Vehicle Intersection Control

McMaster University

Verification and Validation

SE 4G06

Group 6

Alex Jackson	-	1302526
Jean Lucas Ferreira	-	1152120
Justin Kapinski	-	1305257
Mathew Hobers	-	1228607
Radhika Sharma	-	1150430
Zachary Bazen	-	1200979

Table of Contents

List of Tables

1 Revisions

Table 1: VIC Table of Revisions

Date	Revision Number	Authors	Comments
February 27, 2017	Revision 0	Alex Jackson Jean Lucas Ferreira Justin Kapinski Mathew Hobers Radhika Sharma Zachary Bazen	N/A

2 Purpose

The purpose of this document is to examine the previous project goals and requirements, and to see how the end system complies with these requirements. Through validation, it will determined if the project goals were met. Verification will allow for the detection of errors, and build a level of confidence in the system.

This document will include a traceability matrix to map the test cases to the functional requirements. Further more, the test cases will be presented along with a code walk-through, and static analysis.

The intended audience for this document consists of Dr. Alan Wassyng and the course's teaching assistants.

3 Validation

3.1 Project Goals and Functional Validation

The system consists of two main components: Vehicle Controller and Intersection Controller. Each component of the system has its own specific goals. By integrating these component-specific goals with our functional requirements, the entire project goals are realized. Therefore, if we can validate that our system components meet our functional requirements, we can assert that they fulfill our project goals.

Table 2: Vehicle Controller Component Goals

Component Name	**Goals**	**Functional Requirement**
Image Processing	- Detect lanes, obstacles, and the intersection	V2, V3, V5, V6
Vehicle Navigation	- Guide the vehicle movements on the track - Stop the vehicle when necessary	V2, V4, V5, V6
Communication	- Send request messages to the Intersection Controller - Receive response messages from the Intersection Controller	V1
Servo Motor	- Set the desired angle of the wheels	V2, V5, V6
Speed Controller	- Set the desired speed of the vehicle	V2, V4, V5, V6

Table 3: Intersection Controller Component Goals

Component Name	**Goals**	**Functional Requirement**
Vehicle Detection	- Detect location of cars and obstacles present at the intersection	IC1, IC3
Communication	- Receive request messages from the Vehicle Controller - Send response messages to the Vehicle Controller	IC5
Intersection Management	- Control the traffic flow of the intersection	IC4

4 Traceability Matrix

Identifier	Reqs Tested	V1	V2	V3	V4	V5	V6	V7	IC1	IC2	IC3	IC4	IC5
Test Cases	13	4	##	##	##	##	##	##	##	##	##	2	13
HC1.1	#												
HC1.2	#												
HC1.N	#												
HC2.N	#												
IC1.1	2	X											X
IC1.2	3	X										X	X
IC1.3	1												X
IC1.4	2	X											X
IC1.5	1	X											
IC2.1	1												X
IC2.2	2											X	X
IC2.3	1												X
IC2.4	1												X
IC2.5	1												X
IC3.1	1												X
IC3.2	1												X
IC3.3	1												X

Identifier	Reqs Tested	V1	V2	V3	V4	V5	V6	V7	IC1	IC2	IC3	IC4	IC5

5 Verification

5.1 Hardware Verification

5.1.1 Individual Vehicle Hardware Component Verification

4.1.1.1 Servo Verification

Test ID	Requirement ID	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
HC2.1	V2, V5, V6	To test the servo, commands telling the servo to go to a specified angle will be sent to the servo. The actual angle of the servo will be measured using a protractor and the actual angle needs to be within 2 degrees of the desired angle to be considered a pass.	Set servo to -45 degrees	Servo is between -47 and -43 degrees	N/A	N/A
HC2.2			Set servo to -30 degrees	Servo is between -32 and -28 degrees	N/A	N/A
HC2.3			Set servo to 0 degrees	Servo is between -2 and 2 degrees	N/A	N/A
HC2.4			Set servo to 30 degrees	Servo is between 28 and 32 degrees	N/A	N/A

4.1.1.2 Speed Controller Verification

Test ID	Requirement ID	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
HC2.1	V2, V4, V5, V6	The speed controller will be tested by having the car start at rest and then giving the speed controller a specified speed. The speed will be measured by timing how long it takes the car to drive 10 meters.	Set speed to 0.5 m/s	Travel time is 20 s	N/A	N/A
HC2.2			Set speed to 0.8 m/s	Travel time is 12.5 s	N/A	N/A
HC2.3			Set speed to 1 m/s	Travel time is 10 s	N/A	N/A
HC2.4			Set speed to 1.25 m/s	Travel time is 8 s	N/A	N/A

5.2 Software Verification

Some of the modules are not fully implemented, and thus the actual behaviour/output given from the module can not be determined as of yet. To symbolize this issue, any tests with a value of N/A in the *Expected Behaviour* and *Pass/Fail* columns represent a module that cannot be tested at the moment. Any necessary variables for describing the inputs/outputs will be defined prior to the respective verification test table.

5.2.1 Vehicle Software Verification

5.2.1.1 Vehicle Communication Verification

Note: This module is currently not complete.
Variables used:

- request_msg = '1_N_S_3000_1488233082083' (carId_comingFrom_goingTo_listeningPort_timestamp)

Test ID	Requirement ID	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
VSC1.1	V1	An intersection has been detected, and a request has **not** been sent to the Intersection Controller	request_msg	Entire message successfully delivered (all 28 bytes sent)	28 bytes delivered	Pass
VSC1.2	V1	An intersection has been detected, a request has already been sent to the Intersection Controller, and another car approaching the intersection	None	- Intersection Controller response message of 0 (zero) - Car stops at intersection	N/A	N/A
VSC1.3	V1	An intersection has been detected, a request has already been sent to Intersection Controller, and there is **no** other car approaching the intersection	None	- Intersection Controller response message of 1 (one) - Car proceeds through intersection without stopping	N/A	N/A

VSC1.4	V1	An emergency stop signal brodcasted from the Intersection Controller has been received	None	- Intersection Controller response message of 2 (two)	N/A	N/A

5.2.1.2 Vehicle Navigation

Note: This module is currently not complete.

Test ID	Requirement ID	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
VSC2.1	V2	A straight lane has been detected and the vehicle is travelling at a very low speed	- Straight track segment - Speed of 0.5 m/s	- Vehicle travels along middle of lane and stays within lane lines	N/A	N/A
VSC2.2	V2	A straight lane has been detected and the vehicle is travelling at a low speed	- Straight track segment - Speed of 0.8 m/s	- Vehicle travels along middle of lane and stays within lane lines	N/A	N/A
VSC2.3	V2	A straight lane has been detected and the vehicle is travelling at a moderate speed	- Straight track segment - Speed of 1 m/s	- Vehicle travels along middle of lane and stays within lane lines	N/A	N/A
VSC2.4	V2	A straight lane has been detected and the vehicle is travelling at a high speed	- Straight track segment - Speed of 1.25 m/s	- Vehicle travels along middle of lane and stays within lane lines	N/A	N/A
VSC2.5	V2	A curved lane has been detected and the vehicle is travelling at a very low speed	- Curved track segment - Speed of 0.5 m/s	- Vehicle follows curve of lane and stays within lane lines	N/A	N/A
VSC2.6	V2	A curved lane has been detected and the vehicle is travelling at a low speed	- Curved track segment - Speed of 0.8 m/s	- Vehicle follows curve of lane and stays within lane lines	N/A	N/A

VSC2.7	V2	A curved lane has been detected and the vehicle is travelling at a moderate speed	- Curved track segment - Speed of 1 m/s	- Vehicle follows curve of lane and stays within lane lines	N/A	N/A
VSC2.8	V2	A curved lane has been detected and the vehicle is travelling at a high speed	- Curved track segment - Speed of 1.25 m/s	- Vehicle follows curve of lane and stays within lane lines	N/A	N/A
VSC2.9	V4	An intersection has been detected and the vehicle is travelling at a very low speed	- Straight track segment with intersection - Speed of 0.5 m/s	- Vehicle slows down and stops at intersection line while remaining within lane lines	N/A	N/A
VSC2.10	V4	An intersection has been detected and the vehicle is travelling at a low speed	- Straight track segment with intersection - Speed of 0.8 m/s	- Vehicle slows down and stops at intersection line while remaining within lane lines	N/A	N/A
VSC2.11	V4	An intersection has been detected and the vehicle is travelling at a moderate speed	- Straight track segment with intersection - Speed of 1 m/s	- Vehicle slows down and stops at intersection line while remaining within lane lines	N/A	N/A
VSC2.12	V4	An intersection has been detected and the vehicle is travelling at a high speed	- Straight track segment with intersection - Speed of 1.25 m/s	- Vehicle slows down and stops at intersection line while remaining within lane lines	N/A	N/A
VSC2.13	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a very low speed	- Straight track segment with obstacle - Speed of 0.5 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.14	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a low speed	- Straight track segment with obstacle - Speed of 0.8 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A

VSC2.15	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a moderate speed	- Straight track segment with obstacle - Speed of 1 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.16	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a high speed	- Straight track segment with obstacle - Speed of 1.25 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.17	V6	An obstacle has been detected in a curved lane and the vehicle is travelling at a very low speed	- Curved track segment with obstacle - Speed of 0.5 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.18	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a low speed	- Curved track segment with obstacle - Speed of 0.8 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.19	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a moderate speed	- Curved track segment with obstacle - Speed of 1 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A
VSC2.20	V6	An obstacle has been detected in a straight lane and the vehicle is travelling at a high speed	- Curved track segment with obstacle - Speed of 1.25 m/s	- Vehicle stops before making contact with obstacle	N/A	N/A

5.2.1.3 Image Processing Verification

Note: This module is currently not complete.
The following table are verifications tests for the lane detection and lane extraction from a real-world image scenario (VC3.1 to VC3.9). As well as the verification of the image processing logic and identification (VC3.10 to VC3.XXX).
Variable Definitions:

- imgData :
  float leftAngle, rightAngle, leftLength, rightLength
  boolean intersectionDetect, obstacleDetect

imgData Reference - FIGURE XXX

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
VC3.1	V2	At any point of the track, the lanes must be detected and extracted from the image.	Car on straight track segment	A straight line detected on each side of the car	Figure XXX	Pass
VC3.2	V2	‘’	Car on left turn segment	A small left turning curve on the left side of the screen. A large left turning curve on the right of the screen	Figure XXX	Pass
VC3.3	V2	‘’	Car on right turn segment	A small right turning curve on the right side of the screen. A large right turning curve on the left of the screen	Figure XXX	Pass
VC3.4	V2, V3	‘’	Car approaching intersection	Two vertical lines, one on each side of the car, terminating at a horizontal line	Figure XXX	Pass
VC3.5	V2, V5	‘’	Car navigating through intersection	???	Figure XXX	N/A
VC3.6	V6	Any obstacles in the path of the vehicle must be detected	Obstacle ahead of car on a straight segment	Contours of obstacle detected	N/A	N/A
VC3.7	V6	‘’	Obstacle ahead of car on a turning segment	Contours of obstacle detected	N/A	N/A
VC3.8	V5, V6	‘’	Obstacle ahead of car at the intersection	Contours of obstacle detected	N/A	N/A
VC3.9	V5, V6	‘’	Obstacle ahead of car at the intersection	Contours of obstacle detected	N/A	N/A

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
VC3.10	V2	The geometry of the captured image must be valid in order to correctly navigate the vehicle	Car on straight track segment and centered on its lane	leftAngle and rightAngle nearly identical, leftLength and rightLength nearly identical	leftAngle = XXX rightAngle = XXX leftLength = XXX rightLength = XXX intersectionDetect = 0 obstacleDetect = 0	Pass

5.2.2 Intersection Controller Software Verification

5.2.2.1 Communication - Receive

Car:

- Abstract data type that contains all pertinent car request information
- This object is created for each new vehicle request
- Fields: car_ID, destination_Port, destination_bluetooth_address, direction_from, direction_to, proceed_status and proceed_message and time_stamp

Arrival Queue:

- Queue that preserves the order of the intersection requests in the form of Car objects

Note: This module is currently not complete.

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
IC1.1	IC5	Intersection request has been sent to the intersection controller from a single vehicle	Single vehicle intersection request	Car object containing the request information pushed into the arrival queue	N/A	N/A
IC1.2	IC5	Two vehicles arrive at the intersection at the same time and request to proceed through the intersection.	More than one vehicle intersection request	Car objects containing the request information pushed to the arrival queue in the order that they were received	N/A	N/A
IC1.3	IC5	Vehicle intersection requests that are transmitted incompletely should be dropped by it intersection controller	Vehicle intersection request that is terminated prior to receive completion	Timeout/ disconnected receive error is caught and system becomes available for subsequent requests	N/A	N/A

IC1.4	IC5	The system should be able to handle large request volumes without losing requests.	Many vehicle requests	Car objects containing the request information pushed to the arrival queue in the order that they were received	N/A	N/A
IC1.5	IC5	Messages that have invalid or corrupt message contents should be dropped	Invalid message request	Invalid/corrupt message detected and dropped	N/A	N/A

5.2.2.2 Communication - Send

Proceed Queue:

- Queue of car objects that preserves the order determined by the intersection controller that vehicles should proceed through the intersection.
- Proceed commands are sent to the vehicles based on the FIFO sequence of the proceed queue

Note: This module is currently not complete.

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
IC2.1	IC5	Vehicle proceed request has been determined safe and must be communicated to the vehicle	Car object in the proceed queue	Remove vehicle from proceed queue and send proceed message to vehicle	N/A	N/A
IC2.2	IC5	Multiple vehicle proceed requests have been determined safe and must be communicated to the vehicle	More than one car object in the proceed queue	Remove vehicles from departure queue and send proceed message to vehicles in FIFO order.	N/A	N/A
IC2.3	IC5	The system should be able to handle large send volumes without dropping proceed commands	Many vehiles in the proceed queue	“”	N/A	N/A

IC2.4	IC5	System should make further attempts to transmit messages to an unresponsive connection up to a max limit	Car object in the proceed queue	Inactive connection error should be caught. The system should then attempt to send the message again (up to the maximum attempt limit)	N/A	N/A
IC2.5	IC5	“”	“”	Timeout/ disconnected send error should be caught. The system should then attempt to send the message again (up to the maximum attempt limit)	N/A	N/A

5.2.2.3 Communication - Message Extraction

Test ID	Requirement	Description	Input	Expected Values	Actual Values	Pass/Fail
IC3.1			2, ’Red’, ’Blue’	Car(bluetooth Address, 1, ’Red’, ’Blue’)		-
IC3.2			2, ’Red’, ’Red’	Incorrect Message contents		-
IC3.3			-, ’Yellow’, ’Green’	Incorrect Message contents		-

5.2.2.4 ImageProcessing

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
IC4.1			-	-	-	-
IC4.2			<Text Here>	<Text Here>	<Text Here>	-
IC4.3						-
IC4.4						-

5.2.3 Integrated Vehicle Intersection Software Verification

5.2.3.1

Test ID	Requirement	Description	Input	Expected Behaviour	Actual Behaviour	Pass/Fail
VIC.1			- Single vehicle, clear intersection	- Vehicle proceeds directly through the intersection	-	

VIC.5			- Multiple vehicles, parallel directions, clear intersection	- Vehicles proceed directly through the intersection		-
VIC.6			- Vehicle A and Vehicle B, crossing directions, clear intersection, Vehicle A is first	- Vehicles A proceeds directly through the intersection, Vehicle B stops at the intersection		-
VIC.7			- Multiple vehicles, obstacle in intersection	- Vehicles should stop at the intersection		-
VIC.8			- Multiple vehicles, intersection controller not working	- Vehicles should stop at the intersection and wait		
VIC.9			-	-		-
VIC.10			-	-		