Carnegie Mellon University

Robotics Capstone Project

Concept Evaluation

Friction Force Explorers:

Don Zheng
Neil Jassal
Yichu Jin
Rachel Holladay

supervised by
Dr. David Wettergreen

Version 1
October 26, 2016

Contents

List of Figures

1 System Description

NJ: Brief discussion introducing project still not done. Properly insert diagrams

A description of the overall system diagram follows. Descriptions of individual subsystems can be found in Sec. 5.

The initial process begins offboard, where users will generate an input image and process it through a scanner. Image processing will then occur, where the input is processed into a format compatible by the planner and work distribution subsystem Sec. 5.6. Moving forward, the planner module will take in updates to current robot progress and use it to update commands it sends to robot agents.

Commands are sent to individual systems onboard robot agents. Communication protocols are able to send information both to and from the work planner to robot agents (Sec. 5.7). From here, onboard systems are separated into three subsystems: Localization (Sec. 5.3), Locomotion (Sec. 5.2), and Paint Distribution (Sec. 5.1). The paint distributor is involved with all commands regarding engaging and disengaging the writing implement to output paint onto the writing surface. Locomotion is the drive system, which engages wheels and motors used for movement. This subsystem also includes any motion-related safety mechanisms, such as quickly stopping. The Localization subsystem works to determine the position and orientation of an individual robot agent. This subsystem takes input from the sensor module (Sec. 5.9), which provides data about the surroundings for the localization system to process.

The sensor module gets data from external vision markers (Sec. 5.11) for processing by localization. It is important to note that the sensor module, along with the locomotion and paint distribution subsystems are all powered by an individual subsystem Sec. 5.10.

2 Concept Operation

NJ: Properly insert user operation diagramsconcept_operation_user.jpg

NJ: This section references requirements, not sure how to reference requirements spec document

A description of the user operation figure above is as follows. For a further explanation of the user interface, see Sec. 5.8.

Initial setup contains two simultaneous operations: adding the image to be drawn to the system, and setup of the drawing surface. Adding the input image involves generating the image, and then scanning it into the system. This satisfies requirements for input the drawing planNJ: Ref FR9:input drawing plan, and a user interfaceNJ: Ref FR12:user interface. Setup of the system involves placing the drawing surface, placing and calibrating vision markers, and finally placing the robot agents within the bounds of the drawing surface. Once both steps are done, the user can enter any required settings for their use, and begin operation. Processing of the input image is done automatically by the system and is invisible to the user.

Once the autonmous process begins, the user does nothing but observe until drawing completion. However, any errors will be reported to the user, who then has the option of fixing the issue to continue operation, or terminating the drawing process. The autonomous process satisfies functional requirement NJ: Reference functional requirement FR2:Autonomous.

3 Use Cases

RH: Rubric: Use cases provide clear insight into the system and cover a wide range of possible interactions. Develop complete use case and detailed scenarios for the concept

RH: Question: how is this different from in the requirements?

4 Artistic Sketch of System

RH: Rubric: Sketch is very clear, providing significant insight about the design.

RH: Need to either make computer sketch and take a bunch of screen shots or draw a bunch of different views. RH: Explain how some physical aspects lead us to achieve our requirements.

5 Subsystem Descriptions

RH: Rubric: All subsystem descriptions provide a clear idea of each subsystem and any critical component is identified.

RH: Some subsystems might need their own diagram

5.1 Paint Distributor

5.2 Locomotion

drives individual robot. want to go sideways. have enough clearence for writing tool. based on trade studies need wheels.

5.3 Localization

take in input from sensory module and determine accurate position and orientation of individual robot. communicates through communicator to scheduler.

5.4 Input Image Scanner

put in input image. probably take or generate picture then handoff to image processor. critical component: high enough resolution sensor to capture image. has user interaction.

5.5 Image Processor

needs to process image. take image scanned by user and parse it into input regonizable by work scheduling, distribution and planning

5.6 Work Scheduling, Distribution and Planning

see software architecture. couple small senteces.

5.7 Communication

antenna fit within requirements. have certain range. allow multi agent communication. want to be fairly speedy and realiable. possible communication protocols: bluetooth, wifi,

5.8 User Interface

Insert flow chart for box s̈pecify drawing settingsf̈rom concept operation

5.9 Sensor Module

interface to vision markers and localization. Allows for localization. Also needs to be small enough to fit in footprint.

5.10 Power System

Needs to onboard power. probably battery. Battery needs to small and light enough to satisfy the size and weight requirement.

5.11 Vision Markers

Fixed. Put markers on all 4 sides. Calibrated in initialization. Reference trade study

6 Trade Studies

In creating our multi-agent drawing robot, we face design trade-off and decisions for many of our major subsystems detailed in Sec. 5. We investigate four major decision points in the following brief trade studies. Our discussions led to a few technical solutions, when we feel we have enough data to make a reasonable decision. However, for some of our discussion points, further testing and prototyping is needed to evaluate our options fairly. For these points we lay out brief prototyping plans below.

6.1 Localization Method

Localization is an important factor for multi-agent planning that must be accurate in both position and orientation. Keeping in mind limitations in price and ease of use, there are two major methods for localization: vision-based, and marker based. They are described below.

Vision-based localization involves using cameras or other sensors to directly obtain information on the environment, and then localize the robots in the system based on found landmarks in that environment. One example of this is SLAM (Simultaneous Localization and Mapping), often used by autonomous vehicles to build a map and localize to it at the same time. In this system, robots could build a small map of their surroundings, then match their location to features they find in the environment. Benefits include being location agnostic, and requiring no additional parts or external setup. However, pure vision systems are difficult to calibrate and accuracy can depend heavily on static surroundings, which is not something this system can guarantee.

The other main choice of methodology is marker-based. Using markers placed around the drawing surface, robot agents can quickly locate these markers and their position relative to each one, and consequently triangulate their position and orientation. While requiring additional setup and more parts to calibrate than vision-based localization, existing technology makes it convenient and cheap to get marker-based localization working quickly. One example of a marker-based localization system is AprilTags [1], which can be described as 2D barcodes placed in a scene. Within marker localization, however, are two subcategories: passive and active. Passive markers do not output any information, and exist for the robot agent to observe and triangulate accordingly. AprilTags are an example of a passive marker system. On the other hand, active markers will "look at"robot agents to determine where the agents are, rather than the robots searching for markers. While less common, active systems behave well in conditions when the markers may not always be easily visible to robot agents [?].

Given the convenience and ease of use of marker-based localization, it is clearly the better choice. However, it is more difficult to determine whether using active or passive systems will be more effective. A prototype for each system should be made for further evaluation.

6.2 Locomotion Method

One of our functional requirement with the highest priority (FR1) is to be able to move in specified directions with a high degree of accuracy. Additionally, a medium high priority functional requirement (FR 9) is a drive control system that enables this movement.

Therefore, it is clear from our requirements that locomotion is critical to our robot's performance. When considering locomotion options there are three large categories: flight, legged and wheeled.

Our drawing occurs on the two dimensional plane. Therefore, any flight based system would have to heavily constrain its third dimensional of position and two additional dimensions of orientation when drawing. Practically speaking, this seems to over-complicate the problem with little additional gain.

Therefore we are narrowed to a legged or wheeled system. We are inspired by the wide spread success of wheeled robotic systems and especially appreciate their stability, a critical concern when carefully drawing images. While a legged system would have the ability to traverse uneven terrain, this is not necessary in our project due to our assumption (A3) that the drawing surface is flat and homogenous.

Therefore, in our analysis we have concluded that our agent's drive system should be wheeled. In our next analysis we further detail the type of drive train.

6.3 Drive System

In continuing to prioritize our functional requirement (FR1) of being able to in specified directions, we investigate possible drive systems.

Three similar drive systems first come to mind: differential drive, ackerman steering and four-wheel steering. Differential drive on a robot typically consists of two independently driven wheels and a non-driven wheel. Moving up in complexity and taking after some cars is ackerman steering, where the back pair of wheels is fixed in orientation but the front pair can pivot. In more complex is four-wheel steering, which is similar to ackerman steering but allows the back wheels to also pivot. However, these systems suffer from the fundamental issue of being nonholonomic. Therefore, while they could achieve full mobility, this might complicate drawing and path planning.

Therefore instead we want an omnidirectional base that is holonomic. This can be achieved with omniwheels, perhaps more commonly, with mecanum wheels.

6.4 Drawing Tool

RH: No sure. Need to prototype.

7 Software Architecture

RH: Rubric: Describe the system software architecture and detail diagrammatically.

RH: Diagram of software flow. Need think thru.

8 Installation

Setup for the demo of this system requires a drawing surface and setup of the vision markers under specific conditions. Conditions for setup must be in line with the scope and assumptions made for successful operation of the system. Maintaining scope of the project, as described in **NJ: Reference Requirements section 2.3: Product Scope**, the drawing surface must be placed indoors and in an obstacle-free area. For compliance with **NJ: Requirements spec Assumption 2.4 (flat surface)**, the surface chosen must be a flat and homogenous surface.

Once the drawing surface has been placed indoors on a flat surface, vision markers must be set up and calibrated. As per Sec. 6.1, localization markers must be placed around the edges of the drawing surface. These markers must then be calibrated by the user, who will input marker locations into the system. The localization markers serve as calibrated base points from which the robot agents will determine their position and orientation.

References

[1] E. Olson, "Apriltag: A robust and flexible visual fiducial system," in *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pp. 3400–3407, IEEE, 2011.