Carnegie Mellon University

Robotics Capstone Project

Requirement Specifications and Analysis

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1 Executive Summary

This report provides a requirements specification for our robotics capstone project. Through this document we aim to sufficiently and suciently outline our project.

1.1 Project Overview

The goal of this project is to build a multi-agent system that collaboratively and efficiently recreates inputted images at variable scale. This system can be used for either reproducing works of art on a larger scale for aesthetic purposes or for marking elements of infrastructure. By using a team of robots that work together, as opposed to a single robotic system, we hope to gain greater efficiency as well as explore various coordination schemes.

1.2 Document Outline

Following this executive summary, we begin by outline the purpose of our project, including its goals (Sec. 2.1) and motivation (Sec. 2.2). We detail both our intended scope in this project (Sec. 2.3) and assumptions we make about our environment and operation (Sec. 2.4).

Next we review the requirements of our system (Sec. 3). We begin by identifying our functional requirements (Sec. 3.1), which define the functionality of our system. Next we detail our non-functional requirements (Sec. 3.2), which provide us with testable performance benchmarks.

We then identify scenarios where our system could be deployed (Sec. 4). This various scenarios informed our requirements. **RH: Change order to put requirements last?** Finally, we describe the various use cases of our system (Sec. 5).

2 Project Description

We plan to build a multi-agent autonomous robotic drawing system. Our goals, motivation, scope and assumptions are provided below.

2.1 Product Goal

The goal of our project is to use robotic to bring people ideas on paper into a reality. We aim to build a system that takes an image as input and reproduces that image on some surface, such as the ground, poster or pavement. This direct interaction with the physical world drives much of our design, as well as the need to use a dispensible writing tool, such as chalk or a marker.

By using multiple robots we hope to efficienly decompose a possibly large task into smaller, independent pieces in parallel. In doing so we can also explore various coordination and scheduling strategies that naturally arise in a multirobot scenario.

2.2 Motivation

Traditionally robots have been pitched as excelling in the three D's: dull, dirty and dangerous. Our project primarily focuses on automating a dull task. The United States has nearly 47,000 miles of interstate highway and more than 5,000 aiports with paved runways **RH: citations needed**. Each of these pieces of infrastructure in delineated and marked with drawn lines, which, when worn, must be repainted. These tasks are time consuming, expensive and, in many occassions, dirty **RH: citations needed**.

By enabling robotic automation in painting these lines we can improve the quality of our infrastructure while saving time and money in the long term. We can expand past transportation infrastructure to sporting arenas. Sports such as baseball, football or American football have fields with markings that must be regularly maintained to insure fair game play.

While this robot can serve a very functional purpose, it is not without its playful side. The robot can potentially be used a children's toy for bringing the imagination of drawings to life.

2.3 Product Scope

While our robotic system has a great deal of potential, we want to insure that we can reasonably achieve testable goals. Therefore, in this section we will discuss robotic function and scenarios which are out of scope of this project.

We describe as system has being a multi-agent system. Based on our task, the number of robots in the system could scale up immeasurably. Due to time, cost and planning constraints, we begin with a mutli-agent system of two robots.

In our motivation and goal, we mention large scale applications such as airport runways and stadiums. However, for ease of testing we intend to primarily target this early version to smaller scale projects, such as drawing a design on a large, indoor poster. Inherently, there is little that prevents our proposed project from scaling in this dimension aside from increasing the durability of our system. This level of durability, to functional well outside, is considering out of scope at this point.

In describing the functionality of our robot, we have purposefully not specified the eact type of writing implement. There are many possile tools including by not limited to chalk, spray paint, markers, liquid chalk, etc. While we hope to explore several of these options, we do not anticipate being able to explore all options equally.

Delving further into writing implements there are also many smaller, interesting subpoints that we do not believe we will be able to build, such as drawing with multiple colors simultaneously or accounting for a larger variety of sized writing tools.

2.4 Assumptions

In designing and parameterizing the needs of our system we will make the following assumptions about or environment and operation:

A1: We assume that the robots are working on flat, homogenous surface. This disqualifies uneven or muddy ground, which is considered out of scope (Sec. 2.3).

A2: We assume that the writing implement being used by each robot in the system can be loaded into the robot manually by a human. Thus we do not expect our robots to autoload.

A3: We assume that the writing implement can by used by making contact between the tip of the implement and ground, such as a pencil. This assumption removes using writing tools like spray paint.

A4: We assume that between the robots and any controlling host we have near perfect, clear communication. Therefore we will not account for scenarios with excessive noise that would compromise robot communication.

3 Requirements

We outline our systems requirements, both functional and nonfunctional. For each requirement we provide a number, for each of reference, a short description and a longer explanation. We prioritize our system requirements on a Likert scale from 1 to 7, detailed below.

	Lowest (1)	Low	Medium-Low	Neutral (4)	Medium-High	High	Highest (7)
Priority	☐	☐	☐	☐	☐	☐	☐

3.1 Functional Requirements

FR1: Move in 4 Directions Priority 1

· Fill in more details

FR2: Autonomous Priority 1

· Fill in more details

FR3: Robots Localize Globally and Locally Priority 1

· Fill in more details

FR4: Safe Priority 1

· Doesnt run into things. No dangerous external parts

FR5: Within Bounds Priority 1

· Stay within bounds of drawing

FR6: Change Tools Priority 1

· Easy to swap out tools

FR7: Drive Control System Priority 1

· Details

FR8: Turn on or off writing tool Priority 1

· So lift pencil up and down while moving. That way doesn't have to be continuous lines

FR9: Input drawing Plan Priority 1

· how well can you give it commands

FR10: Robots Know Progress Priority 1

· Keep track of how much you have drawn

FR11: Kill Switch Priority 1

· immediately powers off robots for safety

FR12: User Interface to robot Priority 1

· how it gets controlled

FR13: Be In Budget Priority 1

· how it gets controlled

FR14: Documentation Priority 1

· Keep code and design documentation

3.2 Non-Functional Requirements

NFR1: Portable Priority 1

· Small, can be carried, easy to move around. Weight less than 50 pounds. Size: bigger than 2 foot cube

NFR2: Completes Task in Timely manner Priority 1

· Details

NFR3: Quality Priority 1

· Matches input well.

NFR4: Mobile App Priority 1

· Neil go nuts on your bullshit

NFR5: Reliability Priority 1

· Percent up time

NFR6: Battery Life Priority 1

· Needs to last

NFR7: Fault Tolerance Priority 1

· Needs to last

NFR8: Coordination Priority 1

· dont duplicate work or overlap

NFR9: Efficiency Priority 1

· split up work evenly

4 Scenarios

Include pictures in this section

4.1 Chalk Drawing

Drawing large scale items on blacktop/asphalt. People draw for message around campus, proposal, community annoucements

4.2 Parking Lot Lines

Redraw parking lot lines. Can be expanded for highway drawing or street markings. Add pavement lines specifications and details

also lines at airports for runways (get specs)

4.3 Sport Lines

Draw lines for football, american football, etc goal lines and posts.

5 Use Cases

5.1 Reload writing implement

Summary: Actors: writing tool Precondition: no writing tool in the system, or one that no longer works Postcondition: system has working writing tool Alternative: - improper loading results in robot alerting user. Other systems - other robot agents know broken robot cannot draw and replan accordingly Description:

5.2 Process input image

Summary: Actors: image, human Precondition: no existing image being drawn Postcondition: image processed and ready for work distribution between agents Alternative: report error on image processing failure. Description:

Figure 1: This is an example caption

5.3 Localization

5.4 Scheduling and Robot Planning/Coordination

SHOULD THESE BE SEPARATE

5.5 Move robot

5.6 Deposit ink/marker/writing stuff

5.7 Return Home

Referring to the image below, Fig.1.