RoboCon System SRS

Project Yoshita_Sharma_CS568_Project (Requirements Management)

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1 Introduction

This document describes the high-level characteristics and function of a proposed robotic convoy system called RoboCon.

1.1 Purpose

The purpose of this document is to record the decisions agreed to by RoboCon stakeholders and

serve as a basis for detailed system requirements specification and documentation.

1.2 Product Scope

RoboCon consists of a variable number of robots that form a convoy and follow a leader robot to a specified destination. In most usage scenarios, the convoy will include at least four robots, but at least two robots are required:

- One robot in the convoy is designated as the leader robot. The leader robot is provided with a path to follow in the form of a series of spatial coordinates called waypoints.
- All other robots in the convoy are follower robots. Each follower robot uses on-board sensors to track the robot immediately ahead of it in the convoy and follow it.

RoboCon will provide a demonstration and experimentation platform for CS568 Systems image processing and artificial intelligence algorithms. RoboCon will:

- Allow CS568 Systems to conduct internal evaluation of alternative algorithms in different operational scenarios.
- Provide a platform for CS568 Systems to showcase the performance of new algorithms to customers.

1.3 Definitions and Abbreviations

1.3.1 Definitions

Follower: An RCU that does not know the waypoints of the route; uses on-board sensors to follow another RCU immediately preceding it in the convoy.

Guide: The RCU tracked and followed by a follower. A guide may be the convoy leader or a follower. All followers have exactly one guide.

Leader: The RCU that is provided with the route waypoints. The leader proceeds first in the convoy.

Tail: The RCU immediately behind a given RCU in the convoy. An RCU is the guide of its tail.

Waypoint: A set of spatial coordinates indicating a position that the convoy must pass through on its way to the destination of the route.

Route: A route may consist of waypoints, obstacles and charging stations.

Sensors: The sensors include the GPS, IR transmitter, IR receiver and WiFi.

Convoy: The convoy consists of at least 4 RCUs, one leader and other followers.

Architecture: Architecture of RoboCon, including RCUs, ACUs, iRobot Creates, sensors, actuators, and software components.

1.3.2 Abbreviations

SQL: Sequential Query Language

ACU: Administrative Control Unit

GPS: Global Positioning System

GUI: Graphical User Interface

IR: Infrared

LAN: Local Area Network

OS: Operating System

OTS: Off-The-Shelf

PC: Personal Computer

RCU: RoboCon Unit

2 Overall Description

2.1 Product overview

This type of autonomous convoy is a common use-case for CS568 Systems algorithms, having applications in transportation, inventory management, automated farming, and other areas.

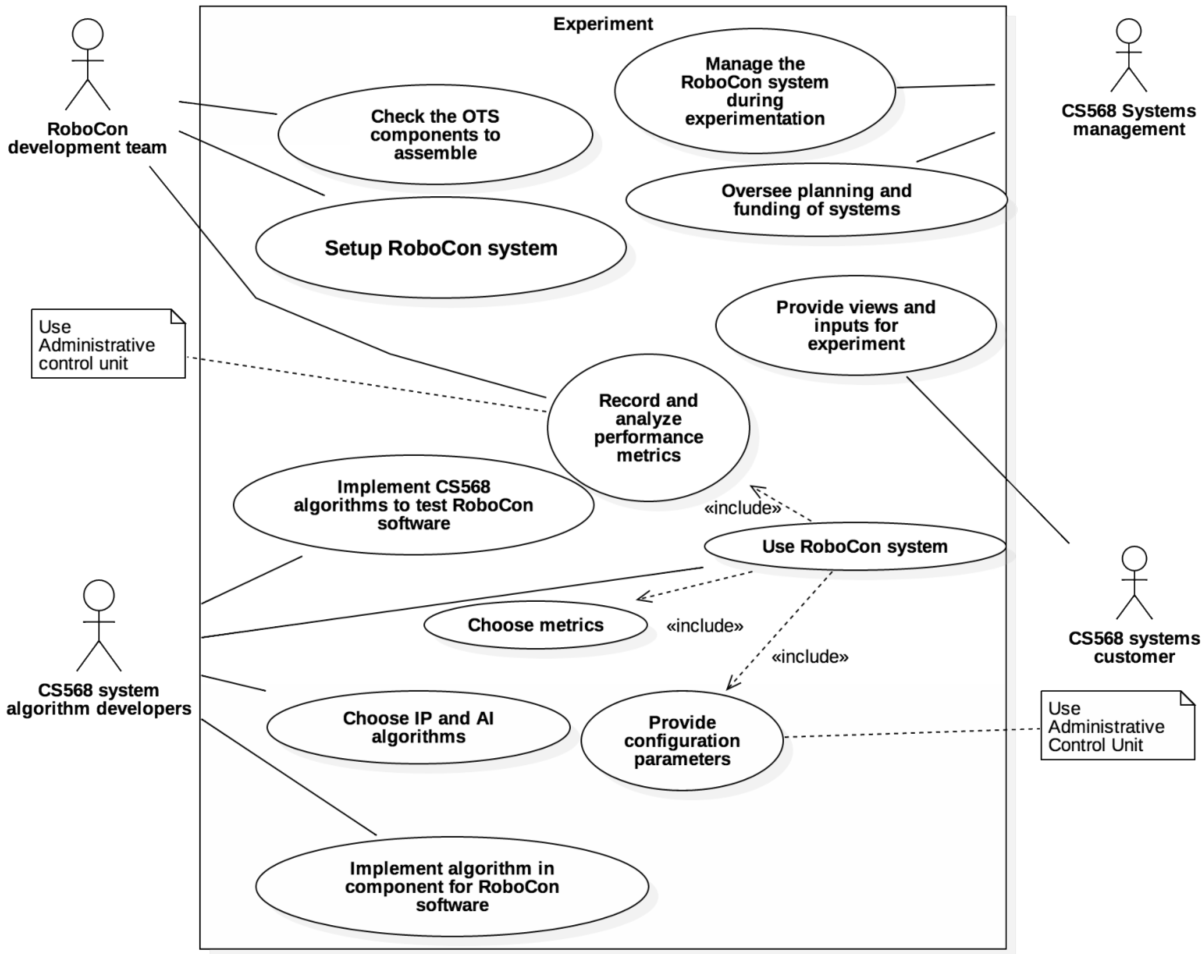
RoboCon consists of multiple robots called RoboCon Units (RCUs) and one Administrative Control Unit (ACU).

Each RCU consists of a robotic hardware platform and a software controller.

- The RCU hardware platform will be assembled from OTS components.
- The RCU software controller will be custom-built by CS568 Systems.

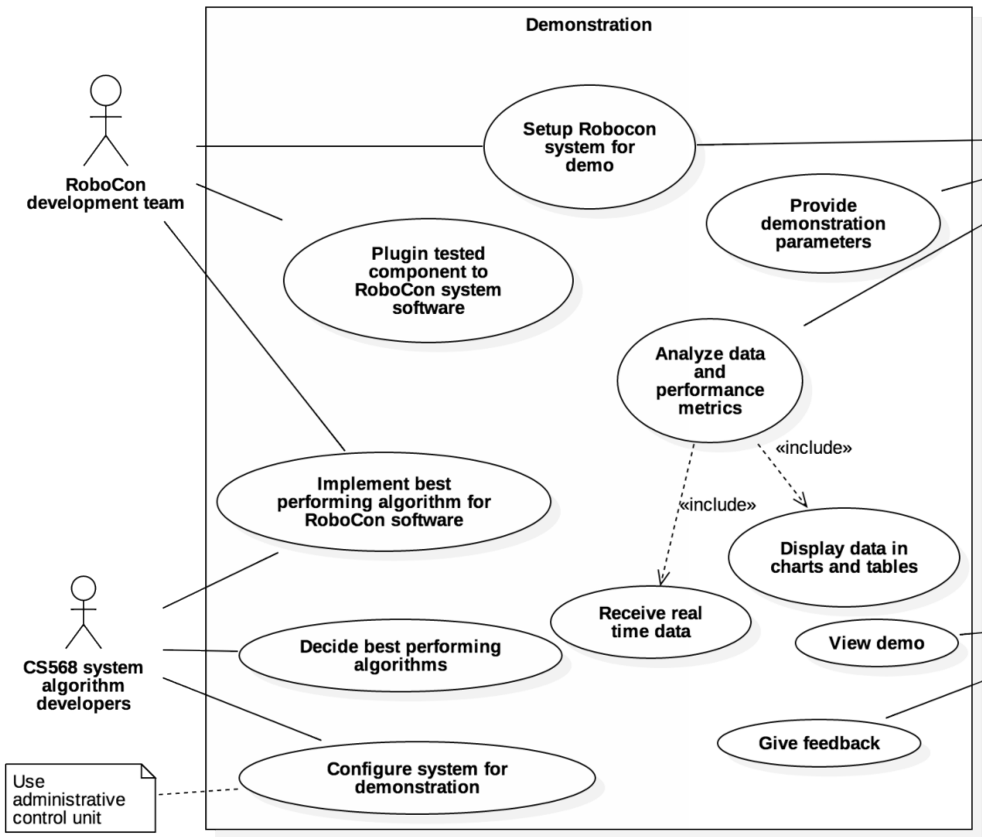
The ACU consists of a standard PC and an administrator application.

2.2 Usage Scenarios
2.2.1 Experimentation



RoboCon will be used internally by CS568 Systems algorithm developers to experiment with different image processing and artificial intelligence algorithms. In this usage scenario, the algorithm under test will be implemented in a component that plugs into the RoboCon software. The RoboCon system will then be configured for a particular experiment (e.g., the number of robots, the starting and destination locations, the lighting conditions, etc.). As the experiment executes, the RoboCon system will record performance metrics such as battery usage, total travel time, number of messages exchanged, etc. After the experiment completes, the algorithm developers will analyze the recorded data to evaluate the algorithm's performance.

2.2.2 Demonstration



RoboCon will be used to demonstrate CS568 Systems algorithms to external customers. In this usage scenario, RoboCon's best-performing algorithms will be plugged into the RoboCon software and the system will be configured for a demonstration that illustrates how CS568 Systems algorithms outperform the competitors' algorithms. For example, a demonstration might illustrate how a CS568 Systems image processing algorithm is able to function in a low-light environment.

2.3 User Characteristics

2.3.1 Stakeholder and Goals

2.3.1.1 The RoboCon Development Team

The RoboCon development team is responsible for building the RoboCon System. The development team has indicated that their primary goal is to successfully complete the project on-time and on-budget.

2.3.1.2 CS568 Systems Algorithm Developers (primary RoboCon users)

CS568 Systems algorithm developers will be the primary users of RoboCon. The algorithm developers have indicated that their primary goals are for the system to:

1. be easy to extend with new image processing and artificial intelligence algorithms
2. be simple to configure for different experiments, and
3. provide rich, meaningful metrics of algorithm performance.

2.3.1.2.1 CS568 Systems Customers

CS568 Systems customers will view RoboCon demonstrations that showcase the performance of CS568 Systems algorithms. Their primary goal is to gain an understanding of how they can incorporate CS568 Systems algorithms into their own products to provide their customers with more value.

2.3.1.2.2 CS568 Systems Management

CS568 Systems management will oversee the planning and funding of the RoboCon development. Management has indicated that their primary goals are:

1. the system has low maintenance costs over time, and
2. the system can be used to provide compelling demonstrations to customers of the value of RoboCon algorithms.

2.4 Design and implementation constraint

Some constraints and design details have to be kept in mind while operating the system.

1. The system shall have at least two RCUs for proper functioning.
2. The system shall have maximum one RCU designated as a leader robot.
3. The RCU hardware shall be assembled using off-the-shelf components.
4. The RCUs need to remain within 6 metres of each other, else the IR sensors may not work.
5. The units of different performance metrics to be recorded should be decided beforehand so that all the stakeholders have a common domain knowledge.
6. desired value.There shall be a specific range of all performance metrics, within a threshold value and the
7. The system shall be configured with well specified ranges of the figures for light conditions, or distances for the sensor selection , for efficient communication between two RCUs.
8. .During convoy formation operational mode, the convoy should be arranged in a single file line.
9. Each follower RCU robot should have exactly one guide.
10. Compatibility between the ACU and the eBox 3854 component of the RCU hardware platform must be tested as the former has the Microsoft Windows OS and the latter runs on Fedora Linux.
11. Both the ACU and the eBox 3854 must be capable of storing at least 1000 (terabytes)TB of memory as communication and data exchange between all the hardware components, software components and ACU collectively would need more than sufficient amount of memory.
12. The real - time data of performance metrics should be displayed in the form of charts and tables.

3 Specific Requirements

3.1 User Interface

The user interface is provided by the Administrative Control Unit, ACU. It is a standard PC running Microsoft Windows 7 and an Admin software application. The Admin provides a typical Windows graphical user interface (GUI) for performing various RoboCon management functions.

It can be utilized by all the four stakeholders of the project. The four stakeholders are:

1. RoboCon System developers
2. CS568 System algorithm developers
3. CS568 System management team
4. CS568 System customer

The primary users are the CS568 System algorithm developers. They will use the ACU to configure the RoboCon system for the performance metrics to be tested using different image processing and artificial intelligence algorithms for different experiments.

The Admin software component of the ACU can be used for the following functions:

- Allows a user to specify experiment and demonstration configurations.
- Uploads configurations to RCU Controllers.
- Receives real-time performance data from Controllers during an experiment or demonstration and displays the data in charts and tables.

The units for the performance metrics can be selected from a top - down list. All the stakeholder should agree on one set of units to be used by a particular standard, preferably using the SI system. The performance data can be viewed on the PC by the stakeholders. It is a choice to use SQL or NoSQL databases, depending on the number of interactions to be carried out.

The performance data for the three operational modes - convoy formation, movement and recharge can be viewed on the PC and the metrics parameters can be modified using the GUI.

3.2 Hardware Interface

The two primary components of the RoboCon system that behave as an interface between the software product and the hardware component of the RoboCon system are the RCU controller software component and the RCU hardware platform. The details of the RCU hardware components can be viewed here and for the RCU contoller software can be seen here.

1. The OS supported by the eBox 3854 hardware component supports Fedora Linux OS.

2. The RCU controller software component runs on the eBox 3854 computer.

3. The RCU Controller software interacts with the RCU Hardware component in the following way:

- Receives sensor data (such as video and IR readings) from the RCU sensors.
- Analyzes sensor data to determine the actions to be taken by the RCU (e.g., move forward, turn, switch off camera, etc.).
- Sends commands to the RCU sensors and actuators to perform needed actions.
- Sends messages to other Controller instances to coordinate convoy activities.
- Records performance metrics for analysis by CS568 Systems engineers and transmits metrics to the Admin component (described below) for real-time visualization.

4. Each Controller instance will communicate with the camera, GPS, WiFi adapter, IR receiver, and IR transmitter using Linux drivers. Each Controller instance will communicate with other Controller instances running on other RCUs in a convoy via an ad-hoc WiFi network.

3.3 Software Interface

1. Each RCU is controlled by a Controller software component that runs on the eBox with the Linux operating system (OS). The Controller provides the core logic that implements the convoy behavior. The Controller includes the following functions:

- Receives sensor data (such as video and IR readings) from the RCU sensors.
- Analyzes sensor data to determine the actions to be taken by the RCU (e.g., move forward, turn, switch off camera, etc.).
- Sends commands to the RCU sensors and actuators to perform needed actions.
- Sends messages to other Controller instances to coordinate convoy activities. • Records performance metrics for analysis by CS568 Systems engineers and transmits metrics to the Admin component (described below) for real-time visualization.

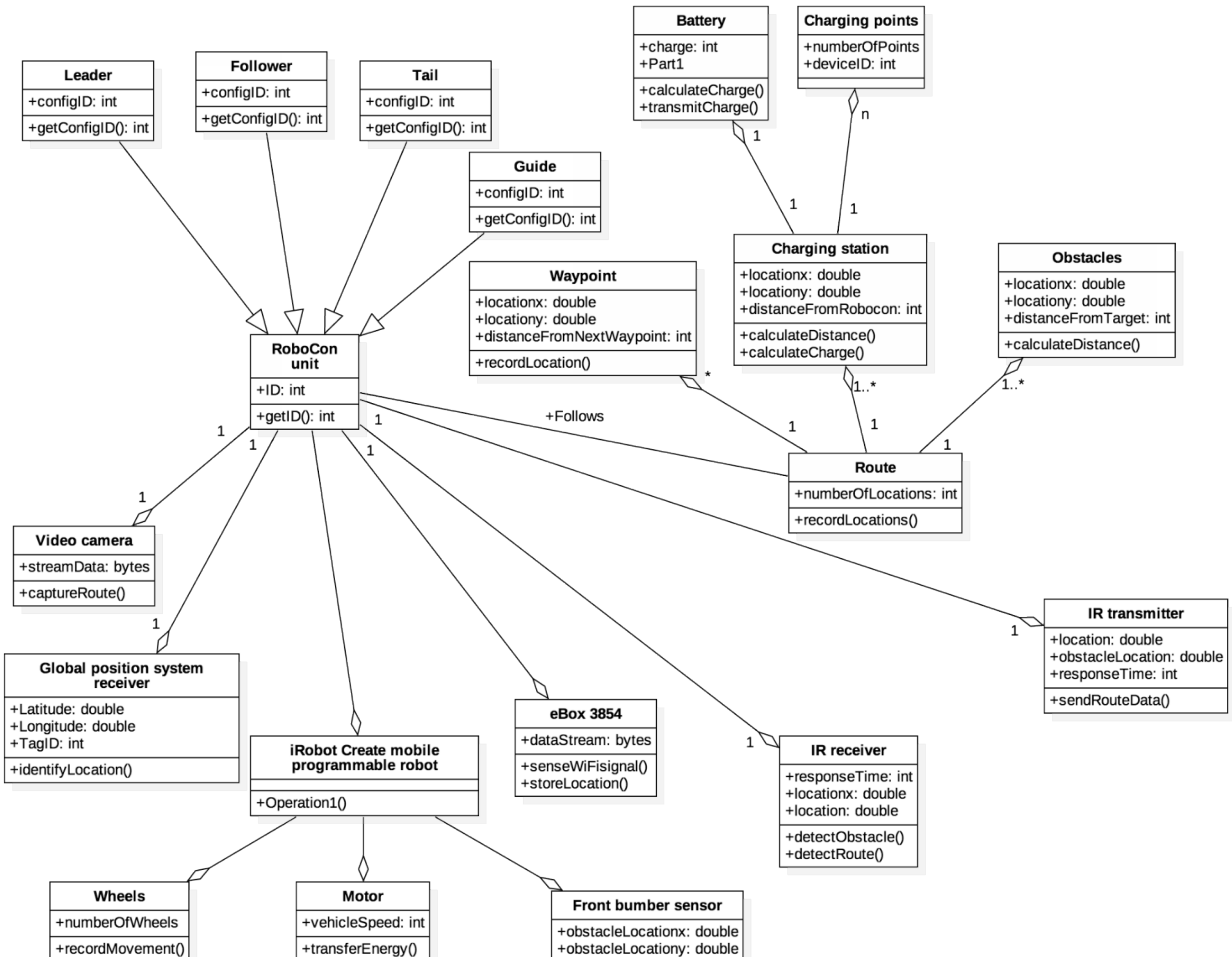
2. The memory of eBox computer should be at least 1000 terabytes(TB).

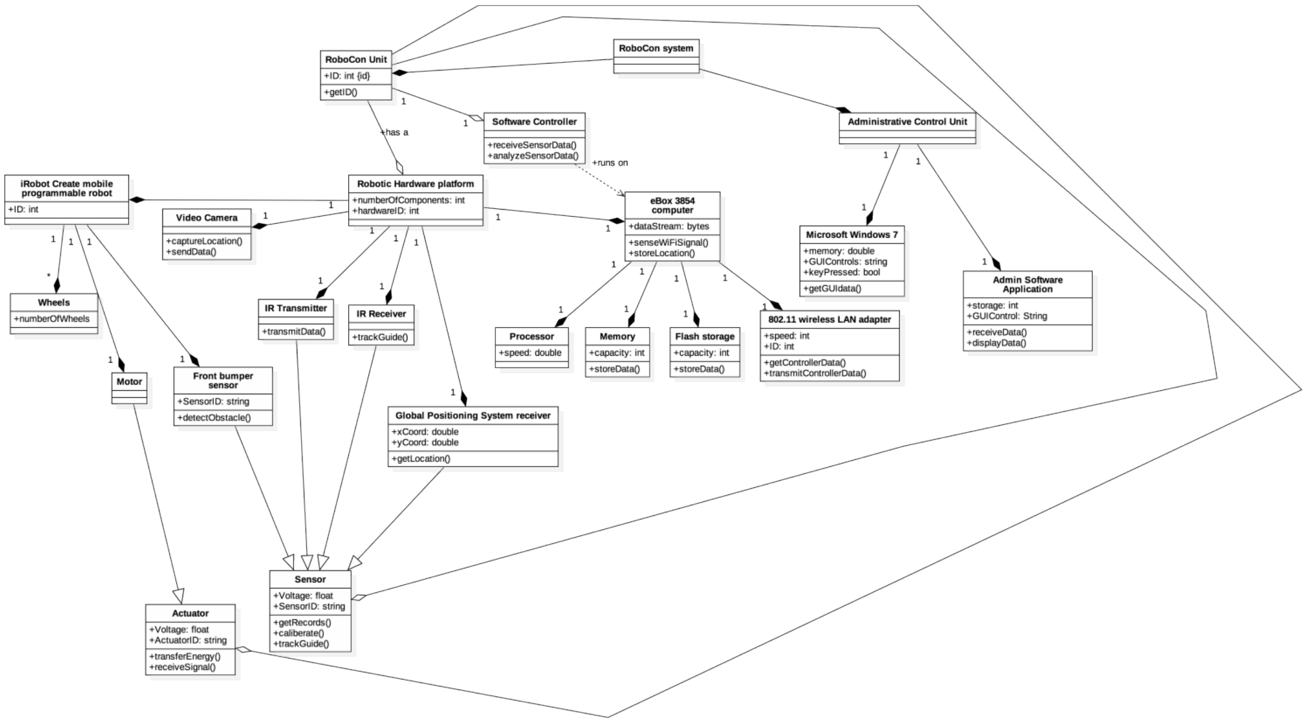
3. The databases used can be SQL or NoSQL, but preferably NoSQL for better storage capacity and faster performance.

4. For data recording and storage, applications in the local computer like Microsoft Office can be used, or online platforms like Microsoft Sharepoint Online or Microsoft Azure are also alternative options.

4 System Features

4.1 System Components





4.1.1 RCU Hardware Platform

1. The RCU hardware shall be assembled from off-the-shelf components. Following are the components of the RoboCon Hardware system:

- An iRobot Create mobile programmable robot. The iRobot has wheels and a motor that can turn and move the robot. The iRobot also includes a front bumper sensor that detects when the robot has run into an obstacle.
- An eBox 3854 computer running Fedora Linux. The eBox contains all standard computer components, such as a processor, memory, flash storage, etc. The eBox also includes an 802.11 wireless local area network (LAN) adapter.
- A video camera.
- A Global Position System (GPS) receiver.
- An infrared (IR) receiver.
- An IR transmitter.

2. The iRobot Create Mobile programmable robot shall have 4 wheels and 2 motors that help in moving and turning the robot.

3. The iRobot shall include a front bumper sensor that helps in obstacle detection.

4. The eBox 3854 shall operate on a system capable of near real-time execution of instructions running in Fedora Linux.

5. The eBox 3854 shall operate on a system having a processor which is capable of multithreading.

6. The eBox 3854 should have the capability and enough memory to run a Virtual host in case the main OS does not function properly for some reason.

7. The video camera shall have sensors efficient enough to detect low light and good light conditions.

8. The IR sensors should be able to detect signals upto a distance of 6 meters.

9. The eBox 3854 shall support 802.11 wireless local area network (LAN) adapter.

10. The RCU hardware shall have the capability of communication with the RCU software controller instances to calculate real time data.

4.1.2 RCU Software Platform

1. The RCU controller software shall receive sensor data from the RCU sensors and store sensor data streams in a database that can handle transaction processing at a rate of 1000 transactions per minute

2. The RCU controller software shall support a Virtual host too in case the main host of the eBox 3854 Linux OS does not function proper due to some technical failure.

3. The RCU controller software shall perform periodical offsite and onsite backups of all configurations and reporting data.

4. The RCU controller software shall support for analyzing sensor data that help in determining actions that need to be taken by the RCU by using RCU sensors and actuators.

5. The RCU controller software shall support wireless encryption protocols WPA [1-2] and WEP.

6. The RCU controller software shall support communication using Linux drivers to communicate with WiFi, GPS, IR receiver and IR transmitter

7. The RCU controller software shall have the functionality to communicate with other Controller instances via an ad-hoc WiFi network to coordinate activities.

8. The RCU controller software shall have a tool and a database that helps to record performance metrics for analysis and also transmits metrics to the Admin component for real - time visualization.

4.1.3 ACU Component

1. The ACU shall consist of Microsoft Windows 7 OS and an Admin software application.

2. The ACU shall support a customizable Windows Graphical User Interface software application for performing various RoboCon management and user interface functions by the CS568 System algorithm developers, who are the primary users of the system.

3. The ACU shall provide GUI controls for the CS568 algorithm developers to specify experiment and demonstration configuration parameters.

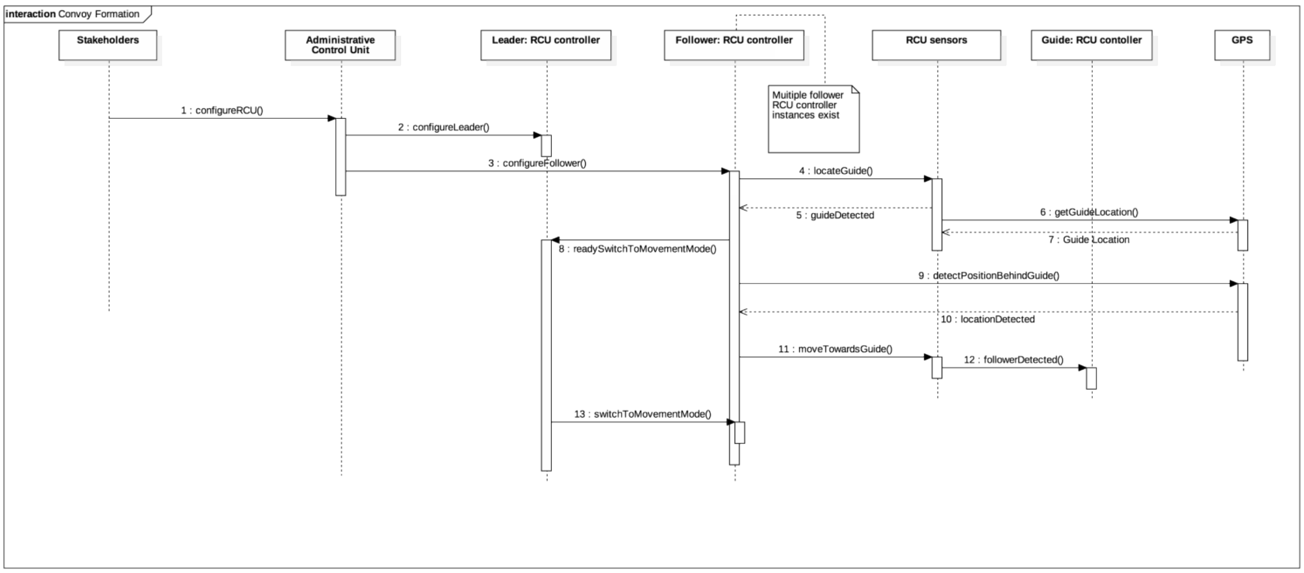
4. The ACU shall support uploading of configurations to RCU Controllers

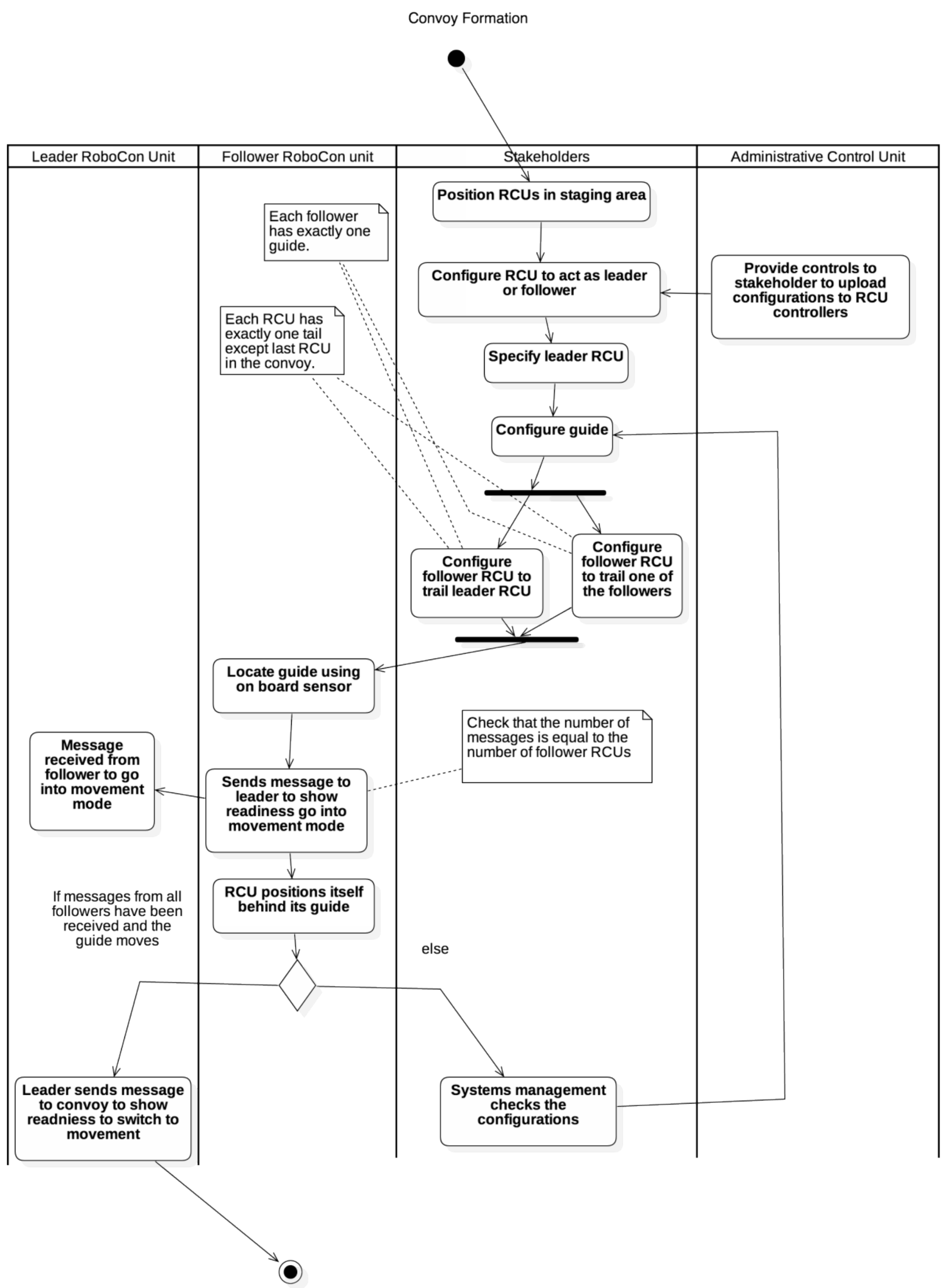
5. The ACU shall allow feature modeling support that helps in a tabular representation of the performance metrics data via charts and tables.

6. The ACU shall control the compatibility of its Microsoft Windows 7 OS and the Fedora Linux OS that supports the RCU software controller.

4.2 Operational Modes

4.2.1 Convoy Formation Mode

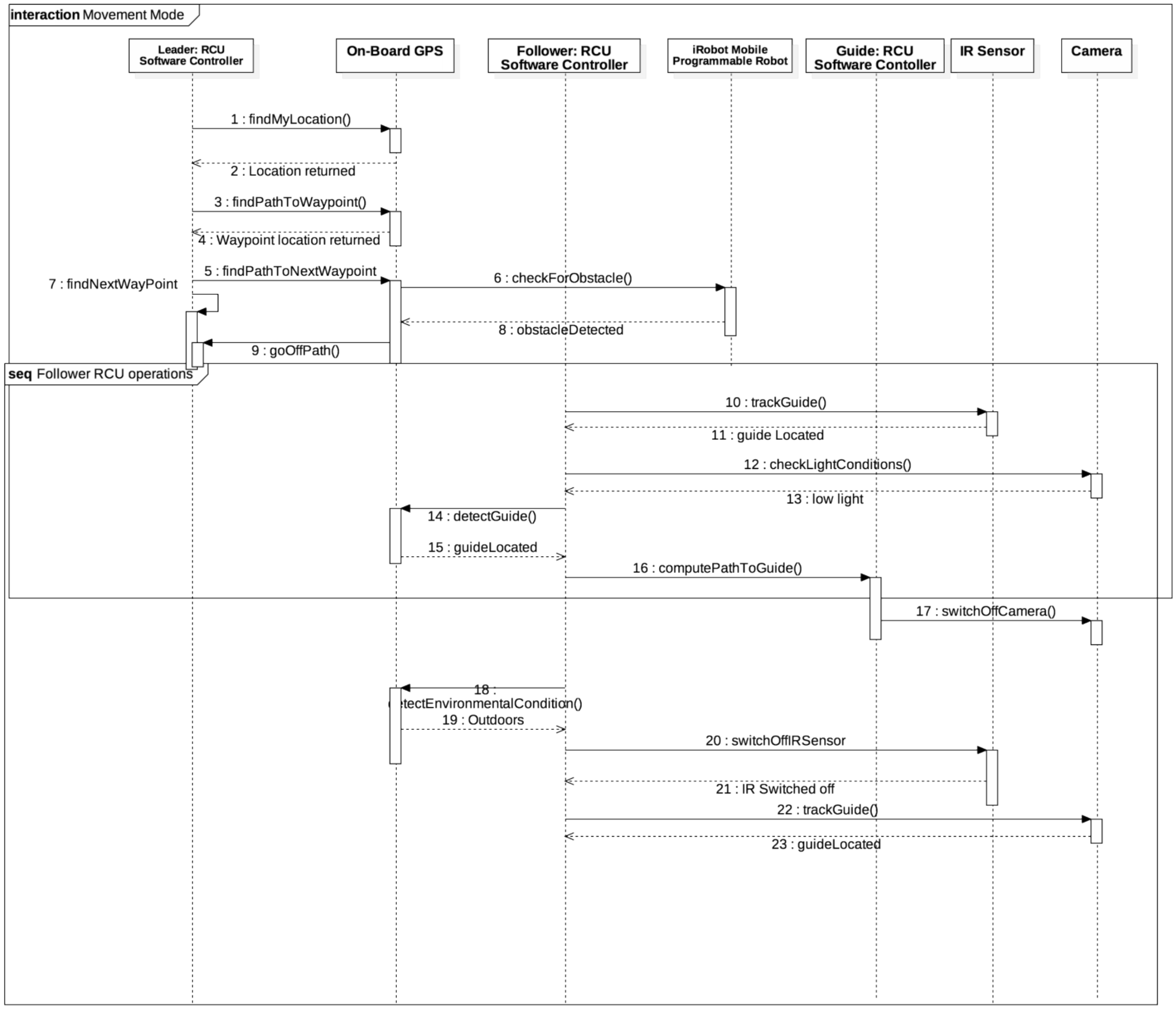


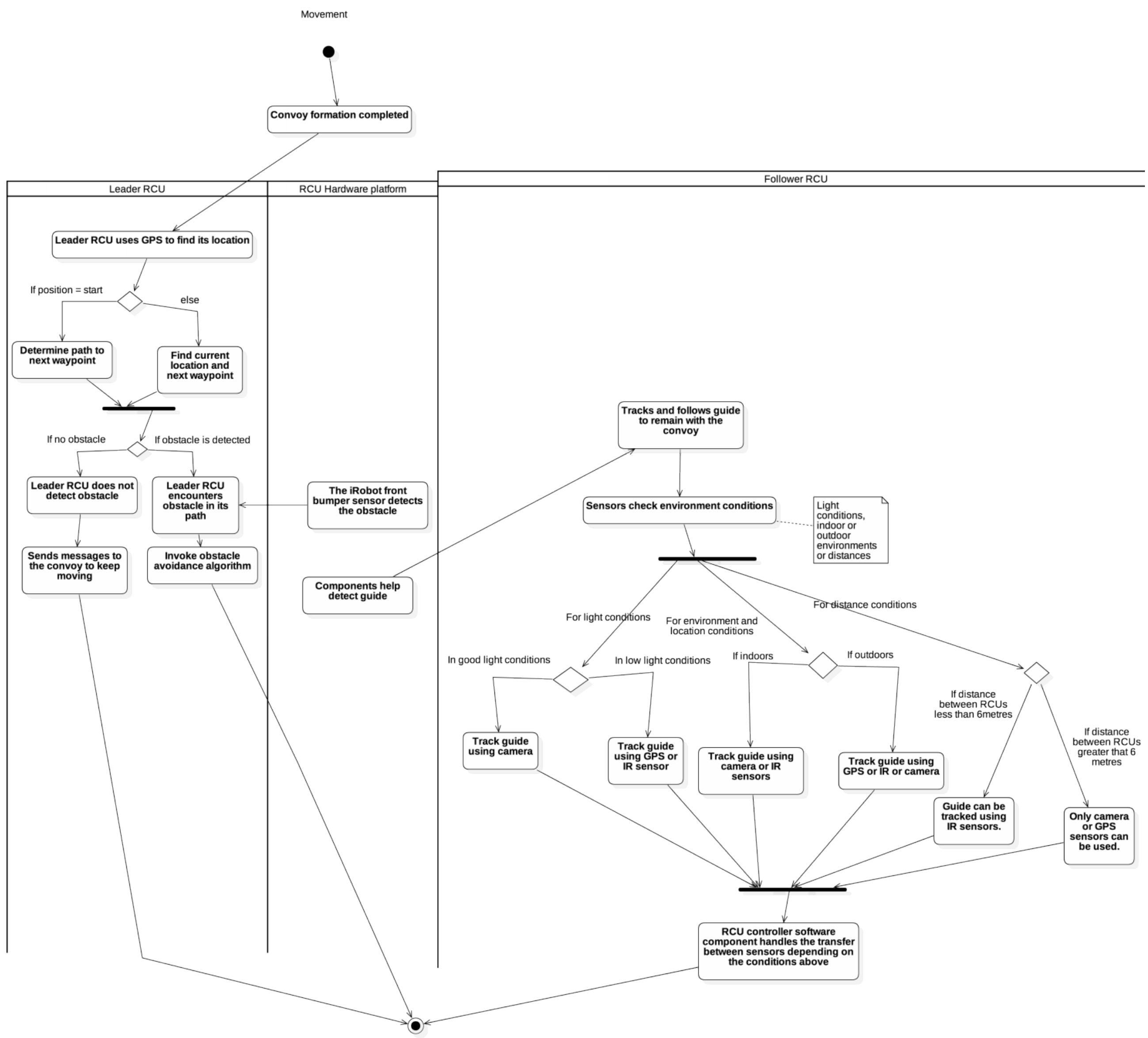


1. The system shall have a set of RCUs positioned in a staging area at system startup. The RoboCon system developer shall place the RCUs at the required positions.

2. The system shall allow every RCU participating in the convoy to be configured either as a leader or follower. The CS568 System algorithm developers shall assure the RCUs are configured efficiently as a leader of a follower via the ACU.
3. The follower RCU shall use on - board GPS sensors to locate it guide.
4. The system shall allow a convoy in which each RCU has exactly one tail and the last RCU in the convoy line has zero tails.
5. The system shall allow the follower RCU to switch to movement mode after the latter has located its guide and broadcasted the message to the leader RCU.
6. The system requires the follower to maintain its position behind the guide, once the guide starts moving. The RoboCon system developers and the CS568 algorithm developers shall ensure this functionality.
7. The system requires that the leader RCU shall receive a message from the follower RCUs when they are ready to switch to the movement mode.
8. The number of messages received from the RCUs involved in the convoy.
9. The system requires that the whole convoy switches to movement mode once the leader RCU broadcasts a message to all follower RCUs.
10. In case of failure of any of the above mentioned operational requirements, the CS568 Systems management team shall work to maintain the system.

4.2.2 Movement Mode

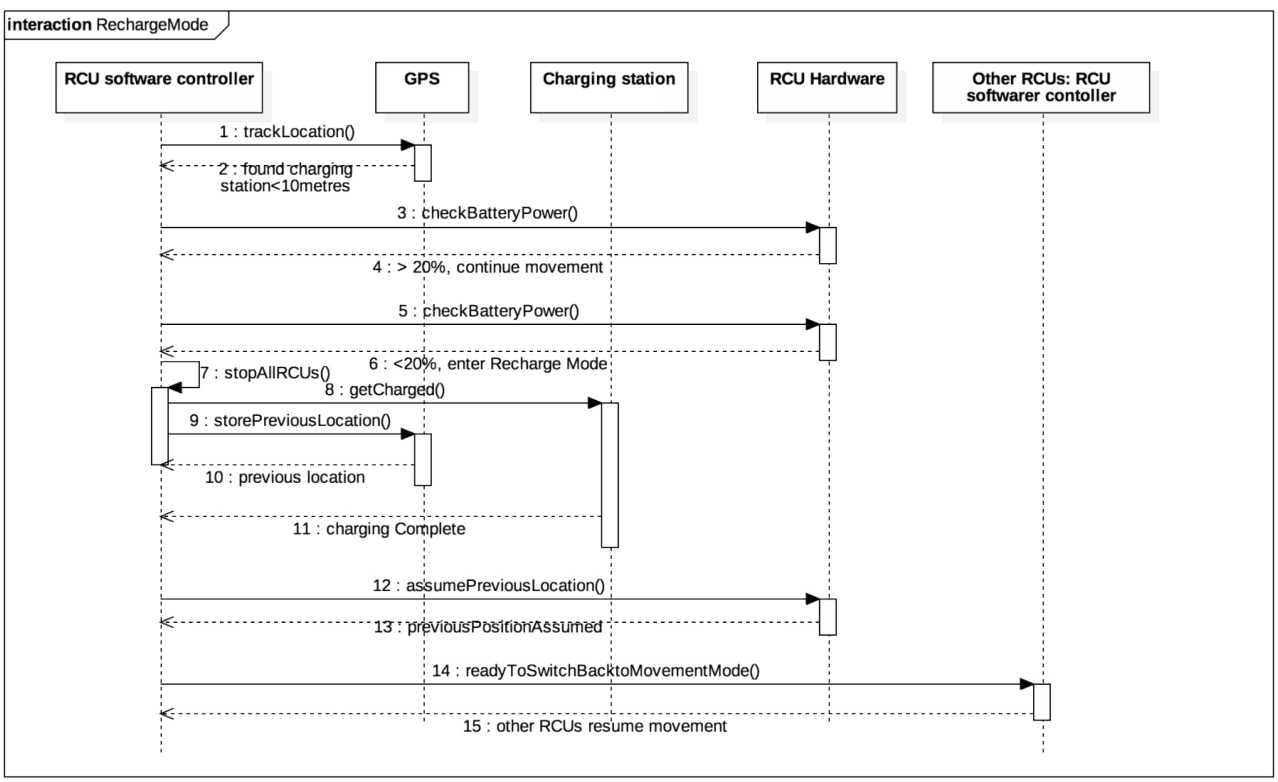




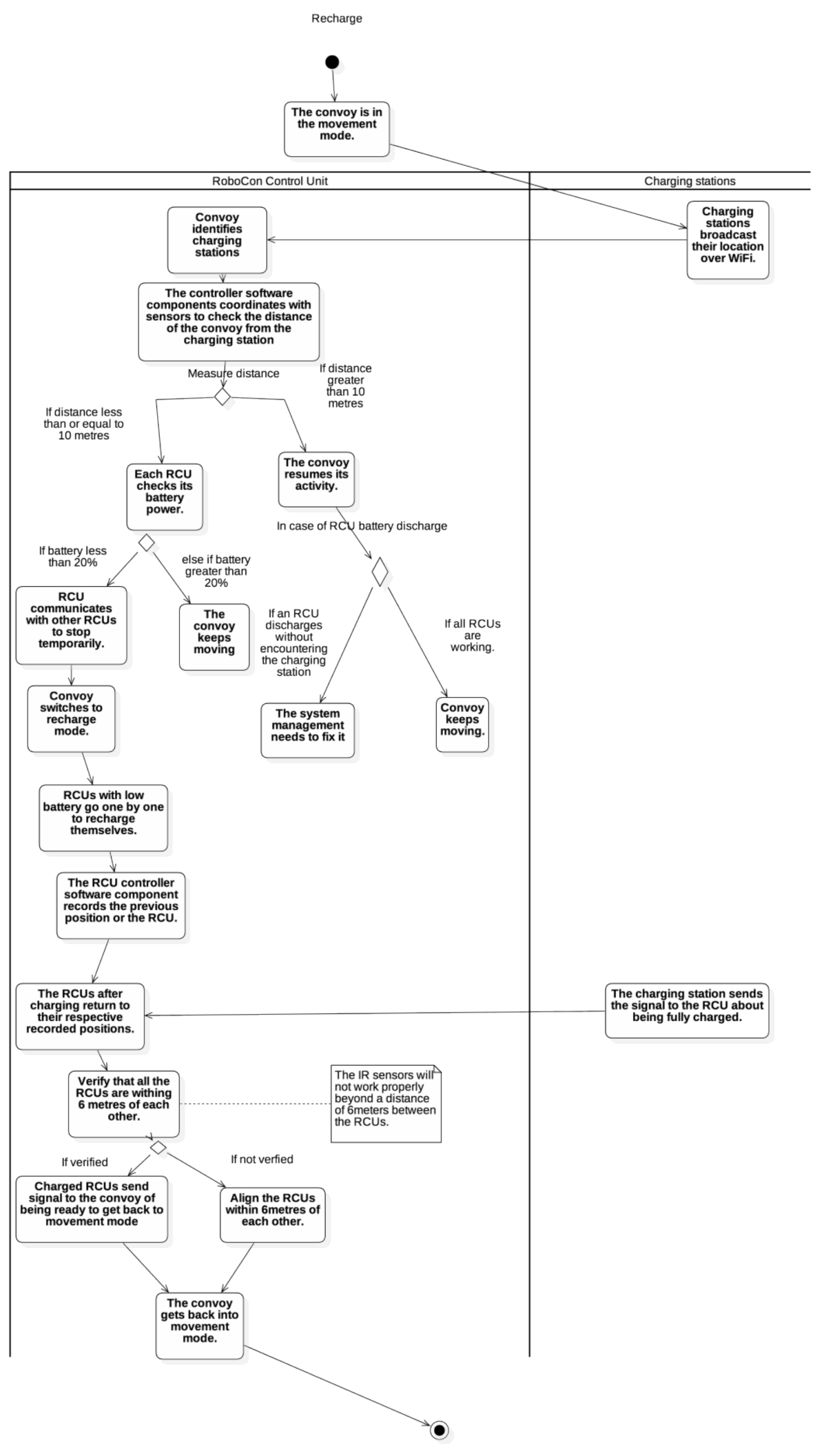
1. The system shall support the functionality of the leader RCU using an on-board GPS device to find its current location and determine a path to the next waypoint.
2. The system requires that when the convoy reaches a waypoint, the leader should compute a path to the next waypoint in the route.
3. The system shall be able to verify whether the
4. The system requires that the leader should invoke an obstacle avoidance algorithm and temporarily take the convoy off the path and do a navigation maneuver if the iRobot front bumper sensor detects an obstacle in the path to the waypoint.

5. The system shall allow the follower to track the guide either through camera or IR sensor
6. The system shall allow the follower to track the guide's location by using a WiFi link, followed by using the GPS to get its own location and compute a path to the guide's location.
7. The system requires that if the environment around the convoy is a low-light environment then the follower RCU cannot use camera tracking and automatically switches to GPS or IR sensors to detect its guide.
8. The system requires that if the distance between any two RCUs in the convoy is greater than 6 meters, then the follower RCU cannot use IR sensor tracking and automatically switches to GPS or camera tracking.
9. The system requires that if the convoy is moving in an indoor environment then the follower RCU cannot use GPS tracking and automatically switches to IR sensor or camera tracking.
10. The RoboCon system developers and the CS568 System managers shall decide upon a range of values or specific threshold and maximum values for the light conditions and the distance range to detect which sensor out of GPS, IR, or camera must be used for tracking the guide.

4.2.3 Recharge Mode



1. The system allows the charging stations in the route diagram to broadcast their location over WiFi to the convoy.
2. The system requires if the distance between charging station and the convoy is less than 10 meters, then each RCU in the convoy has to check the remaining battery power.
3. The system requires that if any RCU has battery remaining less than 20% , it will send a message to all the other RCUs via WiFi to stop the convoy temporarily and switch the convoy to recharge mode.
4. The system supports that all the RCUs having battery remaining less than 20% can go to the charging station one-by-one and recharge themselves.
5. The system allows the RCU to record its position before it went into the charging mode and resume its original position in the convoy once that particular RCU has finished charging.
6. The charged RCUs must send a signal to the convoy indicating their readiness to get back into the movement mode.
7. The system shall ensure that all the RCUs are within 6 meters of each other after the charged RCUs resume their position.
8. The system allows the convoy to switch to movement mode from recharge mode when all the RCUs with battery remaining less than 20% have finished charging.
9. The CS568 Systems Management group can step in to maintain the system.The system shall keep recording the battery usage data in real time using the ACU. This shall be required in case one of the RCUs gets discharged before encountering a charging station.



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5 Other Non-functional Requirements

5.1 Safety Requirements

1. When testing the RoboCon system in the outdoor environment, the space should be larger and there should be no unmanageable obstacle.
2. The Off-the-Shelf components that are used to assemble the hardware platform should be tested beforehand, else the three operational modes: the convoy formation, the movement mode and the recharge mode will not work properly.
3. The ACU consists of Microsoft Windows 7 OS and the GUI. The stakeholders use it to configure the system and observe the recorded performance metrics. The security of the system should be assured as there is potential risk of the system being hacked and the readings and user interface controls being manipulated. The mathematical precision of the performance metrics is very important for both experimentation and demonstration and that shall not be compromised.

5.2 Software Quality Attributes

The RoboCon system needs to have the following attributes for user - friendly functioning and precise results:

1. **Adaptability** : During the experimentation and demonstration of the Image Processing and Artificial Intelligence algorithms, the RoboCon system must be adaptable to the varying conditions.

During experimentation, when a variety of image processing and AI algorithms are being tested to find the best algorithms, the system should be flexible and adaptable enough to be able to handle the functionality of multiple algorithms.

During the demonstration scenario, the system should be able to adapt to varying surrounding conditions like low light, large distances and indoors or outdoors.

2. **Availability:** The system must be available for operation in all situations and testing conditions and during operations, data analysis and recording performance metrics.

3. **Correctness**: The results of the performance metrics should be precise, so that results of multiple algorithms should be compared efficiently. There should be no metrics abuse. It is the responsibility of the CS568 System algorithm developers to provide good quality metrics to analyze the performance of the system.

Following conditions should be

4. **Reliability:** All the components of the RoboCon system should be reliable to provide mathematically efficient results for the performance metrics.

5. **Interoperability**: The RoboCon system consists of eBox 3854 computer and an Administrative Control Unit, with the former running on Fedora Linux OS and the latter running on Microsoft Windows 7 operating system. The interoperability between these two different operating systems should be managed.

6. **Reusability:** The system shall be reusable for different image processing and artificial intelligence algorithms. The CS568 system algorithms developers should be able to backup the data for performance metrics of one experiment and start a new experiment using the same components and same system.

7. **Portability:** The RoboCon units should be light enough so that they can be used at different locations to test in different conditions and locations like low light, large distances, indoors and outdoors.

8. **Robustness:** The system should have enough memory for recording perfomance metrics and enough processing power for repeated experimentation and demonstration. It should not crash midway.

9. Testability: The system should be capable of being tested for upto 1000 transactions per minute. It should be testable for metrics like battery usage of RCUs, total travel time, number of messages exchanged between RCUs, performance in different lighting conditions, distance between two RCUs, locations during different operation modes, recharge status, different image processing and artificial intelligence algorithms, etc.