Simon Fraser University
School of Engineering Science | Burnaby, BC | V5A 1S6

February 16, 2009

Mr. Steve Whitmore
School of Engineering Science - Simon Fraser University
Burnaby, British Columbia. V5A 1S6

Re: ENSC 305/440 Functional Specification for the Motion Sensing Remote-Controlled Vehicle

Dear Mr. Whitmore,

Attached is a document describing the functional specification for the Motion Sensing Remote-Controlled Vehicle from Ron KittenBruan Technologies Ltd. We are designing and implementing a remote controlled vehicle using natural mappings motion-sensing. This innovating way of controlling the remote car is a revolutionary idea that brings a traditional toy into a new era with the up-surging popularity of motion sensing. This project is not only a development of an ordinary toy, but one that has numerous functions attached.

Our functional specification provides a set of high-level requirements for the system's functionality for both the prototyping and production phases of the development. This document will serve as a guide for our team members to follow during development.

Ron KittenBruan Technologies Ltd. consists of five engineering students from different concentrations: Rongen Cheng, Wing Kit Lee, Austen Chan, Bruce Wong, and Brian Cheung. If you have any comments or enquiries, please feel free to contact us by email at ensc440-rkb@sfu.ca or by phone at (778)-862-0982.

Best Regards,

Rongen Cheng,
CEO
Ron KittenBruan Technologies Ltd.

Enclosure: Functional Specification for the Motion Sensing Remote-Controlled Vehicle

Functional Specification for CarSim (Motion Sensing Remote Vehicle)

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Executive Summary

Motion sensing has penetrated many market segments in the last few years. A great example is the Nintendo® Wii®, where people of all ages and all backgrounds can come together and enjoy a video gaming experience. This form of entertainment is very similar to what remote control cars once was like; Various age groups were attracted to the racing excitement of remote controlled vehicles. Currently, all the remote cars in the market use traditional controllers that provide indirect mappings and ordinary controls. The Motion Sensing Remote Controlled Vehicle combines the popular technology of motion sensing with the once widely popular remote controlled vehicles. This project will not only bring a revolution to remote control cars, but also add many fascinating functions that will enhance the usefulness to the toy.

Development of the Motion Sensing Remote Controlled Vehicle will occur mainly in two phases. The first phase includes the design and implementation of the basic functions of a remote controlled vehicle. Upon the completion of phase one, a six-axis remote controller that will follow the natural mappings of real driving will control the remote car. The remote controlled vehicle will be able to move forward, backward, turn right, and turn left at various speeds.

For the second phase of development, various functions such as collision detection, collision prevention, real time video streaming, and possibly auto-piloting through obstacles will be implemented and tested. There will be two modes of collision status, one will prevent the vehicle from colliding with objects detected at various angles and the other will immobilize the vehicle for a period of time after a collision occurs. The real time video streaming function allows the user to monitor and control the vehicle in environments where visual information is minimal, and to search harsh or unreachable areas. Lastly, an auto-piloting function, which will navigate to the desired location no matter what obstacles are in between, will be added onto the motion sensing remote controlled vehicle if time allows. This project are not abided by any professional standards or guidelines, but will be designed to be as safe and intelligent as possible.

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Glossary

ESD Electrostatic Discharge

ISO International Organization for Standardization

RC Remote Controlled

LED Light-Emitting-Diode

LCD Liquid Crystal Display

1 Introduction

CarSim, a motion sensing remote controlled vehicle, is an electrically powered vehicle which adapts a natural mapping control to enhance user usability. This vehicle provides two different operation modes, one is user controlled mode and the other is automated mode. In the user controlled mode, user can control the car in traditional steering motion from our six-axis motion sensing control. In automated mode, the vehicle will move forward and steer itself with the help of onboard sensor and processor. Accompanied with vehicle control, a video streaming camera and display will be implemented on the vehicle and user's remote control respectively. This allows user to understand and visualize the surroundings of the vehicle, hence, provide discovery functionality.

1.1 Scope

This functional specification describes the functional requirements for a properly functioned CarSim. These requirements apply to the proof-of-concept vehicle and production vehicle. Providing a traceable documentation, these requirements will serving as a backbone for our vehicle design.

1.2 Intended Audience

The functional specification is intended for use by development team of Ron KittenBruan Technologies Ltd., executive officers of ENSC 440. During the development cycles, design engineers shall refer to the listed requirements as primary design goal. Improving product performance, design enhancements will be proper documented and discussed within the development team. When development cycles are over, test engineers are suggested to use this document as a reference for setting up testing procedures.

1.3 Classification

Throughout this document, the following convention shall be used to denote functional requirements:

[Rn-p] A functional requirement.

where **n** is the functional requirement number, and **p** is the priority of the functional requirement as denoted by one of three values:

I - The requirement applies to the proof-of-concept system only.
II - The requirement applies to both the proof-of-concept system and the final production system.
III - The requirement applies to the final production system only.

2 System Requirements

The general requirements of CarSim are presented in the following subsections.

2.1 System Overview

The high-level systematic behaviours and functionalities of CarSim can be portrayed using the following block diagram (Figure 1).

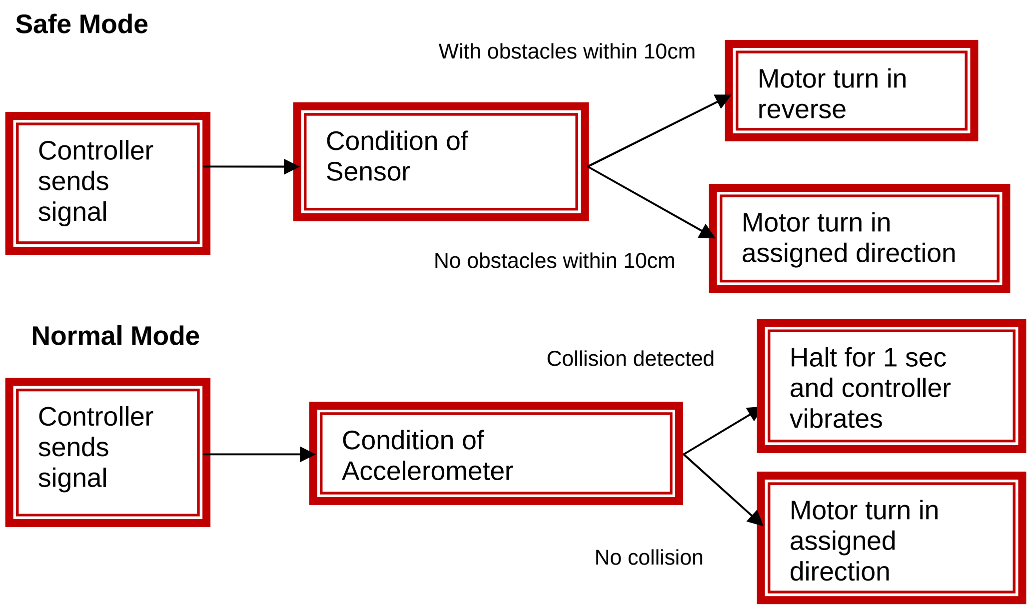

Figure 1 - High-Level Functional Block Diagram

The steering of the car should be done with the 6-axis controller using the normal steering motion of controlling a real automobile, as this is the intended purpose of choosing the 6-axis controller. This can be depicted in Figure 2.

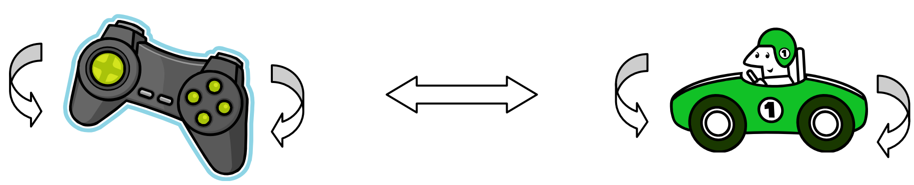

Figure 2 - Controller Behavior

To further the exploration aspects of CarSim, a LCD is connected to the 6-axis controller. This LCD or its related component must be able to stream the video image capture by the web camera located on CarSim. The wireless communication between the LCD receiver and the webcam transmitter must not perturb the Bluetooth communication between the controller and CarSim. The power requirements of the LCD components must be manageable and reasonable such that the incorporation of the LCD onto the controller can be achieved without hassle.

2.2 General Requirements

[R1-II] The enclosure of the electrical components should be non-conductive.

[R2-I] The cost of the prototype shall be under CDN$1000.

[R3-III] Infrared sensors shall be minimally intrusive to the environment and the user.

2.3 Physical Requirements

[R4-II] The height of the car shall be no smaller than the sum of the heights of the battery pack, the thickness of the enclosure, and the thickness of the circuitries.

[R5-II] The width of the car shall be no smaller than the width of the circuitries.

[R6-II] The base of the car should be strong enough to carry all the internal components without collapsing.

[R7-III] The car shall look appealing to all age groups.

[R8-II] The overall mass of the car should be small compare to the motor power provided.

2.4 Electrical Requirements

[R9-II] The power supply shall be sufficient to support all circuitries included.

[R10-II] The battery pack should be rechargeable.

[R11-II] The power adapter for the rechargeable battery pack shall be usable with a wall supply of 110V/120V at 60 Hz AC, which is typical of North American wall outlets.

[R12-II] The car should have a central power on/off control.

[R13-II] All electrical components should be screwed tightly on to the enclosure.

[R14-II] Key voltage nodes shall be easily accessible for measurement, troubleshooting, and debugging.

[R15-II] The battery pack shall be able to resist the thermal dissipation of the electrical component.

[R16-II] The battery pack shall be secured to the enclosure while being easily accessible for replacement.

[R17-II] The battery pack shall have enough power to operate the car for at least 15 minutes.

2.5 Mechanical Requirements

[R18-II] All four wheels should be fixed at the four corners of the enclosure.

[R19-II] The motor shall have enough power to move the car with a speed faster than a normal human's walking pace.

[R20-III] The wheels should be able to turn more than 45 degrees angle.

[R21-III] The motor shall be inside the enclosure.

2.6 Environmental Requirements

[R22-II] The car shall operate normally on normal road conditions.

[R23-II] The car shall operate normally under typical office temperatures (15 – 30°C).

[R24-II] The car shall operate normally under typical office humidity conditions (50%).
[R25-II] The car shall be to operate within the range of 100 meters.
[R26-II] The car shall be silent when it is inactive.
[R27-II] Noise generated during periods of activity shall be minimized.
[R28-II] No chemical pollutant shall be generated during periods of activity.

2.7 Standards

[R29-II] Bluetooth communication device meets the standard of Bluetooth SIG
[R30-II] The car shall conform to ANSI standards.
[R31-II] The car shall conform to ISO 9002 standards.
[R32-III] The car shall pass CSA standards.
[R33-III] The car shall pass UL testing.
[R34-III] The car shall pass FCC standards.

2.8 Reliability and Durability

[R35-II] The car shall withstand collisions under normal operating conditions.
[R36-II] The battery shall last for at least 1 hour of continuous operation.
[R37-II] The car must be able to operate with no noticeable delay.

2.9 Operating Range

[R38-II] The car must be able to detect obstacles under any external environment.

2.10 Safety Requirements

[R39-II] Vibration of controller shall not cause any harm to user.
[R40-II] All units shall be kept away from children under 5 years of age.
[R41-II] The electrical and mechanical components along with power connections shall be enclosed.
[R42-II] The electronic components of the device shall cause minimal interference with other devices.

2.11 Performance Requirements

[R43-II] The response time of the vehicle shall be less than 500ms.
[R44-II] The lifetime of the car battery shall last for at least 200 hours.
[R45-II] The car shall respond to mode changes within 1s.
[R46-II] The controller shall have vibration period according to the strength of collision.

2.12 Usability Requirements

[R47-II] The car shall operate under natural mapping for driving a vehicle.
[R48-II] The car shall be able to operate with either one or both hands.
[R49-II] The display on LCD screen should be readable.
[R50-II] The vehicle shall be powered up by only 2 buttons: car and controller.

2.13 Luxury Functions

[R51-II] Camera shall be able to rotate up to 45 degrees in both directions to capture wider views.

[R52-II] The LCD screen shall be able to display interesting information regarding speed and acceleration.

[R53-II] A mapping of route travelled shall be stored in chip and can be retrieved by USB device.

[R54-II] The vehicle shall be able to travel a certain distance and avoid obstacles automatically.

[R55-II] The vehicle shall be able to detect cliffs ahead.

3 Remote Controlled Car

The cover of the car has the following functions:

- to attract children's interest
- to isolate electric and mechanic components with users, and
- to reduce air friction when accelerating

The base of the car has some important functions, including the following:

- to provide support to the onboard electronics and top cover
- to link the wheels and motors to the car body, and
- to reduce damage to the other parts of the car in collision

Two motors are needed for the RC car: one for turning, one for accelerating. The turning motor is attached to the front wheels while the accelerating motor is connected with the rear wheels. To prevent direct damage to the front wheel and turning motor, the front bumper is designed to have additional length and width to the base. The length and width are defined as below.

Front Bumper length measurement is from the front of the car to the surface of tire.
Front Bumper width measurement is from side to side in top view.

The additional dimension can also reduce the damage to the front wheel and turning motor during an accident because the front bumper absorbs most of the force. To maximize the force absorption, the shape of front bumper is in half eclipse shape.

Rear bumper is also needed to prevent direct damage to the accelerating motor and rear wheels. However, its shape and dimensions will be different with the front because the chance of going backward and crashing is not as high as going forward. The dimension parameters are defined as below.

Rear bumper width is the shorter dimension in the top view and measured from the accelerating motor.
Rear bumper length is the longer dimension in the top view and measured from side to side with the centre matching the car's centre line.

The overall dimensions of car are defined as following.

Car height measurement is from the ground to the maximum point of the car.
Car width measurement is from side to side in top view.
Car length measurement is from the front bumper to the rear bumper.

The junctions between parts use the screws which follow the ISO screw thread standard (1).

3.1 General Requirements

[R56-II] The base of car shall support at least 3 times its weight.

[R57-II] The linkage between body and other parts shall handle 25 times the car's weight.

[R58-II] The cover shall isolate electronics with users who may get electric shock. It shall also prevent ESD from the users and damage the electronics.

[R59-II] The turning motor shall be able to turn at least 30 degree each side with respect to the centre.

[R60-II] The accelerating motor shall be able to go either direction with the same speed. This motor shall be able to stop the car by applying reverse gear.

3.2 Physical Requirements

[R61-II] Front bumper dimension shall be 43% length by 19% width of the length of the car.

[R62-II] Rear bumper dimension shall be 25% length by 10% width of the length of the car.

[R63-II] The gap between tires and bumper shall be at least 15mm.

[R64-II] The gap between the bumpers and the surface of tires shall be 6% of the length of the car.

[R65-II] The diameter of all wheels shall be 20% of the length of the car.

4 Remote controller and microprocessor module

Remote controller is a user interface device, so it is a user-centered design and has the following important functions:

- to use a natural mapping control interface
- to minimize space occupation and weight, and
- to have a comfortable holding shape

The controller is communicating with the RC car through Bluetooth technology, and the control signal is processed with the microprocessor. The microprocessor module has some constraints and features, including the following:

- to support Bluetooth communication
- to operate in long range, and
- to minimize space occupation and weight

The dimension of controller and microprocessor are defined as below.

Length is the longer dimension in the top view.
Width is the shorter dimension in the top view.
Height is the dimension from the button to the highest point of the module in the side view.

The selected electronic components should follow RoHS. (2)

4.1 General Requirements

[R66-II] The weight of microprocessor shall be no more than 0.5 lbs.

[R67-II] The controller shall use natural mapping, i.e. the car turns when user turns the controller and accelerates when user press the controller forward.

[R68-II] The controller shall be powered by battery.

[R69-III] The microprocessor module shall be power by the car battery.

[R70-III] The weight of controller shall be no more than 2 lbs.

[R71-III] The shape of controller shall be comfortable to users.

[R72-III] The microprocessor module shall receive signal from the paired controller to avoid signal jamming with other Bluetooth device.

4.2 Physical Requirements

[R73-II] The dimension of controller shall be no more than 160 mm length by 90 mm width by 55 mm height.

[R74-II] The dimension of microprocessor shall be no more than 80 mm length by 20 mm width by 20 mm height.

5 Collision Prevention and Auto Pilot Functions

To prevent damage to the RC car, the collision prevention function is introduced and has the following features:

- to detect any obstacle on the driving path
- to stop the car automatically when an obstacle is on the driving path, and
- to notify user that an obstacle is ahead

An auto pilot function is also added to this project and operates as following:

1. User sets distance the car should travel, one way only.
2. RC car will travel the set distance automatically.
3. It will look for alternative route by reversing and turning to avoid the obstacles.
4. Finally, it stops after travelling the set distance.

The selected electronic components should follow RoHS. (2)

5.1 General Requirements

[R75-II] The sensors for obstacle detection shall work with any shape and color obstacle.

[R76-III] The sensors shall be powered by the battery of the car.

[R77-II] The RC car shall stop when any obstacle is ahead and ignore any accelerating instruction from the user.

[R78-III] The upcoming obstacle notification to user shall be clear to observe and/or sense.

5.2 Physical Requirements

[R79-II] The sensors for obstacle detection shall be placed around the RC car.

6 Collision Detection Function

As an educational RC car, the simulated collision function is presented as following:

1. The RC car runs into an obstacle.
2. It becomes immobile for a period on time.
3. A collision signal is sent to the controller which will vibrate and notify the user that he/she has run into an accident.

The immobile feature is to prevent further damage to the RC car after the first collision because children are usually not aware of light vibration. The vibration of the controller is to simulate the actual collision of the physical car. If the vibration level is too high, the children will become scared and will not run into an object purposely in the future. The selected electronic components follow RoHS. (2)

6.1 General Requirements

[R80-III] The immobile period shall depend on the collision level.
[R81-III] The vibration level and time shall depend on the collision level.
[R82-III] The accelerometer for collision detection shall be powered by the battery of the car.

6.2 Physical Requirements

[R83-II] The accelerometer for collision detection shall be placed (place) in the middle of the car base so that it shall be able to collect collision from different directions.

7 Real-time Video Streaming Function

A real-time video streaming function helps user to understand the environment around the RC car in a place with minimal vision with the help of LED. To simulate the reality of driving, a video camera is placed to face the front and the user can view the streaming video from the LCD. Due to the limited size of car and power source, the components for real-time video streaming function have some constraints, including the following:

- Minimal size and weight of video camera
- Minimal power consumption of video camera
- Wireless video streaming, and
- Minimal size and weight of wireless receiver and LCD

The dimension of video camera, wireless receiver and LCD are defined as below.

Size of video camera is measured from edge to edge.
Screen size of LCD is measured diagonally.
Length of receiver is the longer dimension in the top view.
Width of receiver is the shorter dimension in the top view.
Height of receiver is dimension in the side view.

The selected electronic components follow RoHS. (2)

7.1 General Requirements

[R84-III] The video camera shall be no more than 1 lb.
[R85-III] The wireless receiver and LCD shall be no more than 2 lbs in total.
[R86-III] The video camera shall be powered by the car battery.
[R87-III] The wireless receiver and LCD shall be powered with portable power source.

7.2 Physical Requirements

[R88-III] The video camera shall be hidden inside the cover of the car.
[R89-III] The size of video camera shall be no more than 40 mm by 40 mm by 40 mm.

[R90-III] The screen size of LCD shall be no more than 2.4 inch.

[R91-III] The size of wireless receiver shall be no more than 70 mm length by 50 mm width by 20 mm height.

8 System Test Plan

Designed as an integrated system, our remote controlled vehicle contains a number of subsystems. During our development cycles, each of the subsystems will be tested with control inputs. Results from these tests will compare with our desired results. When a subsystem passes the test, it will be attached with a different subsystem to form another stage of system. A series of test will also be performed to ensure the overall performance is achieved with control inputs. Each system testing requirements will be based on design specification and functional requirements, which are subject to modify during the entire development cycle.

Since a large portion of our system is located on the vehicle, physical requirements of the vehicle will be listed and tested. For example, the maximum load of the vehicle, the maximum head-on and sideway impact forces, the stopping distance, the maximum speed, and etc. Once the overall system is ready to be mounted on the vehicle, the overall weight of the system will be verified to avoid extreme load to the vehicle. The impact on the original performance of the vehicle will also be determined.

Asides from physical performances of the vehicle, functionality of the electronic components will also be closely monitored during the development cycles to make certain that they function as desired. Because the electronic systems consist of a series of signal processing, computing algorithms, and micro controlled input and output, system stability should be supine to noise and physically interruption, such as vibration, and temperature. Furthermore, from our experiences, a multistage electronic circuit requires debugging as unintended signal interference may be introduced during the development stage. These debugging procedures will be documented as to avoid similar problems from occurring in the rest of the system.

As an electric powered vehicle, a sufficient power supply is necessary for proper vehicle functionality. To estimate the operating period of the vehicle, we measure the power consumption of each subsystem and determine what the power dispersion rate of the overall vehicle is. After calculating the power consumption, we will perform another test by activating all of the onboard components to measure the maximum power usage, for example, turning all the sensors, signaling the microprocessor via BlueTooth, activating both steering and moving motors, and video streaming functionality. When all components are operating, we will be able to measure the heat dissipation of the vehicle. If the temperature reaches to threshold limit of the electronic components, heat sink will be added on different part of the system to avoid thermal meltdown of the system.

8.1 Normal Operation Scenario

To simulate a normal usage of the vehicle, a scenario describes the steps a user would go through to use all the functionalities of the remote controlled vehicle.

1. User turns on the vehicle and the remote control.
2. An LED on the vehicle switches on to notify user that the vehicle is ready to receive a command.
3. User selects the operating mode of the vehicle, e.g. automated control or manually control. If the user chooses automated control, proceed to step 4, and if the user chooses manually control, proceed to step 5.
4. User chooses automated control:
   i. A LED light switches on to notify the user that the vehicle is in automated mode.
   ii. Vehicle moves forward and turns left or right based on the sensor's information.
   iii. Video streaming from onboard camera to the user's remote control.
   iv. The user presses the stop button on the controller to stop the vehicle.
   v. Vehicle stops and signifies the user by a LED light.
5. User chooses manual control:
   i. A LED light switches on to notify the user that the vehicle is in manual control mode.
   ii. The user pivots the control forward to move the vehicle forward or pivots the control backward to move the vehicle backward.
   iii. The user rotates the control left or right to steer the vehicle left or right.
   iv. If onboard sensors sense collision, the vehicle stops and sends a vibration signal to the user via a built-in vibrator in the remote control.
   v. Video streaming from onboard camera to user's remote control.
   vi. The user presses the stop button on the controller to stop the vehicle.
   vii. The vehicle stops and signifies the user by a LED light.

To test the vehicle's performance and stability, the user will need to setup a series of testing similar to the above scenario. After debugging the system, the finalized system will be tested by a volunteer who is not in the development team. This allows a true representation of a typical user's usage. If the volunteer satisfies the performance of the vehicle, a sign-off would be released to confirm the completion of the development cycle, and any new modification will be considered as enhancements. If the volunteer is not satisfied with the performance, he will provide a list of amendments to the development team for modification.

To prevent unnoticed operational and system errors, a simulated error condition will be served as the system input and the corresponding response will be studied. According to functional requirements, when an error input is received, the vehicle should either be immobilized or the error input will be ignored. To avoid system damage during error testing, all error inputs are inserted one at a time. If the vehicle behaves in dangerous motion as a result of certain error input, the situation will be documented and a system modification will proceed to prevent similar results from occurring in the future.

9 Conclusion

This functional specification document unambiguously defined the qualifications and requirements of the Motion Sensing Remote Controlled Vehicle. The development of the entire project will run in two phases, the basic remote control features, and the add-on functions phase. The components have all been received; testing and designing are underway. We are confident that all the functional requirements outlined above will be completed by the middle of April.

10 References

1. ISO 68-2:1998 - ISO general-purpose screw threads -- Basic profile -- Part 2: Inch screw threads:. *International Organization for Standardization.* [Online] [Cited: February 19, 2009.] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=27137.

2. *RoHS - Home:*. [Online] [Cited: February 19, 2009.] http://www.rohs.gov.uk/.