Eraser-Bot

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Requirements Document

Version 1.0

Submitted: 9/16/14

1. Introduction

1.1. Purpose

The purpose of this document is to describe the product requirements for the Eraser-Bot. University of Colorado professors and students serve as the primary market for initial product introduction and testing. This project also fulfills the requirements of senior design for the Ohm-bres capstone group.

1.2. Scope

Lecture time is extremely valuable to both students and teachers at both the high school and university level. Since material is usually presented at a fast rate, a portion of the class time is wasted erasing the whiteboard. An automated solution for intelligently erasing a whiteboard during class increases the efficiency of the lecture, since the instructor can instead spend the time passing out papers, interacting with students, or continuing to lecture. In order to achieve this solution, the device operates with minimal human interaction. The Eraser-bot performs its task using simple directions from a mobile application, limiting the amount of overhead in the device's operation.

1.3. Definitions, Acronyms, and Abbreviations

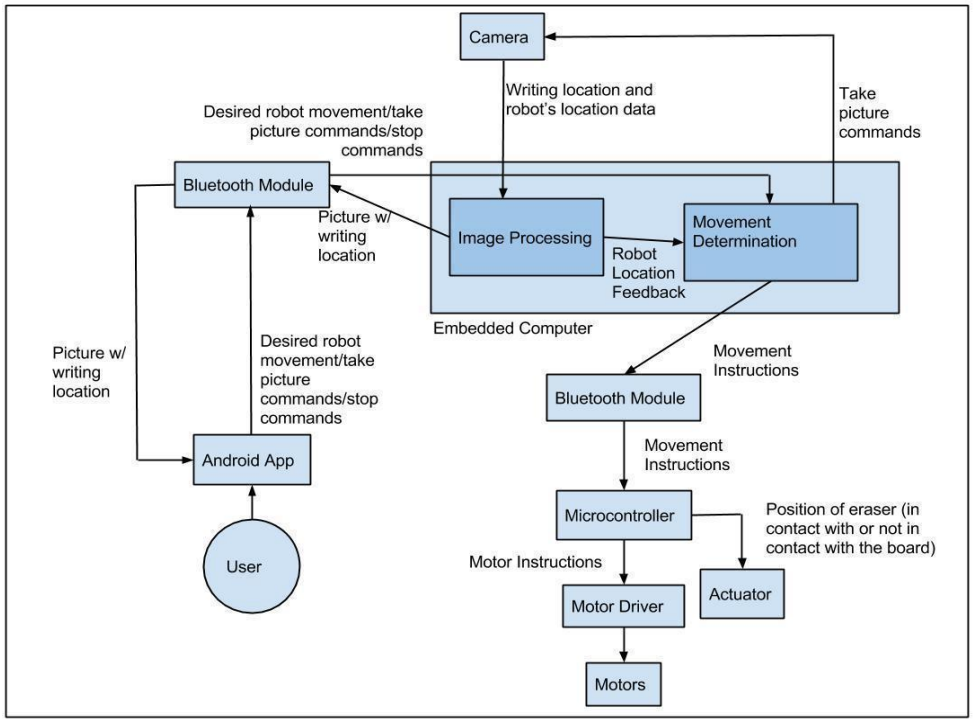
1.4. References

Ford, Ralph M., Coulston, Chris S. *Design for Electrical and Computer Engineers*. McGraw-Hill. New York, 2008.

1.5. Overview

This document outlines the requirements and use cases of the whiteboard erasing robot.

2. Overall Description



2.1. Product Perspective

Commented [1]: Should include only a few big blocks. For instance, you could have the phone, camera, image-processing embedded computer, and board eraser as blocks.

2.1.1. System interfaces

2.1.1.1. The Android App has two-way communication with the embedded computer over bluetooth.

2.1.1.2. The embedded computer communicates to the robot over bluetooth

2.1.2. User interfaces

2.1.2.1. The user can interface with the android app through the on screen interface.

2.1.2.1.1. Main screen has three locations for “Erase All,” “Take Picture” and “STOP”.

2.1.2.1.2. If “Take Picture” is selected, screen has image of board with highlightable areas of identified writing and “Save,” “Erase,” “Edit options” and “Cancel”

2.1.2.1.3. If “Edit options” is selected, the picture of the board remains but the highlighted areas are alterable.

2.1.2.2. The user interfaces with the embedded computer/camera module through a single button, which turns it off and on.

2.1.2.3. The user interfaces with the robot through a single button, which turns it on and off.

2.1.3. Hardware interfaces

2.1.3.1. The camera interfaces to the embedded computer through a bus, built in to the module.

2.1.3.2. The robot has a removable eraser pad.

2.1.3.3. Eraser can be raised and lowered.

2.1.3.4. The microcontroller interfaces with the wheels via a motor driver.

2.1.4. Software Interfaces

2.1.4.1. The Android application interfaces with the bluetooth module in the phone.

2.1.4.2. The embedded computer interfaces with a bluetooth module.

2.1.4.3. The camera module sends image data to the embedded computer.

2.1.4.4. The robot microcontroller sends commands to the the motor driver.

2.1.5. Communications Interfaces

2.1.5.1. Bluetooth is be used for communication between Android and embedded computer, and between the embedded computer and the robot.

2.1.6. Site Adaptation Requirements

2.1.6.1. The camera is mounted with full view of the whiteboard.

2.1.6.2. The charging station is mounted on the corner of the whiteboard.

2.2. Product Functions

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This section describes the features of the product, in priority order.

2.2.1. High Priority

2.2.1.1. The Eraser-Bot completely removes dry-erase marks on a whiteboard.

2.2.1.2. The Eraser-Bot erases marks anywhere on the whiteboard.

2.2.1.3. The Eraser-Bot can erase the entire whiteboard in one battery life cycle.

2.2.2. Medium Priority

2.2.2.1. The Eraser-Bot moves about the board fast enough to keep up with normal erasing requirements during a lecture.

2.2.2.2. The user selects a section of the whiteboard to be erased from a live image of the whiteboard.

2.2.2.3. The Eraser-Bot only erases sections of the whiteboard with dry-erase marks and ignores clean sections.

2.2.2.4. The Eraser-Bot operates during an entire class without needing to recharge.

2.2.2.5. The eraser is easily replaceable.

2.2.3. Low Priority

2.2.3.1. The Eraser-Bot has an inductive charging station in the corner of the whiteboard, removing the need to physically plug the robot in.

2.2.3.2. The Eraser-Bot has the capability to erase a section of the whiteboard certain time after marks have been made.

2.2.3.3. The Eraser-Bot uses whiteboard cleaning fluid to thoroughly clean the board after a lecture.

2.2.3.4. Investigate chalkboard erasing mechanisms.

2.3. User Characteristics

Users	Teachers, Students and Janitorial Staff
Required Knowledge	The user must have experience using Android applications in general. No knowledge of robotics is required.
Responsibilities	● The user must install the camera and the charging station once. ● During lecture, the user must use the Android application to control the Eraser-Bot. ● The user must turn on the camera module and Eraser-Bot. ● Periodically, the user must charge the Eraser-Bot. ● The user must remove and replace the erasers used by the robot.
Success Criteria	The user defines success as the Eraser-Bot being a reliable tool used for increasing the efficiency of a lecture.
Disability Accommodation	The charging station enables the Eraser-Bot to be completely autonomous, so the user does not need to be able to interact with the robot directly. Normal operation can be performed solely from the application.
Language Challenges	The application is mostly pictorial and has few words, so someone who does not speak English can operate the Eraser-bot.

2.4. Design Constraints

2.4.1. The Eraser-Bot must be able to drive on a vertical magnetic surface. Otherwise, the Eraser-Bot will fall off the board, which may damage the robot and waste class time. This leads to the following design constraints.

2.4.1.1. The Eraser-Bot must incorporate magnets near the bottom of the body.

2.4.1.2. The Eraser-Bot must be lightweight enough to overcome gravity when supported by magnets.

2.4.1.3. The Eraser-Bot must overcome the friction due the magnetic force against the board in order to traverse the board.

2.4.2. The image processing of the whiteboard must be done in real time. This leads to the following design constraints.

Commented [3]: The items you have listed are really all engineering requirements that you have imposed (and should relate to high level marketing requirements) and not ones that are being imposed externally. If the teachers, students or janitorial staff had indicated your Eraser-Bot needs to use an Atmel microcontroller for some reason, that would be a design constraint.

2.4.2.1. The image processor must process the image of the board and compute the robot's path without noticeable delay.

2.4.2.2. Results of the image processing must be communicated to the Eraser-Bot in real time, in order to maintain an optimal erasing path.

2.4.3. The Eraser-Bot cannot have any cables connecting it to the outside world, the cable would block useable sections of the whiteboard and become tangled. Therefore, wireless communication must be utilized to pass information between the camera and the Eraser-Bot.

2.5. Assumptions and Dependencies

- The whiteboard is magnetic.
- The classroom needs a location for the camera to be mounted, such as on an overhead projector.
- The user has a device running the Android operating system.
- The camera module and the Eraser-Bot charging station are in close proximity to a power outlet.
- The Eraser-bot requires mechanical parts that are manufactured at the ITLL or another machine shop. Since these tools are owned by another group, they could break or not be available for our use.
- The Eraser-bot utilizes off-the-shelf processors (TBD microprocessor and embedded computer) and electronic components such as motors, motor drivers, and magnetic devices. These parts may not perform to their specifications, or may not arrive in time to meet a deadline.

Commented [4]: Your assumption is the classroom "has" a location...

Commented [5]: Yes, so your dependency is on the tools in the ITLL being in good condition and available.

Commented [6]: These are good things to consider, although really general dependencies for all projects and not necessary to list. If you have a specific dependency on a unique item, that may be worth calling out here.

3. Specific Requirements

3.1 Marketing Requirements

1. The robot should be battery powered.
2. The system should not disturb the class.
3. The robot should have a replaceable eraser pad.
4. The robot should leave portions of the board the user does not want erased

Commented [7]: Minimum operating time per charge is a marketing req. for all battery operated products. Would yours be 12 hrs and charge at night?

Commented [8]: This could be difficult to prove. Your marketing req. serve as a contract. Upon product completion you must prove you have met these req.. The movement of a robot on a whiteboard could be distracting and disturb the class.

Commented [9]: via the Android App?

undisturbed after each task.

5. The system should be easy to install and use.
6. The system should have low cost.
7. The robot should be operated through an Android application.
8. The robot should fit in the corner of the board without interfering with the user.
9. The robot should erase the board in an efficient manner.

Marketing Requirements	Engineering Requirements	Justification
3, 5, 6	There is a simple connector used to attach or detach a whiteboard eraser pad.	This makes finding and installing replacement erasers simple for the user.
5	The eraser robot, camera module, and phone application take no longer than 1 hour to install.	This device is designed for easy implementation for people with limited technical backgrounds.
1, 5	The robot shall be capable of remaining on for 1 hour without needing to be recharged.	The robot is battery powered and must conserve power to maximize time between charges.
2, 9	The robot shall erase at least 0.5 square feet per second.	The robot doesn't improve effectiveness of lectures if the instructor must wait on the robot.
2	The robot shall be no louder than 40 decibels.	The robot needs to be quiet so that it does not interrupt class.
8	The robot's dimensions shall not exceed 12" L x 6" W x 6" H.	The robot needs to fit in the corner of the board to avoid getting in the user's way.
2	The robot grips to the board indefinitely when powered down, without slipping.	The robot can't fall off the board when it isn't being used because this presents a safety hazard.
1	The robot has a low power mode when it is not moving.	Power consumption must be reduced whenever possible to prevent poor battery life.
5, 7	The user interface is an Android application that gives the user control over what the robot erases.	This is a cheap solution accessible by a majority of people.

Commented [10]: Again, this could be difficult to prove.

Commented [11]: <$100, <$1000, etc.? Low cost to you may be very high cost to someone else.

Commented [12]: It feels like you are going through a use case scenario here, a few of these can be consolidated.

Commented [13]: This is a marketing req.

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2, 4	The robot only erases the parts of the board that contain writing.	This allows the robot to save time when erasing.
9	A camera tracks the motion of the robot as it erases the board.	On-board motion tracking is often unreliable and inconsistent. A camera provides a more reliable and accurate feedback system.
4, 5, 9	The camera processes images of the board and identifies portions of the board with writing.	Image processing makes the user interface easier to use and enables the robot to take better paths to improve efficiency.
4, 6, 7, 9	The user interface has a main screen that gives the user the ability to stop the robot, take a picture of the screen, and erase all of the writing on the board.	This keeps the user interface simple and easy to use without compromising functionality.
2, 5, 7	The Android application has a button that ends the robot's current process and its movement within 2 seconds of the button being pressed.	The user may desire that the robot stops erasing if they no longer want to lose certain information or they accidentally set it to erase.
4, 5, 7	The Android application has a button that causes the camera to take a picture of the board, process the image for selecting groups of writing, and uploads this image and information to the phone.	It is simpler for the user to choose where to erase if they are choosing directly from a current image of the board.
5, 7	The Android application has a button that causes the camera to identify all writing on the board and queues the robot to clear the entire board.	At the end of class, it is desirable to erase the entire board for the next topic or teacher. Having this mode saves time because it doesn't require a picture of the board to be uploaded to the camera.
4, 9	The robot has identifiers on the front and back used for orientation.	Since the camera is used to provide feedback to the robot for accurate movement control, these identifiers simplify processing to determine the robot's orientation.

Commented [15]: The camera wont see the front? Why is this necessary to have?

9	The camera module can determine the robot's orientation based upon the identifiers.	Without accurate detection of orientation, feedback control would become unreliable and potentially counter-productive.
5, 7	The camera transmits a picture to the phone within 4 seconds after the image is requested.	The robot is designed to add efficiency to class time. If this function takes longer than a couple of seconds, it begins to detract from this purpose.
4,9	The camera processes a photo every second for feedback while the robot is moving.	The robot requires constant feedback on its location.
9	The robot shall not deviate from its intended path by more than 6 inches without feedback from the camera correcting errors.	If the robot deviates from its path too far, it will no longer be erasing the desired writing and will reduce efficiency.
5, 9	Once the user has selected what writing to erase and communication has been established with the robot, the robot begins moving toward that destination within 2 seconds.	The robot is designed to add efficiency to class time. If this function takes longer than a couple of seconds, it begins to detract from this purpose.
2, 4	The robot can pull the eraser away from the board so that it can move over writing or images the user doesn't want removed without smearing or erasing.	For the robot to get to its necessary location, it may be necessary for the robot to move over parts of the board with writing.
5, 7	When the Android application is opened, connection with the camera module is automatically established.	The camera module performs all communication with the robot. By automatically connecting the phone to the camera, operations can be more quickly performed when a picture is requested from the camera or a command is sent from the phone to the camera module.
5	Once communication has been established between the phone and camera module, communication with the robot is automatically established.	Communication between the camera module and robot should be automatically established to increase the efficiency of the robot.

Commented [16]: You've already stated this in the row above.

5	An LED on the camera module flashes until connection is established between the phone and camera module.	The user should receive feedback quickly when the robot is out of range or not working properly.
5	An LED on the robot flashes until connection is established between the camera module and the robot.	The user should receive feedback quickly when the robot is out of range or not working properly.
5, 8	The robot moves to the bottom left corner of the board and goes into low power mode after the erase all function has completed.	The teacher may be taking the robot to another classroom after it has finished cleaning the board, so it must be reachable.
4, 5	In addition to providing the user with an image, the camera module partitions the sections of writing on the board and provides the user with these sections as possible selections.	By grouping all writing that is in close vicinity together, it makes it easier for the user to select writing they want erased.
4, 5	The app displays the areas of the board, on which writing is identified, over the image of the board.	Showing the partitions over the actual image makes the interface simple.
4, 5, 7	The user can quickly select and deselect the partitions they desire the robot to erase.	The easier the user interface is to use the more efficient our overall system can be.

4. Use Cases

Use Case UC1: Power On Eraser-Bot

Scope: Eraser-Bot

Level: Sub function

Primary Actor: Teachers, Students, or Janitorial Staff

Stakeholders and Interests:

- Teachers, Students, and Janitorial Staff: Want to use the Eraser-Bot and desire the start-up process to function correctly.

Preconditions:

- The Eraser-Bot is powered off.

Commented [17]: If your step 1 is a user action, why isn't this level a User Goal. What does the document say in the handout called WhatTheSectionsMean? Were you referencing that?

- The Eraser-Bot's batteries have sufficient charge for the robot to function properly.

Success Guarantee: A power indication LED turns on and a connection status LED blinks until the Eraser-Bot connects to the camera module. The LED stops blinking and remains lit when the Eraser-Bot is connected.

Main Success Scenario:

1. The user pushes the power button on the side of the Eraser-Bot.
2. The power indication LED on the Eraser-Bot lights up.
3. The Eraser-Bot enters into a loop trying to connect to the camera module and the connection LED blinks.
4. The Eraser-Bot connection LED lights up constantly when the connection is established.
5. The Eraser-Bot enters low-power sleep mode.

Extensions:

(3a) If the robot and camera module cannot connect, the connection LED continues to blink.

Special Requirements:

Technology and Data Variations List:

Frequency of Occurrence: Once per use.

Open Issues:

Commented [18]: This should be past perfect tense which describes what happenED in the use case and is now in "the past". For example: Eraser-Bot connected to the camera module with LED indicators re the connection and entered low-power sleep mode after no use for xxx minutes.

Commented [19]: steadily perhaps?

Commented [20]: Immediately after establishing connection? That's how it reads now. If so, fix my suggested statement for Success Guarantee. If it only goes to sleep after a certain amount of time, say what that is.

Commented [21]: Number this so that it replaces all the lines that should be replaced in this event. I believe that you are substituting line 3 and replacing lines 4 and 5, correct? 3a-5 would be the numbering in that case.

Use Case UC2: Power On Camera Module

Scope: Eraser-Bot

Level: Sub function

Primary Actor: Teachers, Students, or Janitorial Staff

Stakeholders and Interests:

- Teachers, Students, and Janitorial Staff: Want to use the Eraser-Bot and desire the start-up process to function correctly.

Preconditions:

- The camera module is plugged into a power outlet.
- The camera module is powered off.

Success Guarantee: A power indication LED turns on and a connection status LED turns on when the camera module pairs to the phone. A status message appears in the Android application

when the camera module connects with the Eraser-bot and the Android application is communicating with the camera module.

Main Success Scenario:

1. The user presses the power button on the side of the camera module.
2. The power indication LED lights up.
3. The camera module enters into a loop trying to connect to the Eraser-Bot.
4. The Eraser-Bot's connection LED stops blinking when communication is established.
5. The user opens the Android application on their Android device.
6. The camera module enters into a loop trying to connect to the user's Android device.
7. When the camera module establishes connection with the Android device, a successful connection icon appears in the Android application, and the connection LED on the camera module stops blinking.

Extensions:

(3a) If the robot and camera module cannot connect, the connection LED on the robot continues to blink.

(6a) If the camera module cannot connect, the connection LED on the camera module continues to blink and the Android application displays an error message.

Special Requirements:

Technology and Data Variations List: The Android application must be functional for Android software version 4 (KitKat).

Frequency of Occurrence: Once per use.

Open Issues:

Commented [22]: Why repeat all of these steps that match the UC above. Reference that use case for step 1. Step 2 would be what you now show as step 5. Make sense? Or make step 5 be step 1 and say in the precondition that UC x has already been completed. If you THAT, you probably want to fix the last step of the first use case so that it doesn't end with going into sleep-mode but that is an alternate ending (an extension) after a certain amount of time.

Commented [23]: How does it know to do that? Does it do this immediately after connecting with the Eraser-Bot? If so, it would precede step 5, yes?

Commented [24]: Fix numbering -- see comment on similar item in earlier use case.

Commented [25]: fix numbering so this does not just replace step 6 -- if it did, step 7 would still be present and wouldn't make sense.

Use Case UC3: Erase Whole Board

Scope: Eraser-Bot

Level: User goal

Primary Actor: Teachers, Students, or Janitorial Staff

Stakeholders and Interests:

- Teachers, Students, and Janitorial Staff: Want to use the Eraser-Bot to erase the entire whiteboard.

Preconditions:

- The camera module and the Eraser-bot both display power indicator LEDs.
- A lit LED on the robot demonstrates the successful connection to the camera.
- A lit LED on the camera module and a connection icon in the app indicate the successful connection between the two.

Success Guarantee: The Eraser-bot is able to erase the entire whiteboard.

Commented [26]: has erased

Main Success Scenario:

1. The user clicks the "Erase All" option on the Android application.
2. The camera module takes an image to determine what parts of the board have writing and identify where the robot is.
3. The embedded computer creates or updates the robot's path.
4. The embedded computer sends direction instructions to robot every second.
5. The Eraser-Bot executes the movement commands.
6. Loop to #2 until no more writing is detected.
7. The embedded computer directs the Eraser-Bot the lower-left hand corner of the whiteboard.
8. The Eraser-Bot enters low-power sleep mode.

Extensions:

(2a) The image processing algorithm recognizes if the instructor is standing in the way of the robot, and continually takes pictures until the robot is visible.

(3a) The image processing algorithm may need to perform extensive calculations to correct the robot's path. If this is the case, a stop command is sent to the Eraser-Bot so the path can be resolved.

Commented [27]: This is passive voice. Who sends the stop command?

Special Requirements:

Technology and Data Variations List: The Android application must be functional for Android software version 4 (KitKat).

Frequency of Occurrence: Whenever the user desires to not save any of the writing on the whiteboard. This could vary anywhere from every use of the Eraser-bot to only once per day.

Open Issues:

Use Case UC4: Erase Board Sections

Scope: Eraser-Bot

Level: User goal

Primary Actor: Teachers, Students, or Janitorial Staff

- **Stakeholders and Interests:** Teachers, Students, and Janitorial Staff: Want to use the Eraser-Bot and desire to erase portions of the board.

Preconditions:

- The camera module displays the power indicator LED.
- The Eraser-bot displays the power indicator LED.
- A lit LED on the robot demonstrates the successful connection to the camera.
- A lit LED on the camera module and a connection icon in the app indicate the successful connection between the two.

Success Guarantee: The user determines which parts of the board to erase and the Eraser-bot erases only the specified areas while not erasing the other areas.

Commented [28]: has determined

Commented [29]: has erased

Main Success Scenario:

1. The user selects "Take Picture" option in the Android app.
2. The camera module takes a picture of the whiteboard.
3. The embedded computer processes the image to detect where the writing is on the board.
4. Embedded computer transmits the image with data about where the writing is to the android app.
5. The app displays the areas of the whiteboard that have writing on them to the user, as well as buttons for "Erase", "Edit Options", and "Cancel."
6. The user selects the sections he/she is interested in and clicks "Erase."
7. The phone transmits selection to embedded computer in camera module.
8. The camera module directs the Eraser-bot to the specified areas from the user using feedback loop in UC3.

Extensions:

(5a) If the user selects "Cancel", the phone returns to the main screen. No erase instructions sent to the camera module

(5b) If "Edit options" is selected, another screen appears with the image of the board, and a box is shown for highlighting the desired area.

Special Requirements:

Technology and Data Variations List: The Android application must be functional for Android software version 4 (KitKat).

Frequency of Occurrence: Whenever the user desires to save certain portions of writing on the whiteboard. This could vary anywhere from every use of the Eraser-bot to only once per day.

Open Issues:

Use Case UC5: Emergency Stop

Scope: Eraser-Bot

Level: User goal

Primary Actor: Teachers, Students, or Janitorial Staff

Stakeholders and Interest:

- Teachers, Students, and Janitorial Staff: Want the ability to immediately stop the erasing process in case they decide something important is about to be erased.

Success Guarantee: The Eraser-bot stops when the "Emergency Stop" command is pressed on the Android application.

Commented [30]: good idea!

Preconditions:

- The camera module and the Eraser-bot both display power indicator LEDs.
- A lit LED on the robot demonstrates the successful connection to the camera.
- A lit LED on the camera module and a connection icon in the app indicate the successful connection between the two.

Main Success Scenario:

1. The user clicks the "Emergency Stop" button in the Android application.
2. The Eraser-Bot stops and raises the eraser from the board.
3. The embedded computer directs the Eraser-Bot the lower-left hand corner of the whiteboard.
4. The Eraser-Bot enters low-power sleep mode.

Extensions:

Special Requirements:

Technology and Data Variations List: The Android application must be functional for Android software version 4 (KitKat).

Frequency of Occurrence: Intermittent.

Open Issues: