**System Design Document for Roadie**

Sponsor

**Electrical, Computer, Software & Systems Engineering at Embry-Riddle Aeronautical University**

Released 04 December 2014

**Are We There Yet?**

# **Revision History**

|  |  |  |
| --- | --- | --- |
| Date | Reason for Change | Version |
| 27 Nov 2014 | Initial Draft | 0.1.0 |

Table of Contents

[**Revision History** ii](#_Toc404705744)

[**1.** **Introduction** 1](#_Toc404705745)

[**1.1** **Purpose** 1](#_Toc404705746)

[**1.2** **Problem Statement** 1](#_Toc404705747)

[**1.3** **Scope** 1](#_Toc404705748)

[**1.4** **Team Information** 1](#_Toc404705749)

[**1.5** **Overview** 1](#_Toc404705750)

[**2.** **System State Definitions** 3](#_Toc404705751)

[**2.1** **System State Diagram** 4](#_Toc404705752)

[**3.** **Functional Decomposition of System** 5](#_Toc404705753)

[**3.1** **High-Level Architecture of System** 6](#_Toc404705754)

[**4.** **Decomposition of Coordination System** 6](#_Toc404705755)

[**4.1** **Subsystem Architecture** 7](#_Toc404705756)

[**4.1.1** **Assumptions** 7](#_Toc404705757)

[**4.1.2** **Dependencies** 8](#_Toc404705758)

[**4.1.3** **Constraints** 8](#_Toc404705759)

[**4.2** **Requirements** 8](#_Toc404705760)

[**4.2.1** **Navigation** 8](#_Toc404705761)

[**4.2.2** **Challenge Identification** 8](#_Toc404705762)

[**4.2.3** **Hardware** 9](#_Toc404705763)

[**4.3** **Use Cases** 10](#_Toc404705764)

[**4.3.1** **Use Case 1: Line Following** 10](#_Toc404705765)

[**4.3.2** **Use Case 2: Arrival at Challenge Zone** 12](#_Toc404705766)

[**4.4** **Sequence Diagrams** 14](#_Toc404705767)

[**4.4.1** **Use Case 1: Line Following** 14](#_Toc404705768)

[**4.4.2** **Use Case 2: Arrival at Challenge Zone** 15](#_Toc404705769)

[**4.5** **Traceability Matrix** 16](#_Toc404705770)

[**5.** **Decomposition of Challenge System** 19](#_Toc404705771)

[**5.1** **Subsystem Architecture** 19](#_Toc404705772)

[**5.1.1** **Assumptions** 19](#_Toc404705773)

[**5.1.2** **Dependencies** 20](#_Toc404705774)

[**5.1.3** **Constraints** 20](#_Toc404705775)

[**5.2** **Requirements** 20](#_Toc404705776)

[**5.2.1** **Simon Interactor** 20](#_Toc404705777)

[**5.2.2** **Rubik’s Interactor** 20](#_Toc404705778)

[**5.2.3** **Etch-A-Sketch and Card Interactor** 21](#_Toc404705779)

[**5.3** **Use Cases** 22](#_Toc404705780)

[**5.3.1** **Use Case 1: Simon Carabiner Challenge** 22](#_Toc404705781)

[**5.3.2** **Use Case 2: Pocket Etch-A-Sketch Challenge** 24](#_Toc404705782)

[**5.3.3** **Use Case 3: Rubik’s Cube Challenge** 26](#_Toc404705783)

[**5.3.4** **Use Case 4: Playing Card Challenge** 28](#_Toc404705784)

[**5.4** **Sequence Diagrams** 30](#_Toc404705785)

[**5.4.1** **Use Case 1: Simon Carabiner Challenge** 30](#_Toc404705786)

[**5.4.2** **Use Case 2: Pocket Etch-A-Sketch Challenge** 31](#_Toc404705787)

[**5.4.3** **Use Case 3: Rubik’s Cube Challenge** 32](#_Toc404705788)

[**5.4.4** **Use Case 4: Playing Card Challenge** 33](#_Toc404705789)

[**5.5** **Traceability Matrix** 34](#_Toc404705790)

[**6.** **Decomposition of Movement System** 37](#_Toc404705791)

[**6.1** **Subsystem Architecture** 37](#_Toc404705792)

[**6.1.1** **Assumptions** 37](#_Toc404705793)

[**6.1.2** **Dependencies** 37](#_Toc404705794)

[**6.1.3** **Constraints** 38](#_Toc404705795)

[**6.2** **Requirements** 38](#_Toc404705796)

[**6.2.1** **Chassis Requirements** 38](#_Toc404705797)

[**6.2.2** **Movement Requirements** 38](#_Toc404705798)

[**6.3** **Use Cases** 39](#_Toc404705799)

[**6.3.1** **Use Case 1: Dynamic Line Following** 39](#_Toc404705800)

[**6.3.2** **Use Case 2: Right Turn** 41](#_Toc404705801)

[**6.3.3** **Use Case 3: Left Turn** 43](#_Toc404705802)

[**6.3.4** **Use Case 4: Intersection** 45](#_Toc404705803)

[**6.4** **Sequence Diagrams** 47](#_Toc404705804)

[**6.4.1** **Use Case 1: Dynamic Line Following** 47](#_Toc404705805)

[**6.4.2** **Use Case 2: Right Turn Sequence** 48](#_Toc404705806)

[**6.4.3** **Use Case 3: Left Turn Sequence** 49](#_Toc404705807)

[**6.4.4** **Use Case 4: Intersection Sequence Diagram** 50](#_Toc404705808)

[**6.5** **Traceability Matrix** 51](#_Toc404705809)

[**7.** **Glossary** 53](#_Toc404705810)

[**8.** **Appendix A** 55](#_Toc404705811)

[**9.** **Appendix B** 59](#_Toc404705812)

[**9.1** **Competition Course** 59](#_Toc404705813)

[**9.2** **Simon Carabiner** 60](#_Toc404705814)

[**9.3** **Rubik’s Cube** 61](#_Toc404705815)

[**9.4** **Pocket Etch-A-Sketch** 62](#_Toc404705816)

[**9.5** **Playing Cards** 63](#_Toc404705817)

[**9.6** **Scotch Blue Painter’s Tape** 64](#_Toc404705818)

[**10.** **References** 65](#_Toc404705819)

Table of Figures

[**Fig. 1**: State diagram for the Coordination System 4](#_Toc404283020)

[**Fig. 2**: Division of Roadie into three subsystems. 5](#_Toc404283021)

[**Fig. 3**: High level description of the systems in Roadie. 6](#_Toc404283022)

[**Fig. 4**: Decomposition of coordination system for Roadie. 7](#_Toc404283023)

[**Fig. 5**: Decomposition of Challenge System for Roadie. 19](#_Toc404283024)

[**Fig. 6**: Decomposition of Movement System Roadie. 37](#_Toc404283025)

[**Fig. 7** Competition course for SoutheastCon[1]. 59](#_Toc404283026)

[**Fig. 8:** The exact Simon Carabiner to be used during competition [5]. 60](#_Toc404283027)

[**Fig. 9:** The exact Rubik's Cube to be used during competition [6]. 61](#_Toc404283028)

[**Fig. 10:** The exact pocket Etch-A-Sketch to be used during competition [7]. 62](#_Toc404283029)

[**Fig. 11:** The exact playing cards to be used during competition [9]. 63](#_Toc404283030)

[**Fig. 12:** The exact painter’s tape to be used on the course [8]. 64](#_Toc404283031)

# **Introduction**

## **Purpose**

## **Problem Statement**

To create an autonomous robot to compete in the 2015 IEEE SoutheastCon student hardware competition.

## **Scope**

Roadie is intended to compete in the 2015 IEEE Southeast Con student hardware competition. The system is envisioned to complete four unique challenges:

* Correctly play Simon for 15 seconds
* Draw “IEEE” on an Etch-A-Sketch
* Twist one row of a Rubik’s cube 180 degrees
* Pick up and carry one playing card across the finish line

Roadie system is intended to successfully complete the challenges outlined above within a time limit of five minutes.

Roadie is not intended to serve any other functions or fulfill any other purposes other than competing in the 2015 IEEE SoutheastCon competition.

## **Team Information**

|  |  |
| --- | --- |
| Name | Role |
| Brian Powell | Team Leader |
| Michael Philotoff | Software Manager |
| Alex Senopoulos | Developer |
| Brian Sterling | Hardware Manager |

## **Overview**

# **System State Definitions**

In order to better define transitions and states that the system will occupy, **Table 1** has been constructed, providing both the state name, and the description of the associated state.

|  |  |
| --- | --- |
| State Name | State Description |
| Approach | The state in which the system will be once it has entered a challenge area. The approach stage will consist of the system placing itself 4.2 cm ± 0.1 cm from the challenge. |
| Challenge Abortion | The state in which the system will enter upon incorrectly interacting with a challenge. When the system enters this state, it will immediately halt execution of the current challenge, exiting the challenge area and proceeding to the line following state. |
| Challenge Completion | The state in which the system will enter upon successfully completing a challenge. This system will remain in this state until exiting the challenge area. |
| Challenge Identification | The state in which the system attempts to identify the challenge it has arrived at. The system remains in this state until a positive identification. |
| Challenge Interaction | The state in which the system will attempt to complete a challenge. The system will remain in this state for as long as it is interacting with a challenge. |
| Challenge Misidentification | The state in which the system will enter upon falsely identifying the challenge it has arrived at. Should the system enter this state, this will represent a catastrophic failure. The system will proceed to the challenge abortion state. |
| Etch-A-Sketch | The state in which the system will attempt to complete the Etch-A-Sketch challenge. |
| Failed Approach | The state in which the system will enter upon stopping close than or further than 4.2 cm ± 0.1 cm. The system will proceed back to the approach state. |
| Finish | The state in which the system will enter upon crossing the finish line. The system will cease all movement. |
| Line Abandonment | The state in which the system will enter upon failing to proceed along the guidance tape. Should the system enter this state, the system will reverse direction to the last known location of the guidance tape. |
| Line Following | The state in which Roadie is following the Scotch Blue Painter’s tape located on the competition area. |
| Playing Card | The state in which the system will attempt to complete the playing card challenge. |
| Rubik’s Cube | The state in which the system will attempt to complete the Rubik’s Cube challenge. |
| Simon | The state in which the system will attempt to complete the Simon challenge. |
| Staging | The state in which the system commences operation. This state will last from the time the system is placed inside the starting area, until the LED in the starting area is turned off. |
| Zone Identification | The state in which the system will enter upon recognizing a challenge zone or finishing line. |
| Zone Misidentification | The state in which the system will enter upon failing to recognize a challenge zone. If the system were to enter this state, that would represent a catastrophic failure, resulting in termination of the round. |

**Table 1**: States that the system will occupy with their accompanying description.

By using **Table 1**, it was possible to construct the state diagrams shown in the sections below.

## **System State Diagram**

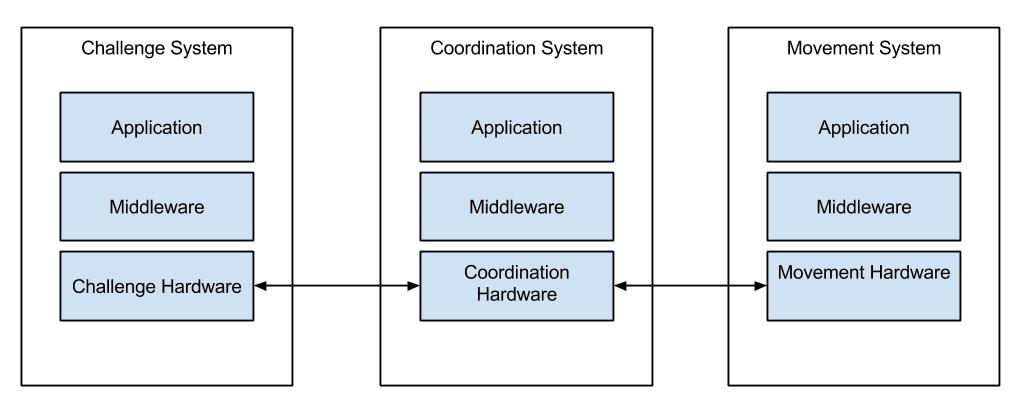
**Fig. 1** below shows the states that the system will be in, and how the system will transition from state to state.



**Fig. 1**: State diagram for Roadie

# **High-Level Architecture of System**

The system architecture of Roadie is designed in a layered approach, depicted in **Fig*.* 3** below, in order to better divide the work being done and to aid in the conceptualization of the system design.



**Fig. 3**: High level description of the systems in Roadie.

The applications in the Coordination system represent feedback from the sensors (line and object detectors) which is translated by the middleware (software) to the physical communications means. From here, the Challenge system and the Movement system are directed by the Coordination system in order to navigate to challenges (Movement system) and complete the challenges (Challenge system). From there, middleware in the form of software is used to talk to the applications. In this instance, the application in the Challenge system represents the challenges (Simon Carabiner, pocket Etch-A-Sketch, Rubik’s cube, picking up a playing card), with the motion application being moving the whole system along the competition area. As Roadie progresses along, the Communication system constantly sends correction information to the Movement system as well as monitor the Movement system’s behavior to correct any anomalies.

# **Design Considerations**

This section outlines the assumptions, dependencies and constraints imposed upon the system as a whole. Additionally, industry standards followed, safety constraints and considerations as well as environmental considerations are enumerated in this section.

## **Assumptions**

## **Dependencies**

## **Constraints**

## **Industrial Standards Followed**

## **Safety Constraints and Considerations**

As the system will be operating in a public venue, safety is a very large concern. It is imperative that any operation or fault in the system will not cause harm or pose a threat to any member of the audience, nor any member of team AWTY. As such, safety considerations imposed upon the system can be found in the sections that follow.

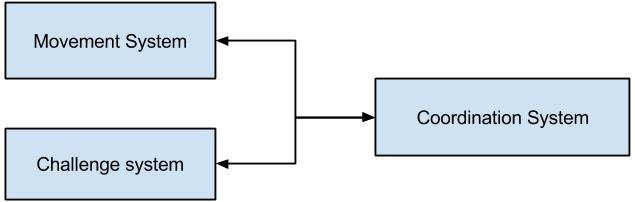
### **Electrical Hazards**

Since the system will be powered by electrical components, especially those which output a relatively high voltage, electrical shocks pose a problem if proper steps are not take to help mitigate such events. To aid in mitigation efforts, all connections originating from the power source have been properly insulated. Furthermore, all ground connections and power connections have been implemented on opposing sides of the chassis to help mitigate accidental contact. All power sources have a single point of connection, which are also insulated. The single connection point helps to ensure that not only will it prove physically impossible to plug the power source in incorrectly, it also ensures that the power source will not be active if not plugged into the system. The final precaution taken in system design is constructing the system out of a non-conductive material. As the chassis has been constructed from wood, if any connection does come loose and makes contact with the chassis, the chassis will not have an electrical charge since wood is not a conductor of electricity.

## **Environmental Considerations**

# **Functional Decomposition of System**

Roadie is broken down three main subsystems: (1) the coordination system, (2) the challenge system and (3) the motion system. The division of these subsystems is illustrated in **Fig. 2**.



**Fig. 2**: Division of Roadie into three subsystems.

The communication and coordination subsystem relays information to both the arm subsystem and the movement subsystem. The components of Roadie were broken into systems based upon what other components they interacted with and what task they set out to perform. For example, all of the interactors for challenges (Simon, Etch-A-Sketch, Rubik’s cube and playing card), were divided into the Challenge System since the interactors represent the means through which Roadie will physically manipulate the challenges. The Coordination System encompasses the microcontrollers as well as the object detectors and line sensors. The reasoning behind such a decisions is that the object detectors and line sensors will send correction information that will be interpreted by the microcontroller to navigate the Roadie to the right challenge as well as identify the correct challenge upon arrival. The Movement system is comprised of the motors and their associated wheels. This is due to the fact that the motors and wheels are responsible for moving the system to the intended destination.

These systems are further divided by functionality to create the high-level architecture as described in Sections 6,7 and 8.

# **Decomposition of Coordination System**

The architecture, requirements, use cases, sequence diagrams and requirements traceability matrix for the coordination system are included in this section.

## **Subsystem Architecture**

**Fig. 4** below, better illustrates the communications that occur amongst the systems in Roadie.



**Fig. 4**: Decomposition of coordination system for Roadie.

As depicted in **Fig. 4**, the Coordination System is composed of two microcontrollers, both communicating with each other over a serial interface. The Arduino Mega is the primary micro controller, interpreting inputs from the reflectance array (line following) and issuing commands based on values received.

The coordination system is responsible for the navigation and challenge identification process of Roadie. The system consist of object detection, line following, and subsystem coordination.

Object detection allows Roadie to identify what object it has arrived at. By using object detection, Roadie will be able to determine what challenge needs to be completed as well as how to align with the challenge.

Line following allows Roadie to traverse the competition area. Roadie will use its line following capabilities to navigate from the starting area to the various game stations.

Subsystem coordination allows Roadie to know what each subsystem is doing at any given moment. This will aide in ensuring that Roadie will successfully complete all tasks.

### **Assumptions**

During operation, it is assumed that Roadie will begin with sufficient battery to complete the course. If the system is started with a battery that is not charged enough, the system will not be able to successfully complete the course.

It is also assumed that Roadie will be operating in the competition area shown in **Fig. 17**, and only the competition area shown in aforementioned figure. Since Roadie has been designed to compete in IEEE Southeast Con 2015, any course modifications will render the system inoperable. Furthermore, it is assumed that the course will be free of obstructions and obstacles. Any obstacles will prevent Roadie from completing the course. Assumptions have also been made regarding the course construction. It is assumed that the course will be constructed according to the methods and materials outlined in [1].

The object detection in the Coordination system will only operate on the challenges outlined in [1]. Any modifications to the challenges or any different items introduced into the challenge area will create a problem for Roadie.

Assumptions have been made regarding the subsystem coordination. If one of the subsystems gives throws an unexpected error, or an error that the master controller is not prepared for, the entire system will fail.

### **Dependencies**

The coordination system depends on the challenge system and movement system to relay information back to it so that it may guide Roadie in course completion. If this connection is broken or fails, Roadie will ultimately fail.

Problems arising from dependencies include any mechanical failure which would render the system inoperable. Furthermore, electrical issues or corrupted data will cause the system to fail the competition round.

### **Constraints**

The coordination system is constrained by the clock speed of the selected microcontroller as well as the interfaces through which the other subsystems will communicate. The system is also constrained by the rules and regulations laid forth in [1]. All code and logic in the Coordination system must fit within the system memory of the microcontrollers.

## **Functional Diagrams**

## **Hardware Diagrams**

## **Interfaces**

## **Parts Budget**

# **Decomposition of Challenge System**

The architecture, requirements, use cases, sequence diagrams and requirements traceability matrix for the challenge system are included in this section.

## **Subsystem Architecture**

**Fig. 7** shows the decomposition of the Challenge System into its major components.



**Fig. 7**: Decomposition of Challenge System for Roadie.

The challenge system is responsible for completing all the challenges listed in [1]. This system includes a Rubik’s & Card interactor, an Etch-A-Sketch interactor and a Simon interactor.

Interacting with the Rubik’s cube means that Roadie will attempt to turn one row of the Rubik’s cube 180 degrees. Roadie will be able to positively identify the Rubik’s cube and position itself over the Rubik’s cube. Interacting with Simon means that Roadie will play Simon for 15 seconds, correctly identifying and pressing the illuminated segments. Interacting with the Etch-A-Sketch means that Roadie will successfully draw “IEEE” on the Etch-A-Sketch. Interacting with the playing card means that Roadie will successfully pick up a playing card and carry it across the finish line.

### **Assumptions**

It is assumed that all challenges will be exactly as described in [1]. Furthermore, it is assumed that all of the Challenges will perform as expected. That is to say that it is assumed that the Etch-A-Sketch knobs will perform normally. They will not have encountered unexpected wear during repeated competition rounds. Furthermore, the Rubik’s cube will be able to be rotated without an extraordinary amount of effort. If the Rubik’s cube requires more effort to be twisted than expected, Roadie will be unable to twist the cube. If the segments on Simon do not illuminate properly after multiple course rounds, Roadie will be unable to properly identify Simon.

It is assumed that Roadie will operate in the competition area shown in **Fig. 17**.

### **Dependencies**

The Challenge system is wholly dependent upon the Coordination system. The Coordination system notifies the Challenge system as to what challenge it has arrived at. From here, the Challenge system will determine which interactor to activate. Without notification from the Coordination system, the Challenge system will be unable to perform its task. Furthermore, the Challenge system relies on the challenges being exactly as described as laid forth in [1].

### **Constraints**

The Challenge system is constrained by the clock speed and memory in the microcontrollers. The Challenge system must be able to coincide with the code and logic from the other systems. Additionally, all hardware being used by the Challenge system must fit on the chassis in a manner in which it will not interfere with the other systems. The Challenge system must abide by all rules in regulations laid forth in [1].

## **Functional Diagrams**

## **Hardware Diagrams**

## **Interfaces**

## **Parts Budget**

# **Decomposition of Movement System**

The following section describes the architecture, requirements, use cases, sequence diagrams, and requirements traceability of the movement system.

## **Subsystem Architecture**

**Fig. 12** shows the decomposition of Roadie’s movement System into major components.



**Fig. 12**: Decomposition of Movement System Roadie.

The Movement system for Roadie consists of the drive motors, wheels and the chassis. This system is responsible for interpreting the movement commands sent to it from the Coordination system. In turn, the Movement system will advance the chassis to the specified location.

### **Assumptions**

It is assumed that the competition area will be as shown in **Fig. 17**. The movement system has been calibrated to respond to the surfaces laid out in the aforementioned figure. If the surface is different from what is described, there is no guarantee that Roadie will be able to correctly move. It is also assumed that the Movement system will be able to interpret all of the commands originating from the Coordination system. If the Movement system is unable to do so, Roadie will not move as expected.

### **Dependencies**

The Movement system is purely dependent upon the Coordination system for the direction and distance to move Roadie. The Movement system also depends on the environment it is placed in being free of obstacles or other movement inhibitors. Furthermore, the environment which Roadie is placed in must be the same as the competition area as shown in **Fig. 17**. Roadie has been constructed to work with this course format and no other.

One problem arising from dependency is that the system will fail to move. If the Movement system is unable to get information from the Coordination system, Roadie will be unable to move, representing a total system failure.

### **Constraints**

All of the code and logic for the Movement system must fit within the space allotted on the microcontroller. Furthermore, the speed at which the code can run is constrained by the clock speed on the microcontroller. The Movement system may only move as fast as the motors that have been selected to drive Roadie. All components in the Movement system must comply with all rules and regulations set forth in [1].

## **Functional Diagrams**

## **Hardware Diagrams**

## **Interfaces**

## **Parts Budget**

# **System Test Plan**

# **Appendix B**

This appendix includes a diagram of the competition course as well as pictures of the individual challenges the system must complete. Also included is a picture of the tape that will designate the line the system must follow.

## **Competition Course**

The course, as shown in **Fig. 17** below, shows the rough outline of the track the system will follow, as well as what a challenge station would look like.

**Fig. 7** Competition course for SoutheastCon[1].

# **References**

[1] IEEE Nova Southeastern University. (2014, September 7). IEEE SoutheastCon 2015 Student Program - Hardware Competition. Retrieved September 7, 2014, from IEEE SoutheastCon 2015: http://www.ewh.ieee.org/reg/3/southeastcon2015/StudentProgram.html