camera system should be comfortable to view while reversing

Explanation: Hard to test and we decided that the display unit is an external actor for our system.

nfr4 System should be intuitive for a driver that's never used system to gauge how far obstacles are from back of car.

Explanation: Similar explanation for nfr3, but this was slightly incorporated by requiring guidelines for system to help driver gauge distance to obstacles without having to play audible alerts to them.

nfr5 Rear camera system should have a low latency that's near real time, 200ms or less.

Explanation: Was not specific enough. We both agreed the system should be real-time processing, which was then added as Global Invariant 2 in the requirements.

4 Invariant Requirements

ir1 The back-up system cannot be disabled without manufacturer permission.

Explanation: While I thought this was a good invariant, Ms Rezaeimanesh pointed out that it would be useful for the driver to have the ability to temporarily mute our system's alarm in case of false positives.

ir2 The back-up system is only active when the vehicle is shifted into reverse and **remains active during the reverse.**

Explanation: We agreed that it was a good idea for the back-up system to only be effective when reversing to prevent alarms or sudden stoppage while the car was moving forwards. The second part was not added since it conflicted with our new requirement of allowing temporary muting of the back-up system. → GI 1

ir3 The back-up system must be able to operate in extreme weather conditions(e.g. -20 degrees fahrenheit and 140 degrees fahrenheit) and under physical vehicle stress (e.g. vibrations from driving, after fender bender, after pothole)

Explanation: We decided that this doesn't belong as a global invariant as it can't be guaranteed.

Back-over Prevention System (Individual Requirements)

Sara Rezaeimanesh

Requirements that were included in the final requirements list are in green and the ones that were not included are in red.

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1. The system must have a high quality rear-facing camera (*hardware constraint*) to display blind spots to the driver on the vehicle's screen when reversing.

Explanation: We included this requirement in our final requirements list but specified what we meant by "blind spots" and "high quality camera." → F1

2. The system must have LiDAR sensors (*hardware constraint*) at the back of the vehicle for detecting pedestrians within an 80-inch radius of the vehicle.

Explanation: We included this in our final requirements list because adding LiDAR sensors to the system can enhance detection accuracy especially in adverse weather conditions. However, we changed "pedestrians" to "obstacles" because the car should avoid obstacles. We also adjusted the LiDAR detection radius after determining that 80 inches was slightly excessive, as it could lead to frequent alarms, and annoy the user. → F2

3. The system must process sensor data with ≤100 milliseconds latency (*hardware constraint*) to ensure real-time detection.

Explanation: We included this as a global invariant since failure to ensure real-time performance can result in back over accidents and therefore, it must be a property that the system should always maintain. → GI2

4. The system must alert the driver through a beeping sound that is distinct from the other alarm sounds of the vehicle if pedestrian is detected between 40-80 inches from the vehicle.

Explanation: We included this requirement because it is important for the alarm to be distinct from the other alarms of the system so that the driver immediately knows there's an obstacle behind the car as soon as they hear the alarm. Similar to the last requirement, we adjusted the distance and changed "between 40-80" inches to "less than 6-feet." I initially thought that distances lower than 40 should just trigger emergency braking. However, we thought it would be better if the alarms were also present in case the system malfunctions. → F3

5. **(Since most injuries are caused by running over the body) The system must take over control from the driver and engage emergency braking when the pedestrian is less than 40 inches from the vehicle. (Human reaction time is 250 milliseconds on average [1] and vehicles back out at the speed of around 3-6 mph. The system also has a 100-millisecond latency. Accounting for vehicle deceleration time, if the**

pedestrian is less than 40 inches away from the vehicle, there is a high chance of collision even if the driver is made aware of the obstacle as soon as it is detected.)

Explanation: We included this requirement to account for human reaction time and system latency but changed pedestrian to obstacle and adjusted the distance. → F7

6. The system must be able to detect faulty sensors, disengage in case of malfunctions and alert the driver.

Explanation: We did not keep this requirement since it would be dangerous for the system to shut down completely because of one faulty sensor. We instead used one of Mr. Nguyen's requirements, which specified that the system should disengage only if ⅔ of the sensors were faulty.

7. The system must use movement prediction algorithms to estimate whether an object currently outside the vehicle's rear detection zone may enter the zone within the next 2 seconds.

Explanation: We did not keep this requirement since extra alerts and sensors for moving objects that are not behind the car will bloat the system and annoy the driver. The current system is capable of handling any obstacles behind the car at any distance. Therefore, iif a moving object ends up behind the car at any point, the system can handle it.

8. The system must maintain more than 99.9% detection accuracy in different weather conditions. (To be more specific, false negatives must be nearly nonexistent to ensure that no pedestrian goes undetected and false positives must be < 5% to prevent driver desensitization to alarms.)

Explanation: We added this as a non-functional requirement since it describes the reliability of the system in detail, highlighting the acceptable number of false positives and false negatives. → NF2

9. The system must disable alerts when the vehicle is moving forward to avoid false alarms.

Explanation: We included one of Mr. Nguyen's requirements with similar implications ("The back-up system is only active when the vehicle is shifted into reverse.") as a global invariant.

10. The system cameras and sensors must be installed at least 12 inches above the ground to avoid false positives.

Explanation: We added this as a non-functional requirement since it is related to the reliability of the system and specifies the height that the camera and sensors should be mounted on ***any*** vehicle to ensure functionality. → NF3

11. The system must allow the driver to turn off the alarm in case of false positives.

Explanation: We included this requirement because the system may still malfunction due to faulty sensors or software. The driver must have the ability to turn off the alarm once they

are confident there are no obstacles behind the vehicle. Without this option, false negative alarms could keep going for a long time and distract the driver. → F5

12. The system must have collision detection sensors at the back of the vehicle to stop the car as soon as collision is detected. (If the software fails to detect an obstacle or malfunctions, there is a hardware mechanism to prevent serious injury in case of collision, especially since most injuries are not caused by the impact itself.)

Explanation: We included this requirement to ensure the system is failsafe. In the event that the sensors or camera miss an obstacle (false negative), or if the vehicle does not stop in time, the system must still be capable of preventing severe accidents. Collision detection sensors can use the braking system to immediately stop the vehicle upon impact. We have specified the types of sensors required to achieve this functionality. → F6

References

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