Chalk Robot

Project Proposal
ECE 445: Senior Design

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I. Introduction

Title - Chalk Robot

This is an idea proposed by MIT Lincoln Lab. Currently the only way to draw pictures or words on the floor or sidewalk is to actually draw it by hand. There are a few disadvantages to this method. First of all, it is time consuming and back breaking for a person to crouch down and chalk the floor. Then the end product is often depends largely on the skill and artistic flair of the individual drawing the image. It is also difficult for the average person to replicate images or logos with a great deal of accuracy. The chalk robot aims to automate this process, making chalking the sidewalk a much simpler task.

Objectives

Goals and Function:

The goal of this project is to develop a robot system that can draw an image on the ground with chalk. This will be a 2-wheel mobile robot with a chalk mechanism. The robot will be able to take in an image file from a usb stick, move accordingly on the floor to draw the image outline.

Features:

- Position tracking relative to the starting point
- Bidirectional motor control allowing for forward, backward motion, turning-on-the-spot
- Control of the chalk mechanism (armature and automatic dispensing)
- Drawing outline of image file
- Writing words from text file
- Up to 2m x 2m range of drawing

Benefits:

- Users can use our robot to easily print chalk advertisement on the sidewalk
- Image outline can be chalked with high level of similarity

II. Design

Block Diagram

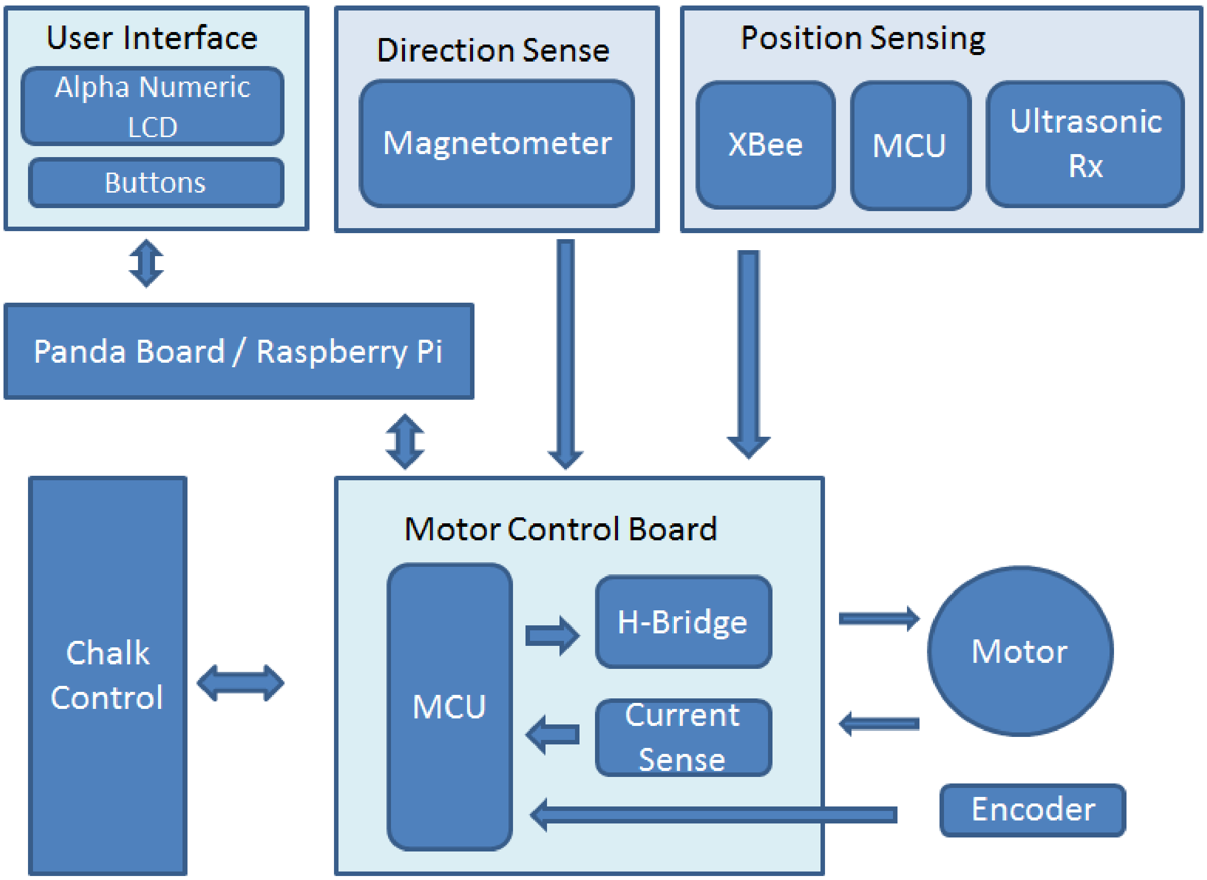

Figure 1: Robot Block Diagram

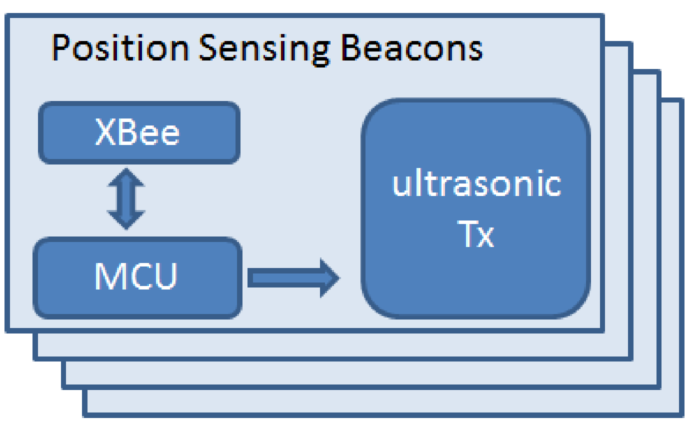

Figure 2: Position Sensing beacons Block Diagram

Block Description

User Interface

The user interface consists of a simple alpha numeric LCD screen and buttons that might be treated as a keypad. This unit will be connected to the panda board and will aid the user in determining the image to draw (in case we have multiple image/text files in the usb flash drive).

Panda Board (Image processing)

The board will take the image or text file from a usb flash drive, produce an outline of the image and create vectors out of it. The vectors will then be converted to sequences of movement (where to move and when to write) to be sent to the microcontroller in the motor control unit. After each sequence is transmitted to the microcontroller, the panda board waits until the movements within that one sequence to finish. The microcontroller will send a command to the panda board once the sequence has finished and will wait for the next sequence. The specifics of how the motors are controlled will be explained in the Motor Control Board section.

Position Sensing (With Position Sensing Beacons)

Position sensing of the robot would be done using an overall setup which includes the position sensing module on the robot and 4 additional beacons. The position is calculated through a combination of synchronization, time-of-flight and trilateration. The position sensing module on the robot would have a microcontroller to control the clock synchronization and handle the calculations required to determine its current position, an Xbee to broadcast an RF signal to synchronize the beacons, and an ultrasonic receiver. Each of the beacons would have its own microcontroller, Xbee receiver and ultrasonic transmitter. They will be placed on the four corners of the predefined workspace.

The cycle begins with a transmission of the synchronization pulse from the robot to the beacons via the Xbees. Afterwhich, based on their order, each beacon will take turn to send an ultrasonic pulse. Using the time reference from synchronization, and based on the time it receives each of the ultrasonic pulses, the robot can calculate the time-of-flight of each ultrasonic pulse. This in turn relates to the distance the robot is away from each beacon. Using trilateration, the microcontroller in the position sensing module on the robot will determine its exact position in the workspace.

Direction Sensing

This simple block's job is only to give information about where the robot is facing. The functionality can be covered by using a magnetometer. The information should be given to the Motor Control Board as a feedback so that it can control the robot to turn to the appropriate direction as required.

Chalk Control

The chalk control mechanism consists of a third-class-lever (a pivot on one end and the load on the other end, with a force applied in between the ends) and a chalk gripper on the load end. The force applied to the lever is achieved by the operation of a servo. When we do not want to write, the servo will push the lever up until the chalk is about one inch off the ground. When we want to write, the servo will let go of the arm and allow gravity to push the arm downward.

The last operation is when the chalk is too short. We will have some kind of contact switch that will be activated when the arm is too low. Once the switch is activated, the gripper will let go of the short chalk and the arm will be adjusted to the desired writing position. A new chalk will then be dispensed in the gripper grips the new chalk. Normal operation then continues. This whole operation will be controlled by the microcontroller in the Motor Control Board since the chalk mechanism needs to coordinate with the robot movement.

Motor Control Board

This controls the power to the motors to move the robot to the x-y location desired from the panda board. It consists of a microcontroller which sends pwm to the H-bridge driver which determines the voltage applied to the motor. Current sensing is down for either current control or just current limit. Feedback from encoders is used for velocity control of both motors. The microcontroller also receives position and direction information and compensates for any error from the encoders.

III. Requirements and Verification

Requirements and Verifications

Requirements	Verifications
1 Image processing a The outline should be completely extracted from simple images b Converts text files into vectorized images.	1 Image Processing a Test with real image obtained via USB, and compare the produced outline with the outline of the image itself. The produced outline can be saved into the USB again, and the two files can be printed out to be tested. The outlines should be identical. b Given a text file, the image processor should be able to produce line vectors resembling the letters in the text file.
2 Motor Control Board a Able to operate at supply voltage 7V ~ 25V. b Maximum continuous output current of 2A per motor. c Peak instantaneous current of 3A per motor. d Able to vary speeds from 0 - 20,000 encoder pulses per 10ms. e Position control to an error or ± 1cm	2 Motor Control Board a Send commands to move motor while varying the supply voltage from 7V to 25V and check for functionality. b Send command for current output of 2A with short circuit load instead of motor. c Send command for current output of 3V with a load of three 1Ω resistors in series, and short it to 1Ω for 0.5s multiple times and check functionality after. d Send commands for motor to move at set velocity and measure the RPM of wheels. Repeat the same test over different set velocities. e Send commands for robot to move in

	the perimeter of a $1m^2$ square (multiple times). Robot's final position should be within 1cm of the initial position.
3 Position Sensing a Able to receive pulses from different beacons cleanly with high enough signal to noise ratio so that each pulse can be identified accurately. b Track the time-of-flight of each pulse relative to the reference pulse accurately within 1% of the result calculated by hand (using math). c RF transmitter should be able to send a reference pulse to all the ultrasound unit (TX/RX) simultaneously.	3 Position Sensing a Have the beacons send pulses in turn (as how we would do it for normal operation) and hook up the receiver to an oscilloscope. Distinguishable and stable pulses are expected to be seen on the scope. b The setup is the same as in part a, but we need to confirm that the time-of-flight information is accurate. Have the robot be placed in different locations inside the area of operation and observe the result. For example, if the robot is placed in the middle, the pulses will appear like a perfectly periodic signal(equal spacing). c Hook up all RF modules in each beacon to a single oscilloscope (a scope that can handle 4 input might be needed) or to a single DAQ for measurements in LabVIEW. The base station sends a reference pulse, and we would observe the 4 pulses from each beacon overlapping.
4 Chalk Control a When writing, the portion of the chalk touching the ground should be exactly in the middle of the two wheels, and the	4 Chalk Control a Put ink on the wheels so that they will leave mark as the robot moves. Send commands to write some squiggly lines

chalk orientation should be as upright as possible. b Through a sequence of controls, dispense new chalk as the chalk gets too short. c During chalk replacement, the robot should not move and continue the drawing where it left off. The line should be as continuous as possible.	over 1 to 2 meter. The chalk line should fall exactly in between the two ink line. b Send command to start writing with no chalk. The contact switch will be activated immediately and chalk dispensing mechanism will start. After the new chalk is gripped firmly, the robot should start drawing. c Start with a very short chalk (short enough to make the armature just above the contact switch), and make the robot draw a squiggly until the chalk needs to be replaced. The chalk dispensing mechanism will then start and normal operation continuous. To check the continuity, just pick up the robot and examine the line drawn.
5 Direction Sensing a Able to tell where the robot is facing with an accuracy of at least ten degree (full rotation is 360 degrees)	5 Direction Sensing a Turn the robot around and observe the orientation given by the magnetometer.
6 User Interface a Alpha numeric LCD should display the information correctly: file name and format (whether its is a text file or an image file). b Choose the file that we want to draw correctly.	6 User Interface a Make sure that all letters and numbers can be displayed correctly. b Upon pushing the button, the LCD should respond accordingly, highlighting the correct choice indicated by the user.

Tolerance Analysis

The most sensitive part of the entire system is the accuracy of the robot position. We will have ultrasonic transmitters put on fixed locations, and the robot will have an ultrasound receiver. According to the block description above, the overall setup itself will be a challenge: to put the beacons accurately. Another difficult task is to make all the transmitter-receiver and wireless communication part operate in a total synchronous fashion. All these will affect the accuracy of the robot position.

Rigorous testing needs to be done to ensure that the position is within ±1cm of the exact known position. The general test is to mark the initial position of the robot, instruct the robot to go over a long distance and come back to the initial position. The final position of the robot should be within the error tolerance relative to the initial position. To test corner cases, deliberately send commands to the microcontroller to make the robot moves around (close to) the border of operation.

IV. Cost and Schedule

Cost Analysis

Parts

Item	Part Number	Qty	Unit cost	Total Cost
Pandaboard	---	1	$180.00	$180.00
Geared DC Motor	Pittman GM8224S014	2	$250.00	$500.00
Servo	HiTEC HS-311	2	$7.99	$15.98
Potentiometer	---	1	$1.00	$1.00
Encoder	1024 P/R quadrature	2	$39.95	$79.90
Position Sensing MCU	dsPIC 30F4011	5	$7.00	$42.00
Motor Control MCU	LPC1114fn28	1	$3.00	$3.00
Ultrasonic Transmitter	Murata MA40S4S	4	$6.93	$27.72
Ultrasonic Receiver	Murata MA40S4R	1	$5.57	$5.57
Xbee 1mW	---	5	$23.00	$115.00
Robot Battery	TP22504SP30	1	$79.99	$79.99
Beacon Battery	YTB13004	4	$20.99	$83.96
Magnetometer (Digital Compass)	HMC6352	1	$34.95	$34.95
Alpha-numeric LCD	Hitachi HD44780	1	$17.95	$17.95
Push Buttons	---	5	$0.35	$1.75
			Total:	**$1,188.77**

Labor

Name	Hourly Rate	Hours/week	Weeks	Total*
Neil Christanto	$40	14	12	$16,800
Enyu Luo	$40	14	12	$16,800
Leonard Lim	$40	14	12	$16,800
			Total:	**$50,400**

*Total Labor(per person) = Hourly Rate X Total Hours X 2.5

Grand Total

Total Labor	Total Parts	Grand Total
$50,400	$1,188.77	**$51,588.77**

Schedule

Wk	Enyu Luo	Neil Christanto	Leonard Lim
2/4	Work on proposal, get components needed	Work on proposal, get components needed	Work on proposal, get components needed
2/11	Schematics of motor control board and direction sense	Configure the Xbees to do RF communication correctly. Program the microcontroller just for the Xbees.	Find/Write code for conversion of simple bmp images to outline.
2/18	Finalise schematics and start PCB design of motor control board	Algorithm for trilateration implemented using microcontroller. Schematics of RF comm and ultrasonic sensing for DR.	Find/Write code to vectorize outline. Either use existing standards or create our own.
2/25	Design Review. Finalise PCB Design. Programming of microcontroller for motor control board(pwm output, current sense, encoder reading)	Design Review. Setup beacon transmitters and position sensor module on the robot. Test for turn based pulse transmission. Program the ultrasonic TX/RX.	Design Review. Integrate code into Panda Board and test.

3/4	Programming of microcontroller for motor control board(communications with other sub components of robot)	Integrate the RF comms and ultrasonic sensing on breadboards. Robot can get rough position.	Program the user interface to interact with Pandaboard.
3/11	Individual Progress. Soldering PCB	Individual Progress. PCB design for the beacons and the base station on the robot.	Individual Progress. Test Functionality of chalk mechanism.
3/18	Spring Break	Spring Break	Spring Break
3/25	Test Functionality of motor control board with robot	Solder PCB, test functionality of everything with the PCB.	Test requirements of chalk control.
4/1	Test requirements for motor control Integrate with ultrasonic sensing	Test requirements for position sensing and verify that everything works within tolerance limit. Integrate with motor control board.	Integrate Pandaboard with motor control board.
4/8	Fix bugs.	Fine tuning, debugging.	First complete test run.
4/15	Begin writing Final Paper. Testing, corner case, rigorous test, unlikely input, etc.	Begin writing Final Paper. Testing, corner case, rigorous test, unlikely input, etc.	Begin writing Final Paper. Testing, corner case, rigorous test, unlikely input, etc.
4/22	Demo	Demo	Demo
4/29	Presentation	Presentation	Presentation