McMaster University

Inspiring Innovation and Discovery

Autonomous Vehicle Control System

Software Requirements Specification

(Deliverable #7)

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Revision 2.0

Revision History

Revision Number	Author(s)	Description	Date
0.1	Steven Back	Created main template for document	01/10/11
0.2	Steven Back	Added content for Sections 1.0 & 2.0	10/10/11
0.3	Colin, Mohit, Greg, Steven, Hector, Matt	Added content in Requirements (Section 5.0) and other content for various sections	20/10/11
0.4	Mohit Bhagotra	Separated Functional and Non-Functional Requirements Added content for Product Overview	21/10/11
1.0	Colin Lobo	Formatted document and final edit for SRS (Deliverable #1) submission	22/10/11
1.1	Colin, Mohit, Greg, Steven, Hector, Matt	The team went through the entire document, making changes as necessary from the first instantiation of the document.	02/03/12
1.9	Steven Back	Made final changes to ensure system requirements are in line with what will be delivered to the client.	03/03/12
2.0	Colin Lobo	Formatted document and final edit for Final Rev SRS (Deliverable #7) submission	04/03/12

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1. INTRODUCTION

1.1 Document Purpose

The purpose of this document is to provide the minimum requirements for a 1/10 scale autonomous car whose main functionalities will be lane following and obstacle avoidance. The document describes the requirements for the entire system as it pertains to the capstone course and will be used as a reference for the System Design.

1.2 System Scope

1.2.1 Purpose

The purpose of the project is to provide the client a well-documented and complete engineering system that completes the following tasks:

1. A system that will be able to navigate a predefined track autonomously.
2. A system that will to stay within a lane of the track at all times.
3. A system that will avoid inanimate obstacles in its path.
4. The solution that will cost no more than $750.00 CAD.
5. A system that will be able to demonstrate adaptive cruise control.

1.2.2 Goals

	GOAL (not in any particular order)
1	KISS – Keep it Simple Stupid
2	Don't crash
3	Stay within the boundaries of road
4	Stay completely within one lane when not changing lane
5	Drive forward when not avoiding obstacles
6	Emergency stop
7	Go as fast as possible without issues
8	Smooth motion of vehicle
9	Advertisement opportunities- money donated if profit
10	Follow other moving object
11	Look good
12	Stay within budget
13	Cost effective
14	Good code
15	Indicate lane change

Table 1: List of goals for the project.

1. KISS – Keep It Simple Stupid
   - Meet all requirements of the client, nothing less and nothing more
   - Keep design simple
   - Implement functionality in the most optimal space (hardware or software)

2. Don’t crash
   - Don’t make physical contact with other objects that are not the ground
   - Don’t cause the car to be able to lose physical control or continue driving when it has made physical contact with an object
   - Don’t cause the car to be able to lose electronic control

3. Stay within the boundaries of the road
   - The entire vehicle is within the boundaries of the road and no section of the car shall leave the boundary

4. Stay completely within one lane when not changing lane
   - The entire vehicle is within a single lane and no section of the car shall leave this boundary when not changing lanes
   - When it is decided to change the lane the vehicle is allowed to cross a single lane and afterwards the above is enforced

5. Drive forward when not avoiding obstacles
   - The vehicle will progress along the track with the front end facing forward as long as nothing is obstructing it's progress
   - When encountering an obstacle the vehicle may manoeuvre in alternate fashions without breaking any other rule
   - Do not react to an object that is not within a physically avoidable distance

6. Emergency stop
   - The car will have a way to come to a complete stop when encountering an object
   - An emergency stop will occur when no other options is available

7. Go as fast as possible without issues
   - Travel as fast as possible without breaking any other rules
   - Maximum speed should not put E-Stop in jeopardy

8. Smooth motion of vehicle
   - Acceleration
     - Maintain constant acceleration while accelerating
     - Do not exceed a predefined threshold of acceleration
   - Decelerate
     - Under normal conditions the vehicle should decelerate within a certain range to maintain smoothness. The vehicle should anticipate this

    - Under exceptional circumstances the vehicle may decelerate as quickly as possible
- Turning
    - When turning the wheels will never skid
    - Navigate a turn at an appropriate and safe speed whilst maintaining smoothness

9. Advertisement opportunities – money donated if profit
    - Sponsors logo placed onto the car with all profit donated to charitable cause

10. Follow other moving object
    - Unique feature of the system
    - The vehicle shall stay a safe distance behind a slower moving vehicle in its current lane

11. Look good
    - Only the sensors of the vehicle should be visible outside the body (preferably)
    - The vehicle circuitry shall be as aesthetically pleasing as possible.
    - Only printed circuitry (No breadboards) optimized for space are allowed.
    - All hardware must be properly mounted and secured

12. Stay within budget
    - Final build must not exceed $750.00 CAD.
    - Budget does not include ‘test’ materials

13. Cost effective
    - No single aspect of the project shall consume the majority of the budget and time
    - Whenever possible economic component shall be used
    - Only one solution to one problem shall be used
    - There shall be no unnecessary redundancy
    - Minimize cost of time and money by avoiding unnecessary part orders

14. Good code
    - Each layer must be insulated from change.
    - Good variable/function naming scheme
    - Avoid major changes to code that's not your responsibility without co-operation
    - Use a consistent coding scheme throughout
    - All modules should only deal with their respective concern.
    - All values relating to real world principles will be dealt with in their real world units.
    - Standardize upon a programming language for each component
    - Only SI units shall be used throughout the project
    - Absolutely comment on WHY specific piece of code was used
    - Document all public-facing API of each module

15. Indicate lane change

- A lane change shall be indicated via signal indicators on the vehicle
- An Emergency stop shall be indicated via flashing indicators on the vehicle

1.2.3 Project Scope

The scope of this project is to test the ability of students in the Mechatronics and Software Engineering disciples to culminate all that they have learned in their academic careers and apply it to a major year-long project. The development team will be designing a system (1/10 scale car) which can autonomously navigate and avoid obstacles in a closed environment provided by the client. Any functionality other than described above is considered out of the project scope.

1.3 Intended Audience and Document Overview

The intended client of this document shall be Dr. Alan Wassyng, while the audience also comprises of Dr. Wassyng's teaching assistants and the project developers. The document is thus tailored towards a technical, well versed, audience that is familiar with basic technical terminology. The document is also tailored towards the developers of the project and is thus organized in a very methodical structure to allow for the design and final product to reference the SRS with ease and create a seamless transition between documents.

1.4 Definitions, Acronyms and Abbreviations

Name	Definition
Object	Inanimate solid mass
Adaptive Cruise Control	A system that allows the vehicle to maintain a fixed safe distance behind another vehicle regardless of its speed in the same lane (See Special Task Document for further details)
Lose physical control	At any moment any one of the four tires loses contact with the ground
Lose electronic control	The vehicles control system loses power, browns out, or loses communication with any devices on the vehicle
Environment	A track provided by the client (See 2.4 Operating Environment for full description)
Road	The area contained within the thick white lines (white 2" duct tape)
Line	White 3M hockey tape
Desired Path	A route in which the vehicle will be able to travel unimpeded
Lane	The area between two lines
Obstacle	An object that is impeding the vehicles intended path or future intended path
Acceleration	To increase the rate of speed
Decelerate	To decrease the rate of speed

Vehicle/ System	The volume encompassing the body of the car, including chassis and any sensors
SRS	Software Requirement Specifications
Client	Dr. Alan Wassyng of McMaster University

Table 1.1: Project definitions

1.5 Document Conventions

1.5.1 Naming Conventions

The following naming conventions are observed in this document:

k_ : constant value
m_: monitored variable
c_ : controlled variable
e_ : enumerated values
y_ : enumeration
i_ : input variable (individual component)
o_: output variable (individual component)
d_: data variable (data in communications packet)
s_: Data Structures
t_: Data Types

The first letter of the constant shall be lower case, and all subsequent starting characters are upper case:

Ex. k_MyDogSkip

Previous values shall be represented by a subscript "-x" where x represents how far in the past

Ex. k_MyDogSkip$_{-2}$

1.5.2 Formatting Conventions

- **Paper size:** US letter (8.5"x11")
- **Margins:** top margin: 0.6", bottom margin: 0.5 ", inner margin: 0.75", outer margin: 0.75", header and footer 0.3" from edge.
- **Header:** Each page shall have a header with the following attributes:
    - Font and size Times (New) Roman, Bold, 14 point for portrait oriented documents
    - Font and size Times (New) Roman, Bold, 18 point for landscape oriented documents (e.g. PowerPoint)
    - Line below, with 2 points separation from text

  - Left, aligned with margin: the month and year of the publication (the venue date)
  - Right aligned to the margin: the document designator, which includes the document number:
  - doc.: Autonomous_Vehicle_Control_System_XX_RevY
  - Where:
    - XX is the abbreviation for the document (SRS – System Requirements Specification)
    - Y is the revision number
- **Footer:** Each page shall have a footer with the following attributes:
  - Font and size Times (New) Roman, Normal, 12 point
  - Line above
  - Left, aligned with margin: the word "Submission"
  - Center: the word "page" followed by the page number
  - Right aligned to the margin: the first author and company (in the format: author_name, company).
- Every document submission must have an author and company as a point of reference for the submission.

1.6 References and Acknowledgements

- The formatting guidelines have been adapted from the IEEE 802.22 Documents guideline

2. OVERALL DESCRIPTION

2.1 System Overview

The product has been conceived by Dr. Wassyng as part of the objective of the final year capstone course for students of the Computing and Software Department of McMaster University. In the following text the system will also be known as the car or vehicle and the environment will also be known as the track the car will run on.

2.2 System Functionality

Two main functionalities that encapsulate the entire project are as follows:

1. The system will have lane following ability.
2. The system will avoid obstacles.

2.3 Users and Characteristics

There are two versions of this project, autonomous and semi-autonomous. There will be no users if the system is autonomous as the system will be self-controlled. Although if we go the semi-autonomous route there will be some user input controlling the speed of the vehicle. In both cases direct input from the users/developers is required in starting up or shutting down the system. In this case the most important users will be the developers of the project. For the purpose of this specific document the developers have chosen for the system to be completely autonomous.

2.4 Operating Environment

Below is a description of the physical layout of the environment the vehicle will be travelling in. Likewise, the environment shall be placed outside the McMaster CAS office located on the second floor of the information technology building for the first two demonstrations. The location of the final demonstration is subject to change; however, the only variable permitted to change is the lighting condition. Likewise, the environment will also include the lighting conditions found at this location. As well within the environment the only other characters shall be the obstacles.

Track Description:

- The track is outlined using tape
- White 2 inch duct tape is used to mark the boundaries of the course
- 3M Scotch Cloth 220 White Duct Tape – Home Depot
- White hockey tape is used to mark the interior lanes
- 3M White Hockey Stick Tape – Canadian Tire
- The carpet is made up of two segments and the seam is covered using black duct tape
- 3M Scotch Cloth 220 Black Duct Tape – Home Depot
- The lane width is ~30 cm wide
- There may be bumps and dirt on the course

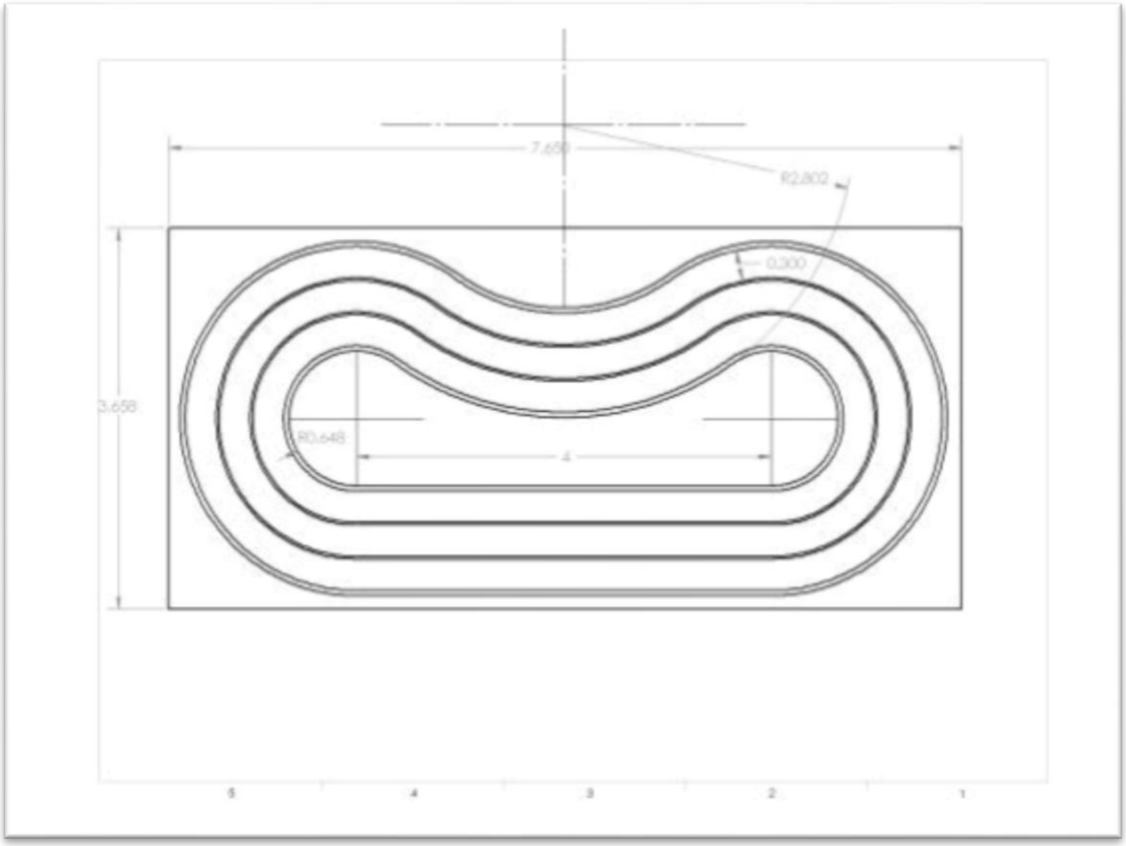


Figure 1: Dimensioning of the environment

Figure 1.1: Visual of track in the environment.

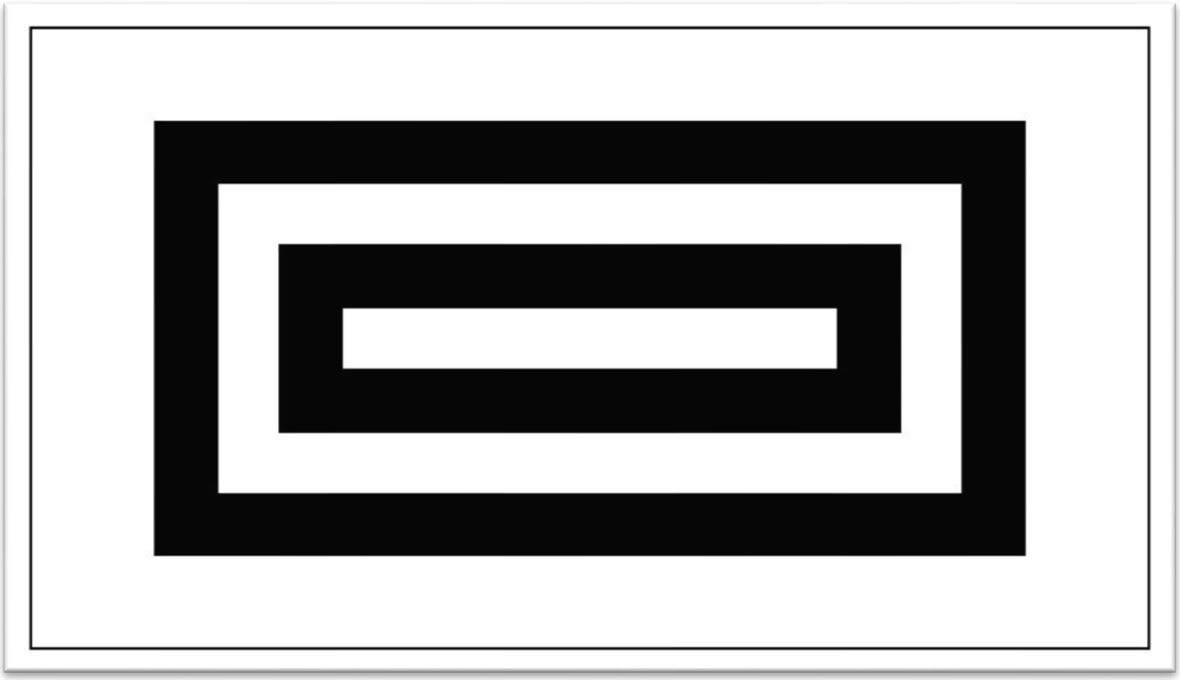


Figure 1.2 Visual of the Obstacle

The obstacles will be in the form of Figure 1.2 and will be approximately 25 cm wide, 15 cm tall and 3 cm thick.

2.5 System Context Diagram

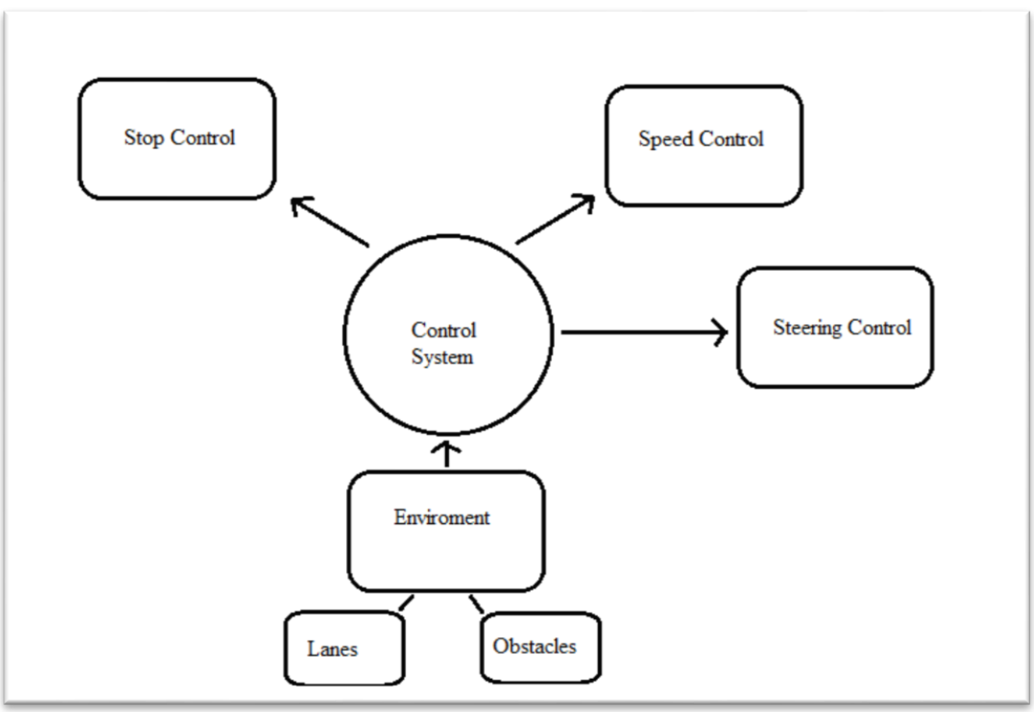


Figure 1.2: System Context Diagram

2.6 Assumptions and Dependencies

- The vehicle shall only operate on the provided track.
- The system demonstration shall take place indoors with adequate lighting.
- No persons or foreign objects other than the system and the obstacles provided by the client shall enter the environment.

2.7 Required Behaviour Description

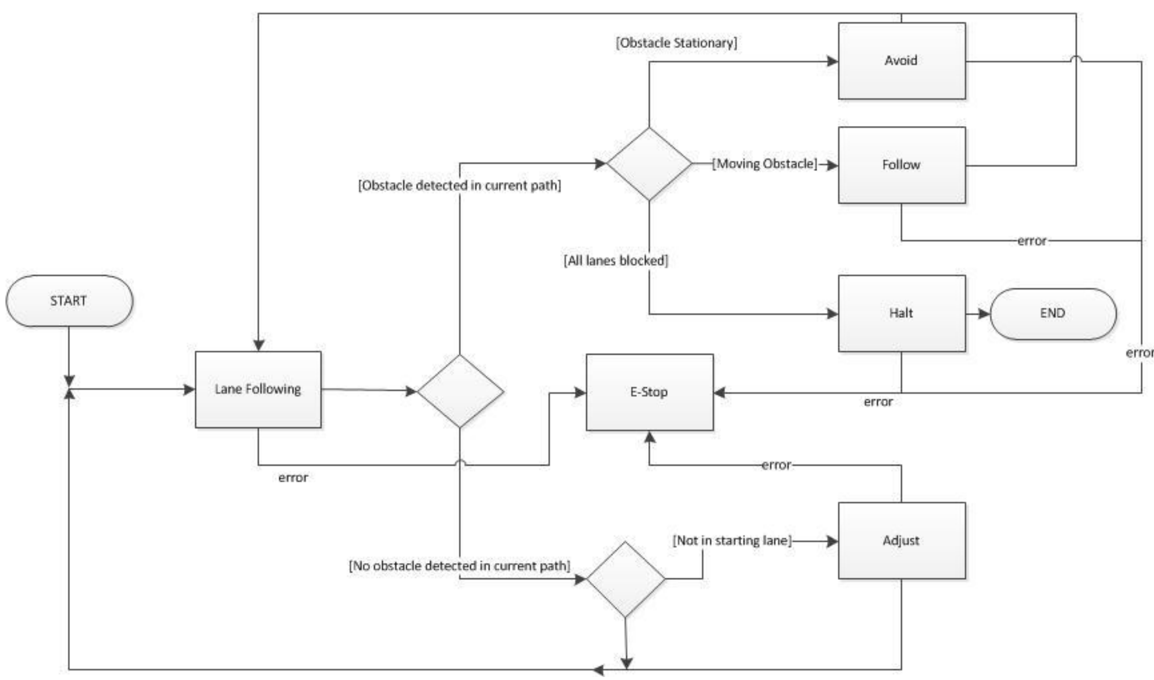


Figure 1.3: State Machine diagram

State	Description
Lane Following	In this state the vehicle will progress (forward direction of vehicle's orientation) along the track while staying in between two lines (lane).
Avoid	In this state the vehicle will switch to the next available lane (ie. any unobstructed lane).
Halt	In this state the vehicle will come to a gradual stop.
Adjust	In this state the vehicle will move to a lane which is or closest to the initial lane. If it's not possible it will do nothing.
Follow	In this state the vehicle will follow a moving obstacle in front of it only if it's in the current lane.

	(Adaptive Cruise Control)

Table 1.2: State Descriptions

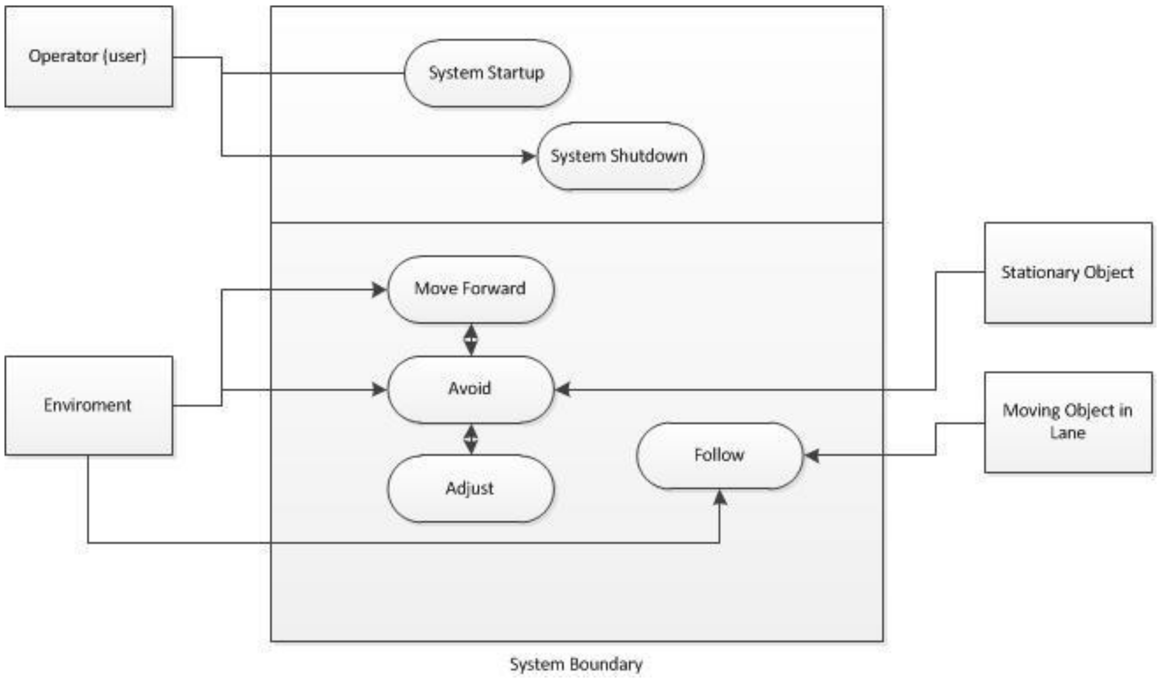


Figure 1.4: Use-Case diagram of system

- The horizontal line dividing the large box represents the user level abstraction; the user shall only interfere in the system to either start the system or to shut it down.
- The large box outline represents the entire system boundary, anything outside this line are factors coming from the environment or the user.
- In the moving forward state, the system shall receive external data from the environment, which will allow it to keep in a lane, and take turns etc.
- In the avoid state the system shall receive data from both the environment and data from an imminent object that is in its path, thus allowing it to take necessary evasive action, while still navigating the path.
- In the adjust state the vehicle should, when possible, move to its initial starting lane, and then return to the moving forward state.
- In the follow state the vehicle will demonstrate adaptive cruise control (maintain fixed distance between moving obstacle in its current lane only).

2.8 Functional Decomposition

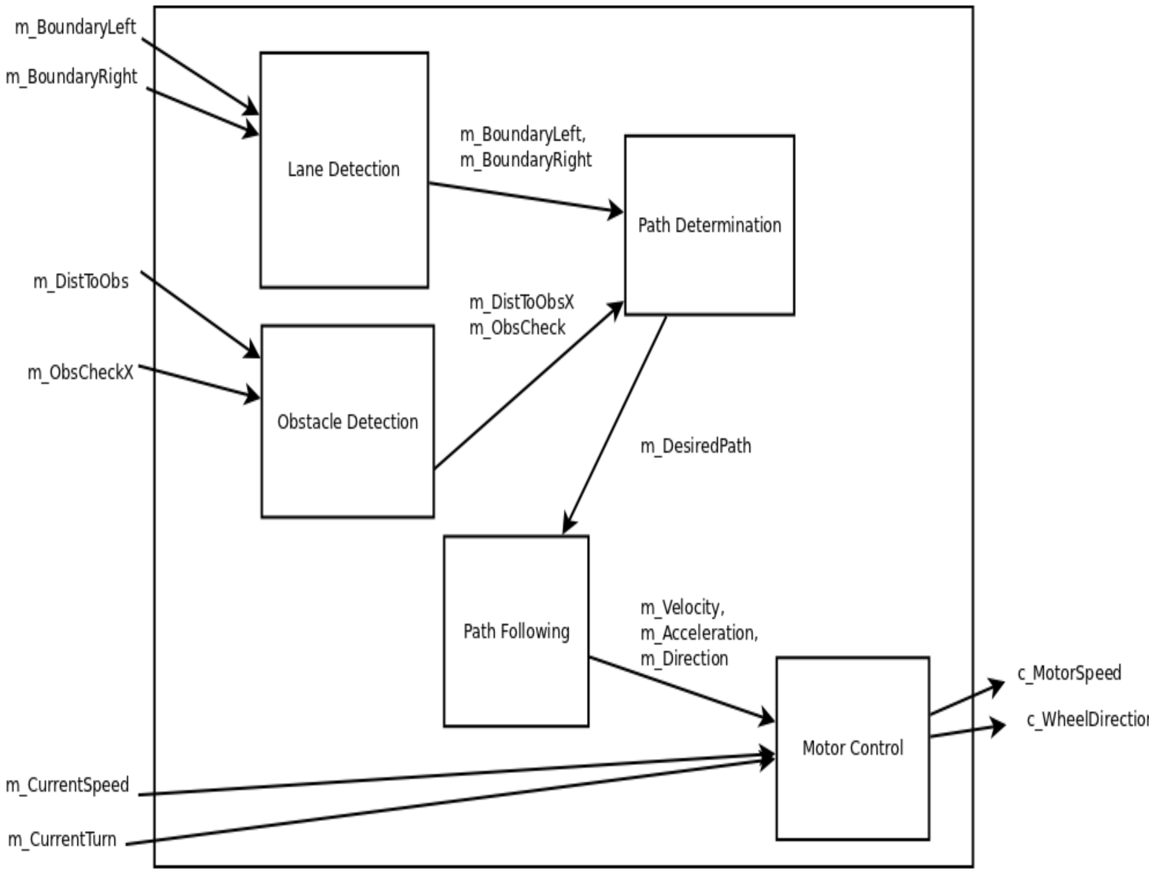


Figure 1.5: Functional Decomposition diagram

The Figure 1.5 depicts the functional decomposition of the system. The outer rectangular box represents the system. Likewise, the signals coming into the system represent our monitored variables from the environment and the signals coming out of the system represent our controlled variables to the environment.

Internal to the system are the main system functionality blocks in order to meet the client's requirements. Each block has signals internal to the system entering and leaving. If the signal is coming from the environment, it might first be transformed into a signal that can be processed by the system (i.e. volts to meters). Likewise the signals leaving a block and entering the environment might be first processed before leaving the system at the systems boundary (i.e. digital to analog). The blocks names are self-explanatory and do not require further expansion until the system design specification.

3. SPECIFIC REQUIREMENTS

Functional Requirements

1. The vehicle shall only be allowed to travel in the forward direction. (3.3.1)
2. The vehicle shall have the ability to determine the boundaries of the road. (3.3.2)
3. The vehicle shall stay within the boundaries of the track when traveling. (3.3.3)
4. The vehicle shall have to ability to detect all lanes on the track. (3.3.4)
5. The vehicle shall be able to determine which lane it is traveling in. (3.3.5)
6. The vehicle shall have a lane following ability. (3.3.6)
7. The vehicle shall be able stay within one lane when traveling. (3.3.7)
8. The vehicle shall have the ability to change lanes. (3.3.8)
9. The vehicle shall only cross one lane at a time. (3.3.9)
10. The vehicle shall maintain control at all times when traveling. (3.3.10)
11. The vehicle shall not make physical contact with another object on the track. (3.3.11)
12. The vehicle shall have the ability to detect obstacles in each lane in the direction it is traveling. (3.3.13)
13. The vehicle shall be able to avoid obstacles. (3.3.14)
14. The vehicle shall have the ability to stop. (3.3.15)
15. The vehicle shall be able to decide to stop when no further progress is possible. (3.3.16)
16. The vehicle shall travel in its starting lane whenever possible. (3.3.17)
17. The vehicle shall indicate the direction it will change lanes to. (3.3.18)
18. The vehicle shall be able to follow another moving object (adaptive cruise control). (3.3.19)

Non-Functional Requirements

1. The vehicle shall travel as fast as possible around the track. (3.4.1)
2. The vehicle shall travel with smooth motion. (3.4.2)
3. The vehicle shall use an efficient lane following algorithm. (3.4.3)
4. The vehicle shall use minimal power. (3.4.4)
5. The vehicle shall not cost more than the allotted budget. (3.4.5)
6. The vehicle shall appear aesthetically pleasing. (3.4.6)
7. The vehicle shall not cause harm or injury onto a person. (3.4.7)

3.1 List of Requirement Likely To Change

1. The vehicle shall only cross one lane at a time
    - Rationale: The client has not specified this as a requirement however we believe this will be needed to execute other requirements given by the client.

2. The vehicle shall travel as fast as possible around the track.
    - Rationale: The client has not specified this as a requirement however we believe it would be a valuable asset (selling point) if it was relatively fast around the track.

3. The vehicle shall appear aesthetically pleasing.
    - Rationale: The client has not provided a proper metric for this, besides circuitry implemented on PCB (Printed Circuit Board); this is a fairly arbitrary requirement.

4. The vehicle shall travel with smooth motion
    - Rationale: The vehicle should always try travelling in a smooth motion but this is an arbitrary requirement.

5. The vehicle shall use an efficient lane following algorithm
    - Rationale: Using an efficient algorithm is always good but this is an arbitrary requirement.

3.2 List of Requirements Not Likely To Change

1. The vehicle shall have to ability to detect all lanes on the track
    - Rationale: With the exception of the values of the constants, this requirement is a fundamental requirement from the client

2. The vehicle shall have the ability to stop
    - Rationale: As one of the fundamental requirements of the client is the ability of the vehicle to stop when faced with three obstacles adjoining one another, this requirement will not likely change

3. The vehicle shall have the ability to change lanes
    - Rationale: Being the method of avoiding obstacles by when the current lane is obstructed this requirement is fundamental to the functionality specifications of the client, and thus will not likely change.

4. The vehicle shall be able to stay within one lane when traveling
    - Rationale: Meaning that the vehicle should not exit the lane unless that is explicitly what it decides to do, this is not likely to change due to the client’s demand that the vehicle should be only in one lane at a time.

5. The vehicle shall be able to determine which lane it is traveling in

- Rationale: As knowing this information is implicitly necessary for the changing lanes requirement, it is likely that this requirement will not change.

6. The vehicle shall avoid obstacles.
   - Rationale: The client has outlined that this requirement's implementation be imperative.

7. The vehicle shall not make physical contact with another object on the track.
   - Rationale: The client has outlined that this requirement's implementation be imperative.

8. The vehicle shall not cost more than the allocated budget.
   - Rationale: The client has given us a specific dollar amount to spend for this project.

9. The vehicle shall be able to decide to stop when no further progress is possible.
   - Rationale: This situation has been specifically addressed by the client and that the vehicle must stop when faced with this situation.

10. The vehicle shall use minimal power.
    - Rationale: The vehicle should use minimal power for two reasons. The operating time of the vehicle should be enough for multiple demos and is a great selling point for the vehicle.

11. The vehicle shall not cause harm or injury onto a person.
    - Rationale: Safety should come above all else.

12. The vehicle shall travel in its starting lane whenever possible.
    - Rationale: The client has given us a specific lane to stay in whenever possible. This lane is the vehicles initial starting lane.

13. The vehicle shall have the ability to detect obstacles in each lane in the direction it is travelling.
    - Rationale: In order to make a lane change the vehicle should sense if there is an obstruction in all lanes in its immediate area in front of the vehicle.

14. The vehicle shall maintain control at all times when traveling.
    - Rationale: Safety is paramount.

15. The vehicle shall have a lane following ability.
    - Rationale: One of the fundamental requirements from the client. The client has outlined that this requirement's implementation be imperative.

16. The vehicle shall stay within the boundaries of the track when traveling.

- Rationale: The client has outlined that this requirement's implementation be imperative.

17. The vehicle shall have the ability to determine the boundaries of the road.
    - Rationale: Required in order to implement lane following ability.

18. The vehicle shall only be allowed to travel in the forward direction.
    - Rationale: The client has outlined that this requirement's implementation be imperative.

3.3 Functional Requirements

Note: All monitored, controlled variables and constants can be found in Appendix A.

3.3.1

Requirement: The vehicle shall only be allowed to travel in the forward direction.

Rationale: The vehicle should never be traveling backwards at any point; the goal is to have the vehicle progressing in the forward direction at all times.

Fit Criteria: The vehicles velocity in the reverse direction shall never exceed 0 m/s.

Dependencies: N/A

Monitored and controlled variables:

- m_Velocity

Performance Requirements:

- The system must capture the environment as specified in the monitored variables at a rate proportional to the speed of the vehicle.

Requirements on Hardware Environment:

- The hardware must have a sensor to monitor the speed of the vehicle.

Requirements on Software Environment:

- The software must have a scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline.

Normal Operation:

- Two possible states Forward and Reverse, the system is considered to be behaving normally when it is in the Forward state.

Undesired Event Handling:

- Detection of travel in the reverse direction
  - The system shall signal the vehicle to enter the safety state.
- False detection of travel in the reverse direction
  - The system shall compensate for any discrepancies in the environment such as bumps that could possibly provide a false reading on the vehicles direction.

3.3.2

Requirement: The vehicle shall have the ability to determine the boundaries of the road.

Rationale: The vehicle must know where the track boundaries are in order to stay within the track.

Fit Criteria: The vehicle shall know the boundaries of the track with a width of up to 1 meter and the boundaries shall be known for 50 centimeters ahead of the vehicles current position.

Dependencies: 3.4.3

Monitored and Controlled Variables:

- Monitored: A signal monitoring the vehicles environment in the forward direction, which will be used to determine the distance the vehicle is from the left and right boundaries of the track.

Constants:

- None

Performance Requirements:

- The system must capture the environment as specified in the monitored variables at a rate proportional to the speed of the vehicle.

Requirements on Hardware Environment:

- The hardware needs to be able to monitor and capture the environment as specified in the monitored variables.

Requirements on Software Environment:

- The software needs to be able to process the image acquired from the hardware periodically with a deadline set by the timing requirements of the system.

Normal Operation:

- Normal operation is when the system stays within the boundaries of the environment.

Undesired Event Handling

- If the vehicle is not able to determine the bounds of the road, the system will enter the emergency stopped state

3.3.3

Requirement: The vehicle shall stay within the boundaries of the track when traveling.

Rationale: The vehicle must stay within the track to make sure lane following is possible.

Fit Criteria: At most only 1cm of any section of the vehicle shall cross over the tape of the track boundary.

Dependencies: 3.3.2

Monitored and controlled variables:

- m_BoundaryLeft
- m_BoundaryRight
- c_TurnAngle

Constants:

- None

Performance Requirements:

- The system must have the ability to react to changes in the environment as specified in the monitored variables at a rate proportional to the speed of the vehicle.

Requirements on Hardware Environment:

- The hardware needs to be able to monitor and capture the environment as specified in the monitored variables at a rate proportional to the speed of the vehicle

Requirements on Software Environment:

- The software needs to be able to monitor and capture the environment as specified in the monitored variables at a rate proportional to the speed of the vehicle

Normal Operation:

- The system is considered to be behaving normally when the vehicle is within the boundaries of the track. If the vehicle begins to exit the track the vehicle must immediately change direction to make sure it stays within the track boundaries.

Undesired Event Handling:

- The vehicle continues to exit the track boundaries
  - The vehicle shall immediately change direction and re-enter the tracks boundaries.
- The vehicle completely exits the track boundaries
  - The system shall signal the vehicle to stop immediately

3.3.4

Requirement: The vehicle shall have to ability to detect all lanes on the track.

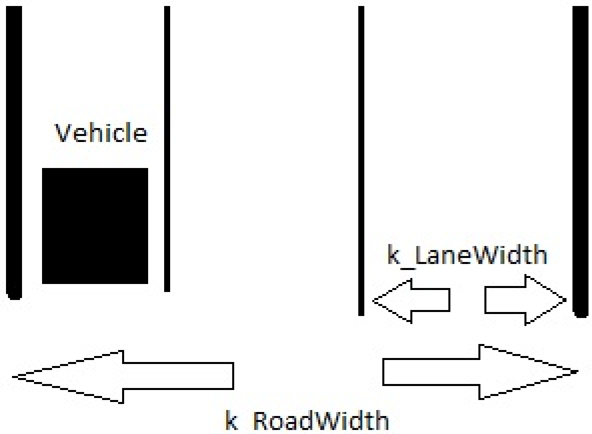
Rationale: In order to complete obstacle avoidance the vehicle must be able to detect the lanes in order to be able to map obstacles to lanes and also to know the vehicle's orientation.

Fit Criteria: The vehicle shall know at all times the distance and direction between its current lane and all other lanes in the environment. The tolerance should be +/- 2.5 cm.

Dependencies: 3.4.3

Monitored and Controlled Variables:

- m_Environment



Constants:

- k_RoadWidth
- k_LaneWidth

Performance Requirements:

- Detect the lanes at a speed that is proportional to the speed of the car.

Requirements on Hardware Environment:

- The hardware needs to be able to monitor and capture the environment as specified in the monitored variables.

Requirements on Software Environment:

- The software needs to be able to process the image acquired from the hardware at a rate proportional to the speed of the vehicle

Normal Operation:

- Periodic collection of the distance and direction between the current lane and all other lanes in the environment.

Undesired Event Handling:

- The image processed is not equivalent to the environment (due to noise or someone walking in front of the monitored variables)
    - The data shall be the weighted average of the previous results, for example: $Data\_i = \frac{1}{2}\, m\_Lanes + \frac{1}{4}\, m\_Lanes_{-1} + \frac{1}{8}\, m\_Lanes_{-2} + 1/16\, m\_Lanes_{-3} + 1/16\, m\_Lanes_{-4}$

3.3.5

Requirement: The vehicle shall be able to determine which lane it is travelling in.

Rationale: This is necessary for determining which lanes are available, and requires a detection of all lanes and the identification of which of those lanes the vehicle is within.

Fit Criterion: This metric can have four states, that is the position of the vehicle can be in the left lane, middle lane, right lane, and an unknown state for start-up.

Dependencies: 3.3.4, 3.3.6

Monitored and Controlled Variables:

- e_CurrLane

Performance Requirements:

- The vehicle shall visually identify all lanes
- The vehicle shall be able to determine in which of the identified lanes it is traveling in.

Requirement of Hardware:

- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A visual unit that can view all 3 lanes.

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

Normal Behaviour:

- The vehicle is said to have normal behaviour if at all times on the track it knows of its position between the lanes and this is position is visually known to be correct by the user.

Undesired event handling:

- The vehicle cannot identify which lane it is in: The vehicle shall go into the emergency stopped state until it can determine its position on the track.

3.3.6

Requirement: The vehicle shall have a lane following ability.

Rationale: The vehicle needs to stay in its lane to be able to follow appropriate rules of the road.

Fit Criterion: The vehicle shall stay within the bounds of its lane while avoiding oscillations that exceed the requirement for smooth motion

Dependencies: N/A

Monitored and Controlled Variables

- m_IsCrossedLane
- m_BoundaryLeft
- m_BoundaryRight
- m_Velocity
- c_TurnAngle

Performance Requirements:

- The system should be able to feed data into the lane following system to avoid crossing a boundary without it noticing

Requirements on Hardware Environment:

- The hardware must report where the boundaries are on the track
- The hardware must report when boundaries are crossed
- The current velocity must allow for fine control to stay within the lane.

Requirements on Software Environment:

- The software must process data from hardware fast enough to avoid crossing the line.

Normal Operation:

- Under normal operation the car will stay within its given lane, avoiding oscillations

Undesired Event Handling:

- If the car leaves the lane, it will attempt to re-merge if it’s safe; otherwise it will go into the emergency stopped state.

Table:

State	Action
Current Lane clear to stay within	Re merges and continues in lane.
Current Lane is no longer safe	Emergency Stop

3.3.7

Requirement: The vehicle shall be able stay within one lane when traveling.

Rationale: This is necessary so that the vehicle does not collide with any obstacles while over taking them, which is part of the required behaviour from the client.

Fit Criterion: This is a binary criterion, in which the vehicle either meets the requirement to stay within the lane or it leaves the lane and fails the requirement.

Dependencies: 3.3.6, 3.3.3

Monitored and controlled variables:
- m_DistEdge
- m_LaneBool

Performance requirements:
- The vehicle must never exit the lane unless it explicitly decides to do so.
- The vehicle must stay at the center of the lanes as much as possible and in a smooth fashion.

Requirement of Hardware
- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A visual sensor that can determine if and when the vehicle leaves the lane
- A sensor that give information as to the distance from the edges of the lane.

Requirement on Software
- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

Normal Behaviour:

- The vehicle shall remain within the confines of the lane at all time, unless it explicitly decides to switch lanes, in which case it should only enter the lane it decides to move into.

Undesired event handling:

- The vehicle exits the lane undesirably: The vehicle shall try and correct the action or else go into the emergency stopped state.

3.3.8

Requirement: The vehicle shall have the ability to change lanes.

Rationale: In order to complete an obstacle avoiding manoeuvre, the vehicle must be able to change its position into a lane that is not obstructed. Subsequently it must be able to move into the default lane whenever this lane is free.

Fit criterion: If the lane in which the vehicle finds itself traveling in has an imminent obstruction, the vehicle must select a free lane. Immediately following this, it must move into said lane in a smooth and quick fashion in order to avoid the upcoming obstacle. Subsequently it must decide if it is possible to move into the rightmost lane, and also do so given the opportunity.

Dependencies: 3.3.2, 3.3.4, 3.3.5, 3.3.6, 3.3.7

Monitored and Controlled Variables:

- m_Ob - A signal feeding information to the vehicle about what is up ahead within the confinements of the whole road. Binary, there is either something, in a lane, or there isn't.
- m_lanePos - A signal providing information as to which lane the vehicle is traveling in (left, middle or right)
- m_ObsDist - A signal providing information as to the distance in cm, between the vehicle and and obstacle in either of the lanes.
- c_TurnAngle - Turning angle given in deg.

Constants:

- k_MinObsDist
- k_MaxObsDist

Performance Requirements:

- Until the vehicle detects an object in the default lane k_MinObsDist cm ahead the vehicle will remain in the default lane.
- When this k_MinObsDist cm thresh hold is reached, the vehicle should move to a free lane.

- The vehicle shall return to the default lane as soon as possible after avoiding a series of obstacles.

Requirement on Hardware:

- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A steering mechanism that enables the vehicle to change lanes
- An image sensor that will enable the vehicle to detect obstacles and change lanes accordingly
- An image sensor to keep the vehicle centered in the lanes.

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

Normal Operation:

- The vehicle is said to be behaving normally when it changes lanes smoothly and swiftly in the case when its current lane is obstructed. After that, it should return to the default lane whenever possible in the same timely manner.

Undesirable Event Handling:

- In the event that vehicle does not change lanes, or stays in between 2 lanes: The vehicle should revert the changes made to its position and return to the lane in was in originally.

3.3.9

Requirement: The vehicle shall only cross one lane at a time.

Rationale: The vehicle should always methodically check its condition and the environment when crossing a line. It should never cross multiple lanes without doing a re-evaluation of its condition and the environment. This also prevents unnecessary lane changes.

Fit Criterion: The system should be able to detect when it crosses a line (white 3M hockey tape).

Dependencies: 3.3.4, 3.3.5, 3.3.8

Monitored and Controlled Variables

- m_IsCrossedLine

Performance Requirements:

- The vehicle should not cross a line (3M hockey tape) if m_IsCrossedLine is in a true state.
- The only time a vehicle can cross a line (3M hockey tape) is when m_IsCrossedLine is in a false state.

Undesirable Event Handling:

- The system fails to sense when the vehicle has crossed a line:
- In this case there will be a feedback system that continually checks the vehicle's position (ie. current lane)

Normal Operation:

- The vehicle shall change if m_IsCrossedLine to a true state if it has crossed a line. Once a re-evaluation is done of the environment and system, m_IsCrossedLine is changed to a false state. Only when m_IsCrossedLine is in a false state the vehicle may cross a lane.

Requirement on Hardware:

- A sensor which detects white 3M hockey tape.

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline.

3.3.10

Requirement: The vehicle shall maintain control at all times when travelling.

Rationale: The vehicle should maintain control for safety reasons.

Fit Criterion: The system should be able to detect if it has lost control. It will have a true state and false state.

Dependencies: All other requirements.

Monitored and controlled variables

- A variable that denotes the state of the system. Either in controlled or uncontrolled state. There will be a feedback system so that if the system is in an uncontrollable state the system will to correct itself if at all possible.

Performance Requirements:

- The system should be able to detect whether it has lost complete control in a timely manner.

Undesirable Event Handling:

- The system enters a 'unsafe' state accidentally:
  A feedback system should be implemented to correct for this.

Normal Operation:

- If the system detects it has lost control then it should come to a complete stop as quickly as possible.

Requirement on Hardware:

- A feedback system to monitor the vehicle's condition.

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline.

3.3.11

Requirement: The vehicle shall not make physical contact with another object on the track.

Rationale: Client's requirement of obstacle avoidance. If physical contact is made this requirement has failed.

Fit Criterion: Using below dependencies, the system should never make physical contact with any object on the track. In the event this does occur a signal will be sent to the system notifying it of this event.

Dependencies: 3.3.12, 3.3.13

Monitored and Controlled Variables:

- The monitored variables would be all the input data from sensors particularly ones dealing with obstacle avoidance.

Performance Requirements:

- The system should be able to detect whether it has hit an object in a timely manner.

Undesirable Event Handling:

- Collision occurs:
  In the event of contact the system should come to a complete stop if in an unsafe state otherwise try to correct itself.

Normal Operation:

- The vehicle should avoid obstacles above all else.

Requirement on Hardware:

- A sensor to detect a collision.

Requirement on Software:

- A scheduling system that would allow for the stop state to have an appropriate priority to meet the performance requirements.

3.3.12

Requirement: The vehicle shall have the ability to detect obstacles in each lane in the direction it is traveling.

Rationale: The vehicle must be aware of all obstacles in adjacent lanes in order to determine its passing algorithm.

Fit Criterion: The vehicle must be able to detect an obstacle within the area encompassing k_LaneDistance by k_LaneWidth in front of the vehicle.

Dependencies: 3.3.4

Monitored and controlled variables:
- m_Environment
- m_ObsCheckX

Constants:

- k_LaneDistance
- k_LaneDistanceTolerance
- k_ObsConfidence

Performance Requirements:

- The frequency of the signals shall be at a rate to allow for the detection of the obstacles in a timely manner.
- The processing of the monitored signals shall be completed within the allocated time frame

Requirements on Hardware Environment:

- A processing unit whose performance allows the deadline to be met.
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner.
- A monitoring system that will allow the detection an obstacle 20 cm ahead of the vehicle within a tolerance of +/- 5 cm.

Requirements on Software Environment:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline.

Normal Operation:

- The system accepts the data from the monitored variables, processes it, and stores the result for other dependent requirements to access the results.

Undesired Event Handling:

- Sudden introduction of an object within the detection area:
    - The environment shall be considered static for each demo and therefore the requirements shall not consider this event.
- False detection of an obstacle.
    - The vehicle shall take an average of the environment such that any false detections would not have an effect on the operation of the vehicle

3.3.13

Requirement: The vehicle shall be able to avoid obstacles.

Rationale: One of the main requirements outlined by the client as the road will be contain obstacles of various sizes and the vehicle is expected to avoid these obstacles.

Fit Criterion: A binary metric of whether the vehicle successfully avoids all obstacles laid out on the track. The goal is that the vehicle does not collide with anything on the track. This requirement shall not be deemed fulfilled unless the vehicle avoids 100% of obstacles.

Dependencies: 3.3.12, 3.3.8

Monitored and controlled variables:

- m_Velocity
- c_Velocity
- m_ObsCheckX
- c_TurnAngle

Constants:

- k_MinObsDist
- k_MaxObsDist

Performance Requirements:

- The vehicle shall attempt to apply the avoidance protocol at least 10 cm ahead of an obstacle.
- The requirement shall be considered successful if the vehicle goes around the track and there are zero collisions with obstacles.

Undesirable Event Handling:

- The vehicle does not avoid an object:
  If the vehicle fails to avoid an object the sensors shall detect a collision or contact with another object the vehicle shall cease to progress.

Normal Operation:

- The vehicle shall stay in its current lane if there is no obstacle. If there is an obstacle ahead of the vehicle in its current lane the vehicle shall move to another lane of the track.

Requirement on Hardware:

- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner

- A steering mechanism that enables the vehicle to move to different areas of the track.
- A feedback system to monitor and control the speed of the vehicle to safely avoid obstacles

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

Current Lane	Other Lanes	Result
m_ObsCheck1 = TRUE	(m_ObsCheck2 && m_Obscheck3) = TRUE	Stop
“”	(m_ObsCheck2 && m_Obscheck3) = FALSE	Change lanes
m_ObsCheck1 = FALSE	Doesn't matter	Remain in Current Lane
m_ObsCheck2 = TRUE	(m_ObsCheck1 && m_Obscheck3) = TRUE	Stop
“”	(m_ObsCheck1 && m_Obscheck3) = FALSE	Change lanes
m_ObsCheck2 = FALSE	Doesn't matter	Remain in Current Lane
m_ObsCheck3 = TRUE	(m_ObsCheck1 && m_Obscheck2) = TRUE	Stop
“”	(m_ObsCheck1 && m_Obscheck2) = FALSE	Change lanes
m_ObsCheck3 = FALSE	Doesn't matter	Remain in Current Lane

3.3.14

Requirement: The vehicle shall have the ability to stop.

Rationale: The system must be able to stop if it detects that all 3 lanes are blocked by obstacles and there is no alternative way to manoeuvre around.

Fit Criterion: The system must be able to reach a velocity of 0 within 15 cm upon receiving a stop signal.

Dependencies: N/A

Monitored and Controlled Variables:

- m_Velocity
- c_Velocity

Constants:
- k_StopDistanceRatio
- k_StopTolerance
- k_StopMax
- k_DecelerationMax

Performance Requirements:
- If the system decides to go into a stop state, the system must be able to stop a distance that is proportional to its current speed (k_StopDistanceRatio) and within a given tolerance.
- Deceleration of the car shall be no more than k_DecelerationMax

Requirements on Hardware Environment:
- A stopping mechanism that would allow the deceleration performance requirements to be met.
- A processing unit whose performance allows the deadline to be met.

Requirements on Software Environment:
- A scheduling system that would allow for the stop state to have an appropriate priority to meet the performance requirements.

Normal operation:
- Two possible states: Stop and Non-Stop
    - Stop: The system stays within the bounds of the performance requirements in order to bring the systems speed to 0 m/s, unless the state is invoked through an undesired event for which the performance requirements may be modified as stated in the undesired event handling section.
    - Non-Stop: The function is idle waiting for an signal to switch states

Undesired Event Handling:
- The system cannot stop within the available distance with a deceleration of k_DecelerationMax.

Stopping has higher priority and therefore the k_DecelerationMax may be breached for only this scenario.

3.3.15

Requirement: The vehicle shall be able to decide to stop when no further progress is possible.

Rationale: To prevent damage to the system and environment the vehicle must detect to stop if it is not able to proceed further down the track.

Fit Criterion: If all three lanes of the track are blocked for any reason preventing the vehicle from progressing, the vehicle shall detect this situation and come to a complete stop 10 cm ahead of these obstructions.

Dependencies: 3.3.12, 3.3.14

Monitored and Controlled Variables:

- m_ObsCheckX
- m_ObsDist
- c_Velocity

Constants:

- k_StopMin
- k_StopMax
- k_StopTolerance
- k_Stop

Performance Requirements:

- If the system decides to go into a stop state, the system must stop within a distance of 10 to 20 cm in front of the obstacle directly in the current lane.
- Deceleration of the car shall be within a range of 0 to - 0.02 m/s^2
- The vehicle shall not attempt to go through the roadblock.
- The vehicle shall not attempt to change lanes when this situation occurs.

Undesirable Event Handling:

- Fail to detect that the road ahead is completely blocked:
  In this case the vehicle will collide with the obstacles and the contact shall be detected by sensors which will start the emergency braking process that will stop the car.
- Attempt to change lanes when roadblock is detected:
  The sensor will be enabled to have a view of the whole road and a value will be assigned to each lane representing the probability that a obstacle exists, with 0 being no obstacle and 1 indicating that there is most definitely an obstacle. If the values are all above a threshold of 0.6 for each lane, than the car will not be allowed to switch lanes.
- Fail to stop ahead of obstacles:
  If the normal braking mechanism does not operate, then this failure will trigger the start of the emergency braking protocol.

Normal Operation:

- Two possible states: Stop and Non-Stop
  - Stop: The system stays within the bounds of the performance requirements in order to bring the systems speed to 0 m/s, unless the state is invoked through an undesired event for which the performance requirements may be modified as stated in the undesired event handling section.
  - Non-Stop: The function is idle waiting for an signal to switch states

- The vehicle shall detect obstacles in all three lanes and deduce that it cannot avoid these and must therefore stop with a distance outlined above within the tolerances stated.

Requirement on Hardware:

- A stopping mechanism that will decelerate the vehicle to meet the performance requirements.
- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A monitoring system that will allow the detection an obstacle 20 cm ahead of the vehicle within a tolerance of +/- 5 cm

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

3.3.16

Requirement: The vehicle shall travel in the lane it began operating in whenever possible.

Rationale: As outlined by the client the vehicle shall travel in the first lane it starts the course as much as possible. This will be known as the "default lane". When avoiding an obstacle in this default lane, the vehicle will overtake it and return back to this lane.

Fit Criterion: This is a binary metric where the vehicle is either in the default lane or not in the default lane if it must change lanes.

Dependencies: 3.3.4, 3.3.5, 3.3.8

Monitored and controlled variables:

- m_ObsCheckX
- e_CurrLane
- $e\_CurrLane_0 = e\_DefaultLane$

Performance Requirements:

- Until the vehicle detects an object in the default lane 30 cm ahead the vehicle will remain in the default lane.
- The vehicle shall return to the default lane as soon as possible after avoiding a series of obstacles.

Undesirable Event Handling:

- The vehicle does not attempt to return to the default lane:

The vehicle shall change lanes when it is safe towards the right side until the edge of the track is detected.

Normal Operation:

- Two states apply for this requirement: In default lane or not in default lane.
- The vehicle is considered to be behaving normally if it is spending a majority of its time on the track in the default lane.

Requirement on Hardware:

- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A steering mechanism that enables the vehicle to change lanes
- An image sensor that will enable the vehicle to detect obstacles and change lanes accordingly

Requirement on Software:

- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner.

Function	**Result**
Default lane is clear of obstacles OR other lanes have obstacles (initial state)	Remain in default lane
Default lane has obstacle AND no other lanes have obstacles	Change lanes
Default lane has obstacle AND all other lanes have obstacles	Stop

3.3.17

Requirement: The vehicle shall indicate the direction it will change lanes to.

Rationale: The system must signal left to the environment if it is trying to change into the left lane and signal right to the environment if it is trying to change to the right lane.

Fit Criterion: The system must be able signal to the environment a lane change in any configuration of obstacles.

Dependencies: N/A

Monitored and Controlled Variables:
- None

Constants:
- None

Performance Requirements:
- If the system decides to go into a lane change state, the system must start signalling its intended lane change before it leaves its current lane

Requirements on Hardware Environment:
- A signalling mechanism that would allow the external environment to easily identify the vehicles intended change of lanes

Requirements on Software Environment:
- None

Normal operation:
- When no lane change is desired, the signal indicators are off. When a lane change is desired the indicator, indicating the appropriate lane change is on and the other indicator is off.

Undesired Event Handling:
- The indicator lights are on during a non-lane change state or the wrong indicator is on for a lane change.
  - This is not a safety critical issue and does not affect any of the other requirements and therefore requires no action by the system during operation.

3.3.18

Requirement: The vehicle shall be able to follow another moving object (adaptive cruise control).

Rationale: As outlined in our special task document, the vehicle must be able to detect another moving obstacle in front of it and follow it a safe distance behind.

Fit Criterion: The system must be able to follow a moving object in its current lane a specified safe distance behind while maintaining safe motion.

Dependencies: N/A

Monitored and Controlled Variables:
- m_ObsCheckX
- m_ObsDist
- c_Velocity

Constants:
- k_MinObsDist

Performance Requirements:
- The vehicle shall stay no less than k_MinObsDist behind a moving obstacle
- The vehicle shall maintain smooth motion on the track when following a moving obstacle

Requirement on Hardware:
- A processing unit whose performance allows the deadline to be met
- A processing unit that has the ability of converting the monitored variables to controlled variables within a timely manner
- A steering mechanism that enables the vehicle to change lanes
- An image sensor that will enable the vehicle to detect obstacles and change lanes accordingly

Requirement on Software:
- A scheduling system that would allow for the processing of the monitored signals within a specified absolute deadline
- Efficient software that will convert input to output values for the hardware in a timely manner

Normal operation:
- The vehicle stays behind the moving obstacle at a set distance, when the obstacle in front slows down the vehicle slows down and when the obstacle speeds up the vehicle speeds up. However, the vehicle shall not go past its maximum safe speed.

- If the moving obstacle stops the vehicle shall pass it accordingly.

Undesired Event Handling:

- The vehicle loses track of the moving obstacle. In this case the vehicle shall continue around the track in normal operation mode
- The vehicle perceives an obstacle to be moving when said obstacle is stationary. Build in tolerances should eliminate any discrepancies.

3.4 Non Functional Requirements

Note: All monitored, controlled variables and constants can be found in Appendix A.

3.4.1

Requirement: The vehicle shall travel as fast as possible around the track.

Rationale: Having a vehicle that can complete the track successfully and at the same time be reasonably fast can be a major selling point.

Fit Criterion: The vehicle will travel around the track in less than a minute

Dependencies: N/A

Performance Requirements:

- Having the vehicle complete one lap in under k_LapTimeMax.

Normal Operation:

- The vehicle should travel around the track as quickly as it can while obeying all other requirements.

3.4.2

Requirement: The vehicle shall travel with smooth motion.

Rationale: This requirement ensures that the vehicle will travel in a smooth matter to avoid making occupants sick. Note this requirement only places requirements on others, and is not its own module.

Fit Criterion: The vehicle shall at no time appear to travel with an unwanted or jerky motion. Specifically, the vehicle will not exceed a deceleration of k_DecelerationMax, it will not exceed a forward acceleration of k_AccelerationMax of 10cm/s. As much as possible the vehicle will steer smoothly in and out of turns. The vehicle will maintain its speed unless a change is required to navigate. The car will avoid oscillating at more than 0.5cm/s with no more deflection then 0.5cm to either side.

Dependencies: N/A

Constants:
- k_DecelerationMax
- k_AccelerationMax

Normal Operation:
- Under normal operation the vehicle should travel in a simple smooth fashion to observers.

Undesired Event Handling:
- If the vehicle acts in a non-smooth fashion, no action is taken by software beyond trying to bring the vehicle back into compliance. If the issue is caused by a lack of control, then the requirement about maintaining control takes precedence, as expected.

3.4.3

Requirement: The vehicle shall use an efficient lane following algorithm.

Rationale: This requirement ensures whichever algorithm we use will run within our constrained processing environment.

Fit Criterion: Our implemented algorithm should be able to run on our embedded hardware platform.

Dependencies: N/A

Performance Requirements:
- Our tracking software should run at an appropriate speed to accomplish our goals.

Normal Operation:
- The tracking software should handle everything as normal.

Undesired Event Handling
- If our algorithm begins to run too slow, the vehicle will enter the safety state to avoid collisions.

3.4.4

Requirement: The vehicle shall use minimal power.

Description: In order to make the running life of the system as long as possible, the system shall use as little power to power and run the hardware

Fit Criterion: The battery shall at minimum last the length of the demo

Dependencies: N/A

Constants
- k_BatteryLife = 1 hour
- k_BatteryDrain = 1000 milli-amps an hour

Performance Requirements
- The life of the battery shall be equal or more than k_BatteryLife

Requirements on Hardware Environment:
- A battery that has a milliamps per hour rating high enough to meet the performance requirements

Normal Operation:
- The battery is being drawn at a rate of k_BatteryDrain

Undesired Event Handling:
- The motor of the system draws a large amount of current in one instance
    - There shall be a dedicated battery for the control system and a dedicated battery supply for the monitoring system and the processing system

3.4.5

Requirement: The vehicle shall not cost more than the allotted budget.

Rationale: The client has outlined a hard cap for the amount of money spent on developing this vehicle at $750.00 CAD.

Fit Criterion: A simple binary metric determining whether the group is over or under the budget.

Dependencies: N/A

Undesirable Event Handling:
- The project goes over-budget
    - If this event occurs the group shall reassess the costs incurred and re-evaluate the materials and resources used.

Requirements on Hardware Environment:
- The most economical hardware that fulfills the main objectives will be used.

3.4.6

Requirement: The vehicle shall appear aesthetically pleasing.

Rationale: The vehicle's hardware implementation should be easily accessible and understandable.

Fit Criterion: Electrical cables connecting sensors should be neatly tucked; the sensors themselves should be properly mounted and only exposed from the shell if necessary. All complex circuitry should be implemented on PCB's.

Dependencies: N/A

3.4.7

Requirement: The vehicle shall not cause harm or injury onto a person.

Rationale: The system will in no way inflict any harm to anyone.

Fit Criterion: During the whole development process this will be fulfilled if there are no casualties.

Dependencies: N/A

Requirements on Hardware Environment:

- The hardware shall not be made of harmful material.
- Number of sharp pointy edges in hardware shall be minimized as much as possible.

Undesired Event Handling

- If a person does get harmed during the development or use of this system they shall be attended by professional medical personnel as quickly as possible.

APPENDIX A

1. VARIABLES MASTER LIST

1.1 Monitored Variables

Monitored Name	Description	Type	Units
m_Environment	A signal monitoring the environment directly in front of the vehicle for detection of lanes at a frequency that allows the system to detect all three lanes k_LaneDistance (20 cm) ahead of the vehicle within a tolerance of +/- k_LaneDistaneTolerance (5 cm). (as per section 5.11.1)	Digital	cm
m_Velocity	A signal monitoring the speed (m/s) of the system in relation to the environment.	Analog	m/s
m_IsCrossedLane	A signal monitoring whether the vehicle has crossed a line (white 3M hockey tape). Refer to Requirement 5.11.0001	Digital	boolean
m_SystemState	A variable that is triggered by an event that causes the system to be in an uncontrolled state. Refer to Requirement 5.11.00002	Digital	boolean
m_ObsCheckX (1 <= X <= 3)	Store whether an obstacle is present in lane x.	Digital	boolean
m_BoundaryLeft	The distance between the vehicle and the left boundary of the track with respect to the vehicle.	Digital	cm
m_BoundaryRight	The distance between the vehicle and the right boundary of the track with respect to the vehicle.	Digital	cm
m_ObsDist	The distance between the vehicle and an approaching obstacle in the current lane.	Digital	cm
m_DistEdge	The distance between the vehicle and the edge of the adjacent lane	Digital	cm
m_ForwardBool	The variable used as a check to make sure that that the system is moving in a forward direction and never in the reverse direction.	Digital	boolean
m_Impact	Determine if system has collided with another object in the environment	Digital	boolean
m_LaneBool	Check if system is within boundaries of lane or not	Digital	boolean

1.2 Controlled Variables

Control Name	Description	Type	Units
c_Velocity	The controlled variable, the system speed	Analog (PWM)	m/s
c_TurnAng	The turning angle of the wheels of the system	Analog	Degrees

1.3 Enumerated Variables

Enumerated Name	Description	Type
y_CurrLane	The current lane the vehicle is situated in {Inner, Middle, Outter}	Digital
y_DefaultLane	The lane the vehicle began the track in	Digital

2. CONSTANTS MASTER LIST

Constant Name	Value	Units	Description
k_LaneDistaneTolerance	5	cm	Acceptable tolerance when measuring distance between lanes
k_StopMin	10	cm	Minimum stopping distance
k_StopMax	20	cm	Maximum stopping distance when vehicle detects a need to stop
k_DecelerationMax	-0.02	m/s^2	Maximum rate of negative acceleration
k_DecelerationMin	0	m/s^2	Minimum rate of negative acceleration
k_AccelerationMax	10	m/s^2	Maximum rate of positive acceleration
k_ObsDetAcc	0.1	s	The accuracy needed to detect an object approaching the current lane.
k_RoadWidth	100	cm	The width of the road.
k_StopTolerance	5	cm	Acceptable tolerance when measuring stopping distance.
k_Stop	0	m/s	The stop state when the system is not in motion.
k_StopDistanceRatio	TBD	TBD	The stop distance determined by the current speed of the vehicle as soon as stop mechanism is activated.

k_ObsMaxDist	20	cm	The maximum distance where the system should detect an obstacle.
k_ObsMinDist	10	cm	The minimum distance where the system should detect an obstacle.
k_LapTimeMax	2	minute(s)	This is the max time for 1 lap of the track
k_LaneWidth	30	cm	The width of one lane.
k_ObsConfidence	2	s	Confidence in which the system can react in the allocated that an obstacle is present in the current lane
k_BatteryLife	1	hour	Minimum required battery life.
k_BatteryDrain	500	mAh	Rate at which battery loses charge