Project 2 Report
Team 21

Andrew Berkeland, Andrew (AJ) Eubanks, Steven Johnson, Eric Mitchell, Alvi Topuzi

10/11/2024

Executive Summary

This project had many subgoals. For Project 2 specifically, we had to use image processing techniques to detect changes in a background image. We implemented a webcam as an optical sensor. Using background subtraction, image erosion, and various detection techniques, our program identifies the colors and shapes of objects on a sheet of paper. We also used mathematical operations to calculate the angle at which the shapes are located with respect to the center of the image. In addition, we addressed some of the parts of the design process for our final project. We developed engineering requirements from customer requirements. Also, we brainstormed many final project ideas and concepts. Using a weighted decision matrix, we decided on the best concept for our final design. We created a non-functional mock-up of our final design. Lastly, our team developed a website to document our project's progress. Through this project, we learned about different computer image processing techniques and website design fundamentals. We also learned how to convert customer needs into descriptive engineering requirements. Our most important lesson is that we need a better light source for our camera setup. We faced many issues with our image washing out, and we believe constant lighting will lessen the effect of other lights in the room.

Camera Subsystem Design - Engineering Requirements

Hardware

The hardware design requires a camera height of 16-18 inches to capture the entire game board. This DIY setup, constructed from cardboard, includes a camera positioned above the board to capture images of the gameboard. This will compare each chip location with an original blank board. The design required a backdrop to prevent lighting issues and a stable surface for the camera, as seen in the demo and will not be in the final design.

The camera is an appropriate sensor because it effectively detects changes between the original blank board and the board during gameplay. It captures sufficient detail for the game, and this test setup is used to evaluate the camera's resolution, clarity, and integration with MATLAB detection software with a resolution of 480x640. Currently, the camera connects directly to the computer via USB, but in the final design, it will be integrated into the Arduino system for more streamlined processing. This design ensured accuracy and functionality during our demo.

Figure 1: Hardware Demo Design

Software

The flowchart below illustrates the image processing workflow implemented in MATLAB to detect shapes and colors on our gameboard. The process begins by capturing a background image, followed by capturing a test image with stickers placed on the board. MATLAB then performs background subtraction to isolate the stickers from the background, computes a binary image, and applies an edge detection process (e.g. erosion) to define the regions of interest. These regions are analyzed based on their size, and those with a region area within the desired range (greater than 100,000 and less than 300) are selected for further processing.

Once regions of interest are identified, the software uses shape detection algorithms to categorize the stickers. The circularity of the regions is calculated to determine the shape: if circularity is 0.9 or above, the shape is classified as a circle; if it is 0.7 or higher, it is classified as a square; otherwise, it is categorized as triangle. Additionally, the program calculates the hue value from the central pixel of each region to detect the color. The hue range determines whether the sticker is red, yellow, green, or blue. These results, including both shape and color, are then stored and displayed for the user. The program loops through all regions until the entire image has been processed, after which the results are shown.

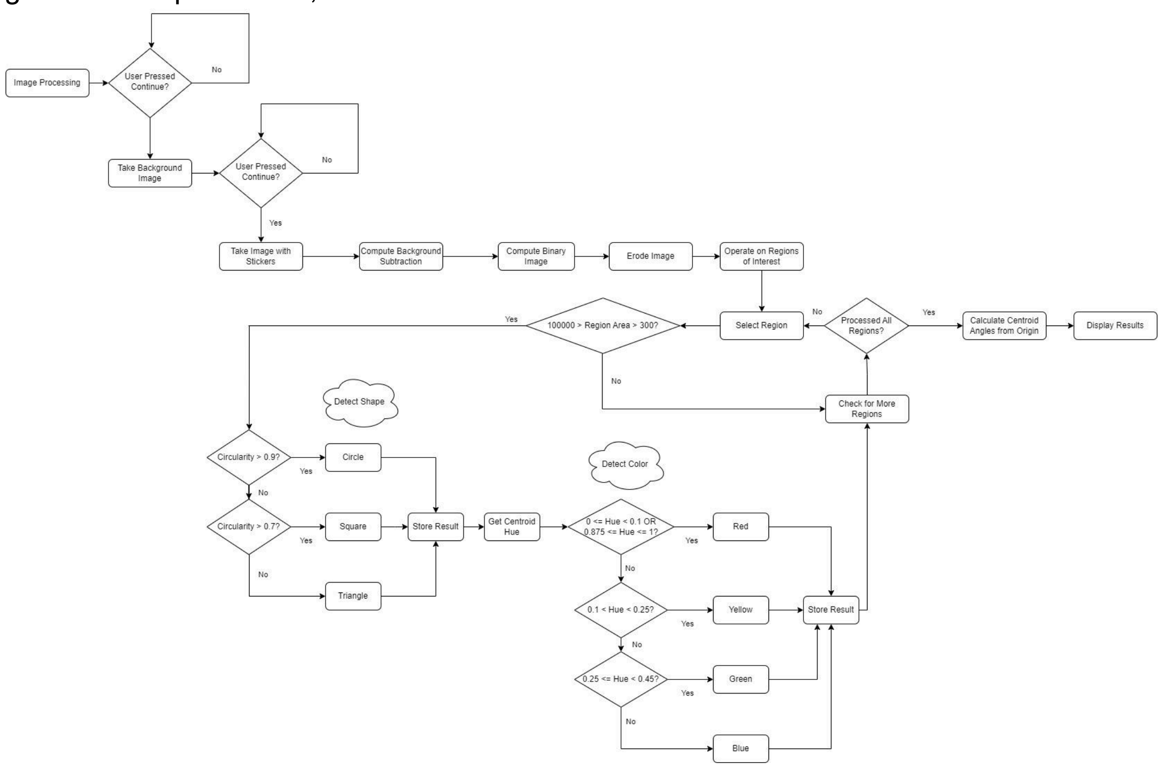

Figure 2: Software Flowcharts

Engineering Requirements for the Entire System

Customer Requirement	Engineering Requirement	Test to be conducted
Autonomous	The system must be able to play a turn without user instruction. The last command the machine should receive before making its move is when the user takes their turn.	If the robot can not move after the user presses a button for the desired location, this test is a failure
Inexpensive	The system should cost less than $200 for parts and assembly.	Write a parts inventory and total the costs. If the total cost is less than $200, the test passes.
Quiet	The system should generate less than 80 dB (max normal conversation volume) of noise while running.	Measure the loudness with a decibel meter. If the loudness is greater than 80dB, the test fails.
Robust	The frame should be resilient when impacting a table from a 3” drop or impacting a hand with a force of 500 N (lowest adult punching force)	Drop the enclosure and hit the enclosure's sides with a light punch. If the frame breaks or the machine fails to work, this test fails.
Fast	The system should be able to take its turn within 10-15 seconds	Set a stopwatch when the user’s turn ends. If the robot’s turn takes more than 15 seconds, this test fails.
Efficient	The robot should be able to take a turn with 10 or less total movements from any of the moving system components	Count the number of component moves for the system. If the robot makes more than 10 physical movements, the test fails.
Safe	The moving system components should be in an enclosure that is not open to the outside	If all moving parts are enclosed, the test passes.
User-Friendly	The GUI must be easily understood by an average person that knows the rules of the game	Sample 10 people from campus randomly. If 80% of them can play the game based on the on-screen instructions, the test passes.
At least one closed-loop	A closed-loop motor with PID	Use a motor. If there is a

controlled motor with smooth motion	control must be used so the motor travels from one point to the next in a continuous motion without making visually noticeable abrupt stops	visible jitter in the mechanism, the test fails.
Detect coins off the board and move them to the desired location on the board determined by the user and a GUI	Use a webcam to detect where available coins are on the side of the board The piece moves to the location selected by the user on a screen. The screen displays all available moves	If the robot can grab and place pieces without interfering with placed pieces, the test passes.
Clears the gameboard upon completion and places pieces back in their appropriate locations	The robot can move all pieces back to a color-coordinated rack on the side of the game board after a winner is detected and the user initiates a board reset	If the system can reset the board to its original state with all pieces in the correct locations, the test passes.
Displays that the game is complete and declares the winner (if any)	The GUI will display “Game Over” and the winner	The GUI detects when the game is over at all appropriate times and displays the winner.
16” x 16” board with each space being 2” x 2”	The board spaces will be square with 2”x2” dimensions per square and a 16” by 16” board	The board is made as described.
Game pieces of 1.5” in diameter	The game pieces will be of two colors and circular with 1.5” diameters	The pieces are constructed as described.

Design Solutions

For all three design solutions, we are treating the z-axis as vertical movement. Our board is horizontal, and we will treat the x-axis as left-to-right movement and the y-axis as forward and backward movement, both with respect to the camera lens. The camera will be mounted above the board, looking down on it.

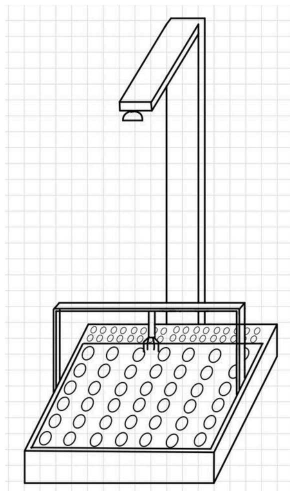

Figure 3: Design Solution #1

Design #1: Manipulator claw with x- and y-axis traversal. Under the board, there will be two sets of rails for movement along across the board. These will move the claw along the x- and y-axes. The claw will open, grab a piece, move to the selected spot, and drop the piece in place.

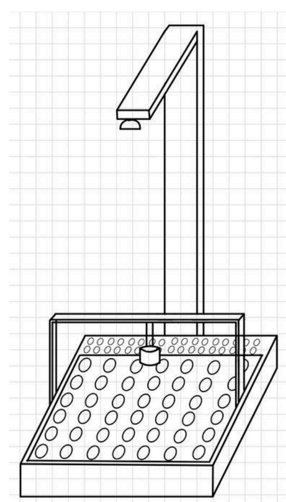

Figure 4: Design Solution #2

Design #2: This design is the same as Design #1 except the claw is replaced with an electromagnet. We will attach a ferromagnetic object to each of the game pieces. The electromagnet will be used to move game pieces around the board.

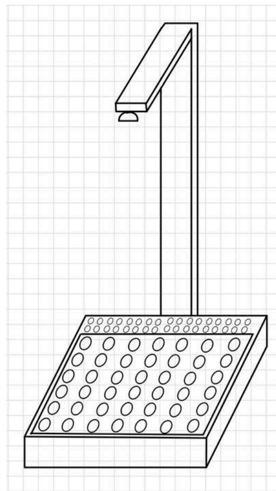

Figure 5: Design Solution #3

Design #3: This design is similar to Design #2. In this design, the electromagnet will stay under the board. The electromagnet will drag the game pieces across the board into the places selected by the user and the computer.

Concept Evaluation

		Design Choice 1	Design Choice 2	Design Choice 3
Autonomous	5	5	5	5
Inexpensive	3	3	5	3
Quiet	3	3	5	5
Robust	3	5	5	5
Fast	5	5	5	5
Safe	5	5	5	5
User-Friendly	3	3	5	5
Easy to Create	1	3	5	3
Lightweight	1	3	5	5
Aesthetic	1	3	3	5
Total Score		**126**	**148**	**142**

Our chosen weighting factors, 1, 3, and 5, represent optional, important, and critical. Our score for each criterion was chosen to be 1, 3, and 5 also, which represent not meeting the criteria, partially meeting it, and completely satisfying it. From this decision matrix, our final design that we will first test is Design 2. This includes an electromagnetic that will move the pieces where they need to go from above. While this is not as aesthetically pleasing as having the magnet on the bottom, it will be cheaper since the magnet does not need to be as strong and easier to create since we will not be working underneath the board. The weighting factors were chosen for each design based on their importance. We ranked autonomous, fast, and safe as being absolutely critical for the design. It must be autonomous, otherwise there is no point in creating this machine in the first place. It must be fast because if it is not, the user would rather play with a normal game board. Finally, it must be safe, so that there is no potential for harm. Next, we ranked inexpensive, quiet, robust, and user friendly as important things to consider. It is important for the design to be inexpensive, because the cost relies on us to make the system with no profit. It should also be quiet and robust, as these are part of the customer's desires. Finally, it must be user friendly because we do not want the game design to be complicated and frustrate the user. The user should be able to play the game and know how it works without any questions. Finally, we ranked easy to create, lightweight, and aesthetic as optional criteria. This is because they are not a part of the customer requirements, but things that we desire our design to have. Design Choice #2 ranked the highest overall, since it fully satisfies most of these requirements. The only ones that it does not excel in are aesthetics. This is because it will have to have some things done above the gameboard. Ideally, everything would be hidden, but this would cause other issues that are more important than the look of the game. We believe that even with this design choice, we can manage to make it look as aesthetically pleasing as possible once we start designing to mitigate any losses we plan to encounter based on this design choice.

ECE 4950 Project 2 – Sensor and Website Rubric

Use the guidelines below to complete your report and add at the end of your report.

Group Number (and Name):____

Score	Pts		
	5	**General Format - Professional Looking Document/Preparation (whole document)** a) Fonts, margins (11pt, times new roman, single spaced. 1" margins on all sides). b) Spelling and grammar are correct c) Layout of pictures – all figures need numbers and captions and must be referenced in the text d) Follows the page limitations below. e) References. Use IEEE reference format. f) This grading sheet is included as the final page.	**O3-SA1:1**
	5	**<u>Page 1: Title, Group Name, Group Members, and Date</u>** **<u>Executive Summary</u>** (1 concise, well-written paragraph) Provide an overview of this project. Briefly describe what you did and what you learned.	**O3-SA1:1**
	20	**<u>Subsystem Design</u>** **<u>Page 2: Engineering Requirements for the Camera subsystem</u>** (~1 page) In the context of just the Camera-as-a-Sensor, make a two column table that contains a column for the Customer Requirements (what are the functions of the sensing system?) and the resulting Engineering Requirements. Each row should contain a specific customer requirement and the resulting engineering requirement. One customer requirement may generate multiple engineering requirements. For example, the customer will want an "accurate" system, the Engineering Requirement could be 99.5% detection success.	**O1-SA5:2**
	20	**<u>Pages 2-3: Document Hardware</u>** (1 page) Describe and show images of the equipment used, connection diagrams, calculation of resolution – pixels per square inch/cm on game board etc. Is the camera an appropriate sensor?	**O2-SA2:1**
	20	**<u>Pages 3-4: Document Software</u>** (2 pages) Using Flowcharts, state diagrams, data structures etc. describe how the software is implemented. There is no need to include the source code.	**O2-SA2:1**
	30	**<u>Overall System Design</u>** **<u>Page 5: Engineering Requirements for the Entire System</u>** (~1 page) Make a three-column table that lists the Customer Requirement in the first column and the resulting Engineering Requirement(s) in the second column. Note that a customer requirement might branch to multiple engineering requirements. The third column should list the test that will be done on the prototype to verify that the design chosen meets each requirement.	**O1-SA5:2**
		<u>Pages 6-7: Design Solutions</u> (~2 pages) Use a brain storming session to generate concepts. Document your top three most feasible ideas with sketches and brief descriptions while explaining the main features of each concept.	**O2-SA1:4**
		<u>Page 8: Concept Evaluation</u> (~1 page) Use a complex (weighted) Concept Evaluation Matrix to show how the final design was chosen from the three best ideas described previously. Include a description of the weighting factors. Make sure to use at least six of your most important criteria in the matrix and be sure to provide and include the weighting factor (i.e. importance) for each criterion.	**O2-SA1:4**

		Describe your final design choice (~1 paragraph) The robot mock up will be graded based on the following criterial: a) Does it demonstrate the proposed concept in sufficient detail? b) Is it well thought out? c) Does it look like the final construction using this concept will be robust?	
		Page 9: Grading Sheet	
	20	**General Website Format** – *provide link here:* Is the website: a) Aesthetically clean b) Complete. Does it include: 1. The Team Description? 2. Reports 1 and 2? 3. Outline of future sections? 4. Proper use of graphics? c) Follow accessibility compliance at: https://siteimprove.com/en-us/accessibility/ada-compliance-website/	**O3-SA1:1**

Website Link (to insert into rubric): https://ajeubanks.github.io/ece-4950-team21-website/