

Final Design Report

Smart Table Top

Senior Project

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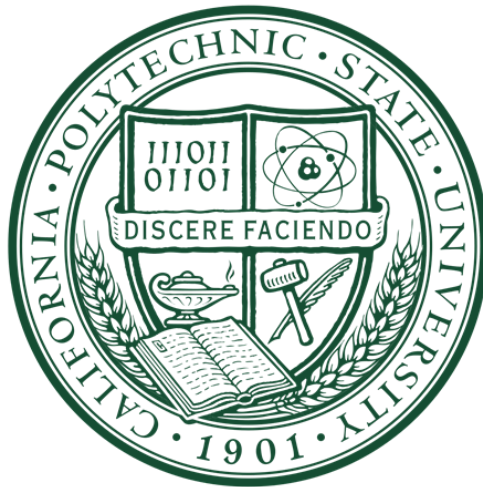


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ABSTRACT

Dungeons and Dragons 5th Edition (D&D) is a tabletop role playing game (TTRPG) with complicated mechanics and a seemingly overwhelming amount of information. D&D players are often looking for ways to more effectively track information and products that enhance their game experience. One such product is a custom miniature; players use these to track their character's location and for the enjoyment of creating a physical representation of their imagination. Virtual Tabletops (VTT's) were developed to make the entire experience digital. The digital nature of VTT's make all of the game's rules and mechanics accessible at the click of the mouse; however, it also alienates players from a physical connection to the game. The smart game board offers digital convenience while preserving the physical connection to the game. The game board wirelessly communicates with the pieces on the board to provide quick access to their specific rules and mechanics while also determining their location on the board. The board utilizes a digital display to swap between different game boards/maps. The smart game board saves time and simplifies the experience for players by displaying only the most relevant information and it enhances their experience by utilizing their custom miniatures. This makes the game more accessible to beginners, reduces risk of error for the game master and allows everyone to focus more on enjoying the game. This product could easily be adapted to accommodate any board game with pieces large enough to contain wireless communication technology. Future developments of this product could also include an automatic board setup feature if the piece has a known board layout such as chess, checkers, or monopoly.

I. INTRODUCTION

Tabletop Role Playing Games (TTRPG) are a unique form of interactive storytelling where a game master (GM) creates a setting for player characters to explore. Most aspects of the game reside purely within dialogue and imagination; however, some elements are best played using visual aids. Combat encounters can be some of the most fun, most complicated, and most time consuming experiences of any TTRPG. These aspects result in a very high learning curve that disrupts new players from enjoying the game; they become reliant on experienced players and it deters them from playing as a GM.

Every character and everything has an associated “datasheet” that describes who they are, how well they can operate, and how long they can last. Combat encounters confront the GM with everyone’s datasheet all at once. This project streamlines combat encounters by gathering and displaying the critical information the GM needs as each piece is placed on the table. The Smart Game Board (SGB) eases the strain by tracking some of the most intensive elements of the game, therefore saving time and reducing risk of error for the narrator.

Over 50 million people currently play D&D, with 40% of this fan base being composed of new players, and the numbers continue to rise steadily. The smart game board simplifies the game for new players so that they can spend less time feeling overwhelmed and more time playing the game.

II. BACKGROUND

The Smart Game Board has three main facets: Locate pieces, Collect information, and Digital display.

A. Collect Information:

The first component of the project is its ability to gather information from the pieces placed upon it. We had two main ideas on how to accomplish this goal: NFC chips and RFID tags. The major issue with NFC chips is their extremely short range of detection; there would have to be a reader beneath each of the 1"x1" squares on the grid of the display, which would increase costs significantly. The benefits that NFC provides are that it has up to one megabyte of data storage, and can be read from and written to by the same NFC reader. RFID tags allow us to read a more than sufficient number of tags simultaneously, while having enough range to cover the entire board with a single reader in the center. All the RFID tag would store is a locator number, which points to where the character's details are stored in the accompanying software, therefore the kilobyte of storage space available to an RFID tag would be sufficient, and the ability for the reader to also write data to the RFID tag would be unnecessary as well (atlasRFIDstore).

B. Locate Pieces:

The second component of this project is the ability for the board to detect and track the location of all the desired pieces on the board. We considered using RFID, Computer Vision, light triangulation, touchscreen technology, and inductive sensors in order to satisfy this demand. The trouble with using RFID for location is resolution; this project requires a minimum of 1"x1" tracking, which RFID is not suitable for. In a previous senior project, students used RFID to track bean bags around a cornhole board; they were capable of defining 3 large zones for the RFID to track the bean bags but these areas are much larger than a 1"x1" square (Behroozian et al.).

Computer Vision is an approach used by another Cal Poly senior project in order to track chess pieces during a game (Belshe). Computer vision is a very reasonable approach for this project as well. Chess has an advantage compared to this project in that the board itself never changes. A uniform board provides a stable reference point for the computer to measure the location of the pieces against. Whereas a 1"x1" grid is often used in tabletop games the grid is usually an overlay on top of a more detailed setting. The display could even be subject to change mid game. This does not nullify the ability to use computer vision but it does make the approach more complicated.

Light triangulation in a simple form utilizes LED's and CCD sensors to determine the location of objects based upon the shadows they create (Lab 1314 : Real Innovation with DIY !). The major merit to this approach is the cost of components. Unfortunately, light triangulation breaks down when multiple objects are grouped near each other. The resolution of detection grows wider as more figures are placed on the table. This approach also does not have a method to distinguish between objects the users want to be detected and objects they don't want to be detected.

There are two main forms of touchscreens, capacitive and resistive. Capacitive touchscreens are activated by conducting a charge from the surface. The location is determined by where on the surface the charge was conducted from. This provides a reasonable manner to determine the location of a figure so long as the base of the figure can conduct the charge appropriately. This also allows for users to choose whether or not they want the surface to detect an object by placing it on a non conductive platform. The downside to this approach is the touch point maximum. The average modern touch screen has a touch point maximum between 7-10 points. This would restrict the number of figures the board could locate at one time. Resistive touchscreens are typically dimmer and more durable than capacitive touch screens. Unlike capacitive touch screens, resistive touch screens are activated by pressure. This pressure is greater than the average tabletop figure which makes this approach infeasible.

The inductive approach is utilized by Teburu to accomplish this task in their similar product. A layer of coils beneath the play surface reacts to a magnet embedded within the figures. The induced current is analyzed to determine the location of the figure. This is a very effective method that allows for a greater number of figures than a touch screen. Teburu also uses RFID to identify their figures on the play surface; the difference in our designs comes down to the third facet of the Smart Game Board.

C. Digital Display:

The third component of the Smart Game Board is the digital display. The digital display allows DM's to upload their maps and environments directly to the play surface. A digital display is already becoming a common approach for many TTRPG groups; this is done by mounting a television inside their game table. DM's already use software to create maps, this approach eliminates the need to print them out. This makes changing the environment as simple as a click of a button; none of the pieces will even have to move in order to do it. This feature is what differentiates the SGB from Teburu's product. Physical maps are still necessary for their board since it relies on the strength of magnetic fields in order to recognize location.

It is the combination of these three components that distinguishes the SGB. It integrates all of the efficiency virtual table tops offer with a tangible medium.

III. REQUIREMENTS

TABLE I: CUSTOMER REQUIREMENTS

Customer Requirements		
<ol style="list-style-type: none"> 1. Average/Standard Tabletop game board size 2. Low/Reasonable cost 3. Fast and responsive 4. Accurate location detection 5. Accurate figure recognition 6. Simplifies searching for relevant information 		
Customer requirements	Engineering Specs	Justification
1, 2	Board Min: 10" x 10"	Must be large enough to accommodate a typical encounter/game. (10-15" x 10-15")
2	Less than \$800	This is a luxury item, so as cheap as reasonable without sacrificing quality
3	Less than 0.25 sec to display/clear information	Reading and transferring the detailed piece information and location determination should have minimal delay. The average reaction time for a human from visual stimulus is 0.25 seconds, therefore to seem instantaneous recognizing pieces and their locations should be less than this.[here]
4,5	Tracking 1"x1" mini Distinguishes between min of 8 figures on board and Only Displays Desired Objects	Location determination should be accurate to at least the resolution of the game board grid.
6	Displays summary Character information for all characters, map information and character location on map.	This is important information that will be useful to the gamemaster when conducting the game.

IV. SPECIFICATIONS

TABLE II: ENGINEERING SPECIFICATIONS

Spec. #	Parameter Description	Requirement or Target	Tolerance	Risk	Compliance
1	Size	10" x 10"	Min	L	I, S
2	Cost	\$800	Max	M	A
3	Speed	0.25 sec	Max	L	T
4	Location detection	1"x1" Square	1mm	H	T
5	Figure detection	8	Min	H	T

V. FUNCTIONAL DECOMPOSITION



Fig. 1: Level 0 Block Diagram

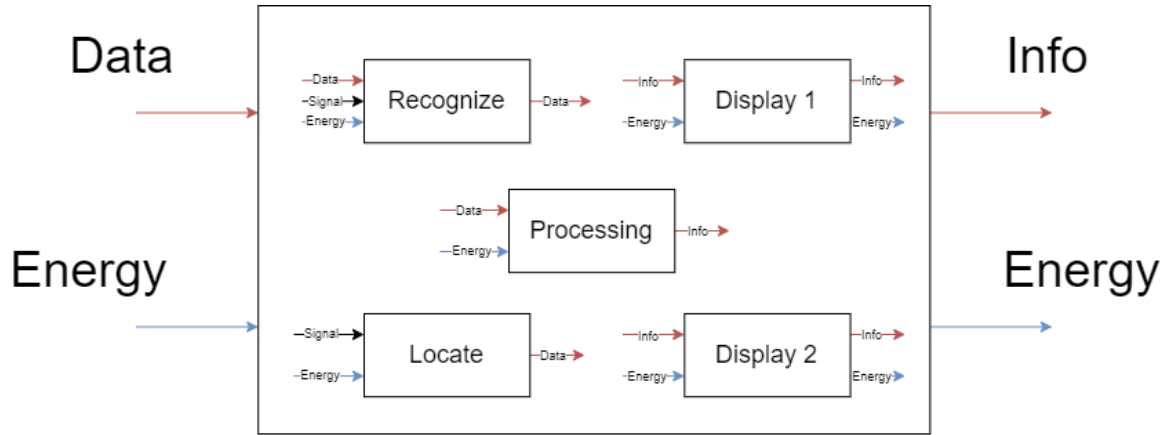


Fig. 2: Level 1 Block Diagram

TABLE III: LEVEL 0 DECOMPOSITION BLOCK

Input(s)	Energy (Power), Data (RFID, Token Location, User Input)
Outputs(s)	Energy (Light, Heat [Waste]), Info (Character Stats, Map Display, DM Display, Token Location)
Functionality	Tracks the location of pieces on the board and reads the RFID tags on them to display the encoded information and locations to the user, as well as displaying the image the user inputs on the board.

TABLE IV: LEVEL 1 RECOGNIZE FUNCTION BLOCK

Input(s)	Energy (Power), Signal (RFID), Data (stored on RFID Tag)
Outputs(s)	Data (Character Info), Energy (Heat [Waste])
Functionality	Transmits and Receives a signal to read the data stored on the RFID tag and push that data to the rest of the system.

TABLE V: LEVEL 1 LOCATE FUNCTION BLOCK

Input(s)	Energy (Power), Signal (Touchscreen)
Outputs(s)	Data (Location Info), Energy (Heat [Waste])
Functionality	Reads and outputs the location of pieces on the game board.

TABLE VI: LEVEL 1 DISPLAY 1 FUNCTION BLOCK

Input(s)	Info (User Input), Energy (Power)
Outputs(s)	Info (Image Display), Energy (Light, Heat [Waste])
Functionality	Displays the image given to it by the user

TABLE VII: LEVEL 1 DISPLAY 2 FUNCTION BLOCK

Input(s)	Info (Character stats and Locations from system), Energy (Power)
Outputs(s)	Energy (Light, Heat [Waste]), Info (Location and organized RFID information, display 1 control UI)
Functionality	Machine Human interface to see the processed information and control the system.

TABLE VIII: LEVEL 1 MICROCONTROLLER FUNCTION BLOCK

Input(s)	Energy (Power), Info (Input from other systems outputs [Locate, Recognize, User Input])
Outputs(s)	Info (Image to Display 1, character stats and locations to Display 2), Energy (Heat [Waste])
Functionality	Process the incoming data into organized information

VI. COST ESTIMATES

TABLE IX: MATERIALS COST

Parts	
Optimistic Estimate (a)	\$460
Probable Estimate (b)	\$500
Pessimistic Estimate (c)	\$800
Estimate Cost = $(a+4b+c)/6$	\$543.33

There are two main options for RFID sensors: the lower cost sensor is 125 kHz and is \$100 while the UHF sensor is \$245. The touchscreen monitors can range between \$250-\$400. Arduino's can range between \$25-\$50. Additional fees due to taxes and shipping causes the pessimistic estimate to get to \$800.

TABLE X: LABOR COST

Labor	
Hours Estimate	82.5
Labor Cost Estimate	\$7,425

The labor estimate is calculated for 3 people working 2.5 hours/week for 3 quarters at a rate of \$30/hr. Finals week is included in the quarters for a total of 11 weeks of labor.

VII. DESIGN

Physical Design

Computer

The first part of our design is the computer. This is the processing module in our Level 1 block diagram and can actually be satisfied by multiple devices. The device in question is a Mini PC originally intended for home theater purposes. The main purpose of the computer is to allow us to connect to the internet so we could use the bubble.io app we created and so we could display or mirror the screen to a larger display. We will talk more about the bubble.io app in the software section and we will focus on the implementation using the Mini PC, seen in the figure below, for the rest of the report.



Fig. 3: Computer - Mini PC

Display

The next major component in our design was the display, particularly the touch screen display the players would interact with. We went with an ASUS 10-point touch screen

display because it was the cheapest, reliable and functional display we could find for our purposes. It was important to find a display that would allow many touch points at once so we could reach our requirement regarding multiple simultaneous figure location tracking. We picked a 21.5” size monitor because that would let us reach our requirement for the desired board area space. This display allows us to fulfill part of the Locate and Display modules in the Level 1 Decomposition.



Fig. 4: Display- ASUS VT229H 21.5" Monitor

RFID Scanner

We chose the ID-20LA as our RFID Reader because it gave us the basic functionality we were looking for and also it was economical when compared to other RFID readers. This helps us satisfy the recognize module in our Level 1 block diagram. Using the reader and the RFID tags, we can uniquely identify the figures being used in the game. The range is small so a tag must come within about an inch of the reader to be recognized. Also the reader will only recognize one tag at a time.



Fig. 5: RFID Scanner- ID-20LA (125 kHz) and RFID Tags

Figures

The last major component of our physical design is the figures. The figures, along with the display complete the Locate module of the Level 1 Decomposition. The figures we are using were made from a 3D printer and are being reused from their original purpose. Attached to the bottom of the figures are small black bases. The purpose of these bases is to give a cavity to hold other components important for implementing extra functionality for these figures. In the cavity we hide the RFID Tag and a conducting silicon rubber nib, similar to the ones on styluses. The RFID Tag should allow us to uniquely identify the figure and the nib should allow us to use the touch screen functionality through the figure base.



Fig. 6 & 7: Figures- Custom 3D Printed Figures, Bases and Nibs

Software Design

To interface our physical components with virtual assets, we decided to use bubble.io and make a web application for this project. As a brief summary, bubble.io is a visual web development platform that allows users to create and launch web applications without coding. It offers a drag-and-drop interface, a powerful backend, and a variety of pre-built elements and workflows to build fully functional web apps.

Data Types

To organize and store related data, we created several data types. They are Figtag, Character, Maps and User. The summary of what kind of information can be found in each data type can be seen in the figure below. Figtag stores data related to a figure. It holds information like the RFID tag, initiative, HP and links to a character profile. The Character data type holds character information whether a player character (PC) or a nonplayer character (NPC). This includes a slew of usual character stats like wisdom, strength, charisma and so on, as well as a name for the character, a photo and a copy of the character sheet. Maps contains the image to

display a map as well as some metadata fields like its name and description. Lastly there is the User which keeps track of the profile being used for the log in session.

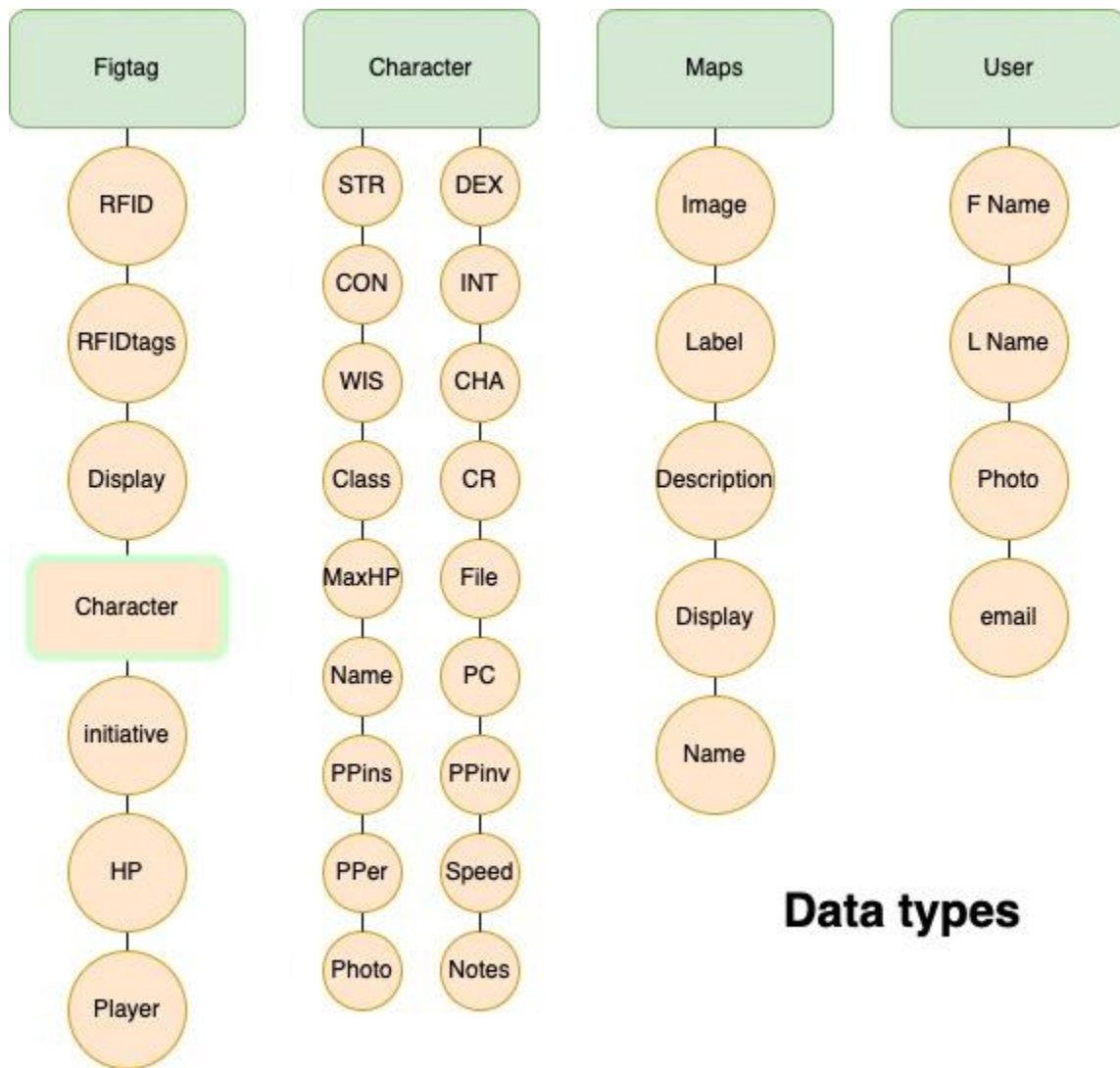


Fig. 8: Summary of Data Types Structure

Pages Overview

The app we created consists of a few important pages. There is the Library which houses a summary of all characters and figure information, followed by the players page where you can get more detailed information. Then there is the Map page where maps can be added and changed. There are many components on each page, and the figure below summarizes

components used across the pages. In the following sections, we will give a more in depth explanation of each page.

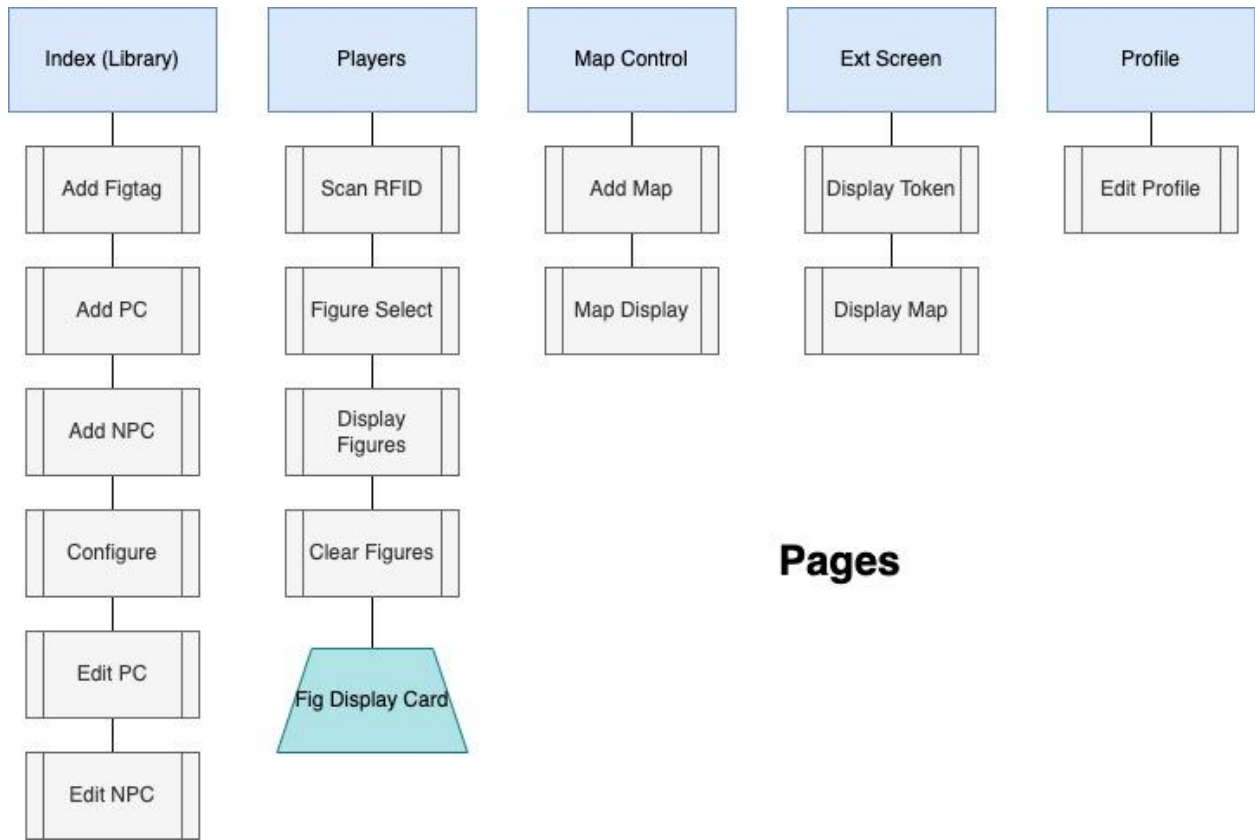


Fig. 9: Smart Game Board Pages

Library

This page is the Smart Game Board’s home page; it is defined as the index page to bubble, but within the app it is referred to as the library page. This page displays the user’s database of characters and figtags. Users may add to the database of characters and figtags by pressing the associated “add” button. This triggers a popup window with the various input fields for the associated datatype. In order to use the RFID scanner the serial port must be initialized by pressing either “Initialize Scan” or “Read RFID” button and selecting the appropriate port for the scanner, which can be found on the figtag popup windows. The serial monitor plugin for bubble

does not work perfectly and will often only read a portion of the tag number. To account for this the figtag field "RFIDtags" stores the results from multiple scans which is later used to decrease the amount of scans necessary to identify the figure.

Characters in the database can be modified or deleted by pressing the "edit" button on their display card in the library. "Figtags" can be edited and connected to their associated character by pressing the "configure" button on their library entry. The separation between figtags and characters allows for different RFID tags to represent the same character type. This also allows DM's to change which character is being represented by the same RFID tag quickly; this is helpful since it decreases the number of RFID tags a user needs in order to effectively represent their entire character database. This page is designated as the home page since there is no other means to develop the user's character and figtag database, which are crucial for utilizing the primary features of this tool.

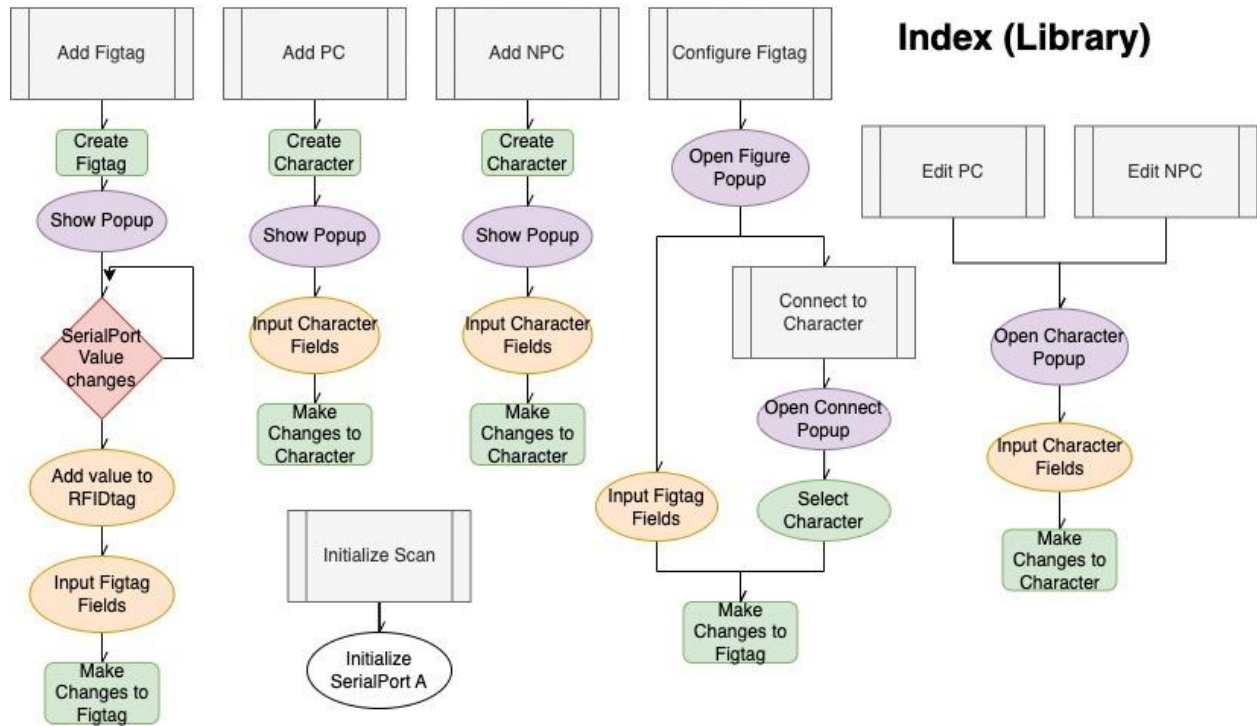


Fig. 10: Library Workflow



Adventure Awaits

The integrated adventurer's toolset for enhanced gameplay

The screenshot shows the 'Library' page with the following data:

Section	Name	Class	CR	RFID#	RFID Partials	Current Char	Player
PC's	V	Player	CS	5002066F3B0	08, 808, 8080808, 050...	Holga	DM
	Asgeir	Sorcerer	CS	07	07, 807, 0807	V	
NPC's	Forge		8	050080303	0803, 803, 303, 08030	Edgin	
	Doric		5	0500801368	00801, 1368, 68, 136...	Ininarei	Nathan
	Goblin		1/4	050080111090	01, 801, 8011109...	Goblin	CS
	Simon		5	0500207A154A	0500207A1...	Simon	DM
	Holga		5	0500206F3B0	1, 11, 11111, 211111...	Goblin	
Figure Tags				002	805, 805467, 467, 67	Doric	

Fig. 11: Library Page

Players

The “Players” page is the first page that directly works towards the Smart Game Boards primary objectives. This is meant to be the “quick reference” page for DM’s while actively playing a game. Whereas the “Library” page displays all figtags and characters, this page only displays the figtags that have been selected. When an RFID tag is scanned the application will search through its figtag database for all figtags whose “RFIDtags” contain the number within its list. All figtags that have a matching value within their “RFIDtags” list will appear on the screen for the user to select between. Once a figtag is selected their quick reference display card will appear within a list below and a digital token with their photo will appear on the ext. screen.

The quick reference card displays all the fields entered for that figtag's character while also providing an input for the figtag's initiative (ini), current HP (HP), and concentration/status. The color of the reference card designates whether the figure is a player character or not: PC reference cards are outlined in blue and NPC cards are red. These features reduce the amount of time a DM takes to look up character details. This list restrains the amount of information to only the relevant figures while keeping the most commonly used stats on display at all times. In the case that a DM needs more information on a figure or they want to remove one from the list the options are available from a dropdown on the figure's display card. The figtags are organized within the list by their "initiative" value. This is to help DM's keep track of the order of combat and whose turn is next. At any point in time the user may clear the list by pressing the "Clear" button above the list.

The goal of the Players page is to focus the information given to the DM on the players and characters currently in action. The featured elements of this page are the active figure list, control buttons, RFID tag display/input, and the figure selection display. The active figure list continuously organizes Figtags based upon the "Display" and "initiative" fields. The list first finds all Figtags whose "Display" is "yes" then they are all arranged in descending order by their "initiative" number. The list actively hides all entries whose "Display" is "no". When an RFID tag is scanned the value is displayed in an input window above the active figure list. The value is then compared with all of the entries within the "RFIDtags" field for each "Figtag". Each "Figtag" that contains the value is displayed on a figure selection display window above the active figure list. User's may assess which figure they were intending to add to the active figure list and either press the corresponding "+" button, scan again, or delete the value to clear the window.

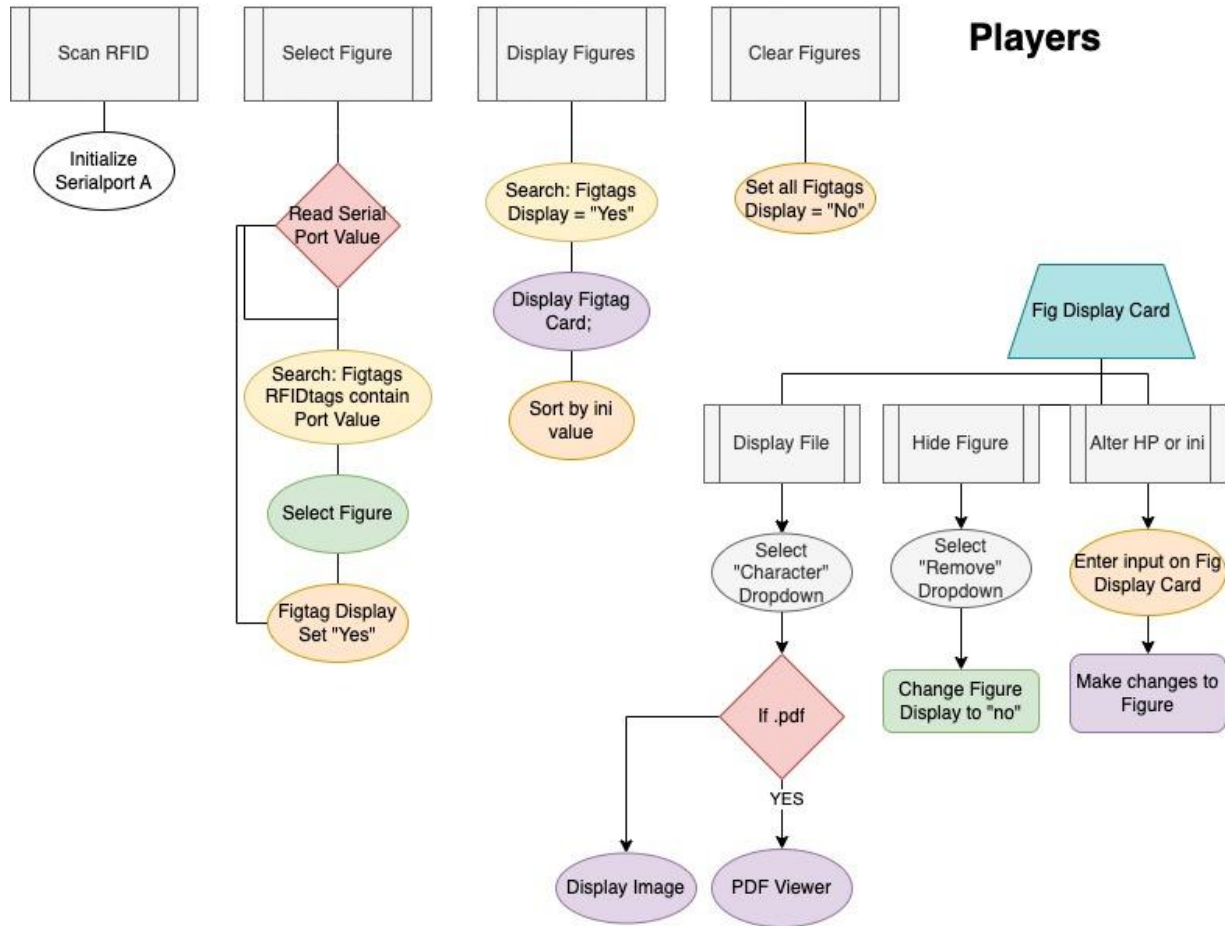



Fig. 12: Players Workflow




Library Players Map Notes

Scan RFID: 803



Holga
Class:Barbarian, RFID: 5002066F3B0, Player:



Edgin
Class:Bard, RFID: 050080303, Player:





	AC	HP	Speed	STR	DEX	CON
15	15	30 / 31	30	12	17	13
	Pass Per	16		INT	WIS	CHA
	Pass Inv	18		18	15	7
	Pass Ins	14	concentration/status	Options		
Goblin						
	AC	HP	Speed	STR	DEX	CON
11	15	6 / 7	30	8	14	10
	Pass Per	9		INT	WIS	CHA
	Pass Inv	10		10	8	8
	Pass Ins	9	concentration/status	Options		
Edgin						
	AC	HP	Speed	STR	DEX	CON
6	14	7 / 110	30	14	16	14
	Pass Per	13		INT	WIS	CHA
	Pass Inv	12		14	16	18
	Pass Ins	13	concentration/status	Options		
Holga						
	AC	HP	Speed	STR	DEX	CON
1	15	120 / 120	40	19	14	16
	Pass Per	13		INT	WIS	CHA
	Pass Inv	10		11	16	13
	Pass Ins	13	concentration/status	Options		

Fig. 13: Players Page

Map Control

The Map Control page determines the majority of what is displayed to the players on the external screen. Users can build their database of “Maps” on this page and can scroll through their library. Selecting a map from the library will display the image centrally while also changing the background image displayed on the external player’s screen.

The page consists of a central element and an image library. The central element continuously searches through the user’s “Maps” database for those that have the field “Display” set to “yes” then it displays the image of the first “Maps” found. The image library searches for all of the user’s “Maps” and displays the image and title for all “Maps” found. When a user

selects a “Maps” from their library all “Maps” have their “Display” set to “no” and the selected Maps is set to “yes”. Figure 14 below displays the workflow chart for the page.

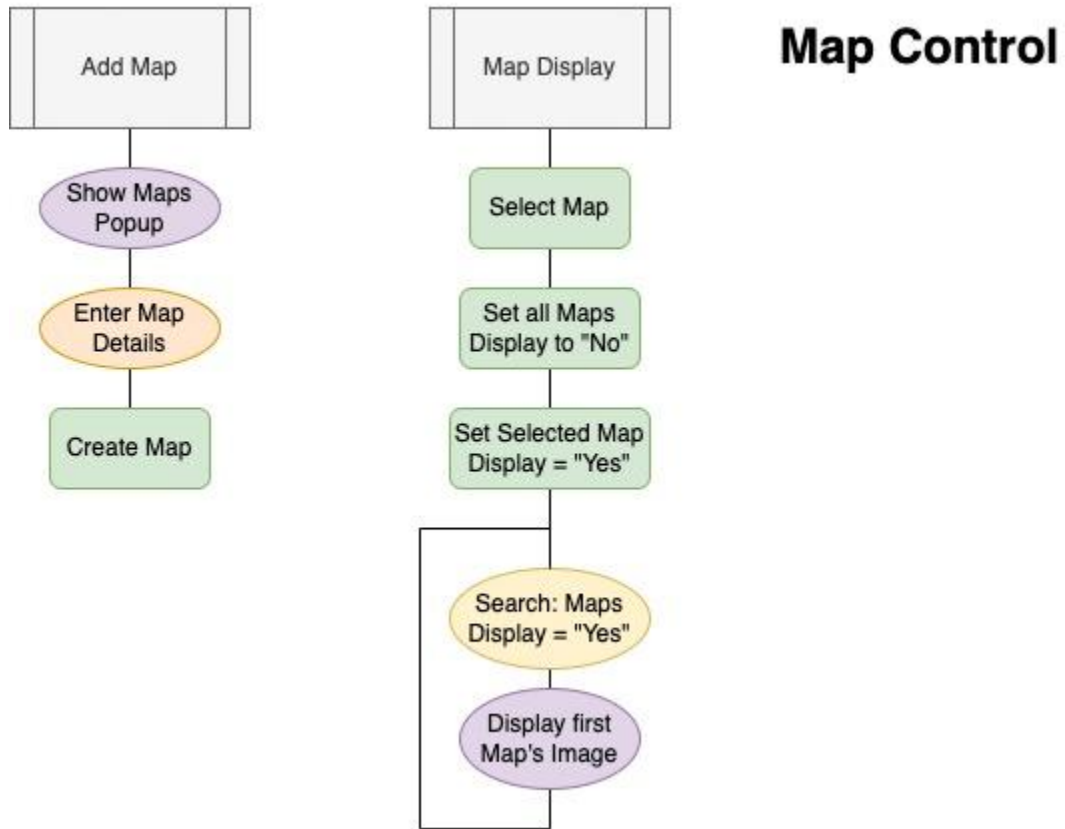


Fig. 14: Map Control Workflow

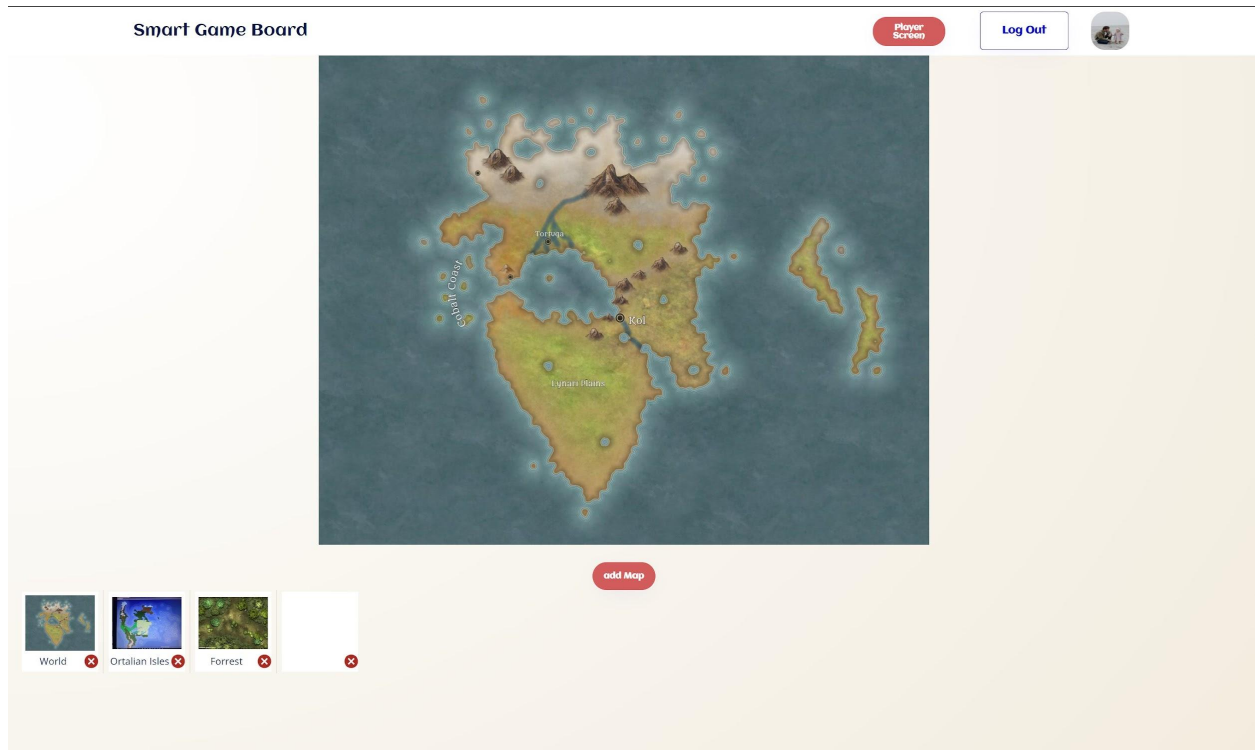


Fig. 15: Map Control Page

Ext. Screen

The Ext. Screen page is a shared space between the DM and the players. The other pages in this application are intended to be only seen by the active DM. The external screen is where the DM and the players may exchange information. This will primarily be done in the form of figure location and map details. The DM decides the location and movement of NPC's as well as the external screen's background image. The background image displayed is chosen on the Map Control page and all digital tokens are sourced from the Players page. Digital tokens are available for tracking the location of figures; however, the primary intent for the external screen is to be the board on which figures are placed.

Similar to the Map Control page the Ext. Screen functions by continuously searching through the "Maps" library and displaying the "image" of the first "Maps" with "Display = yes". The maximum number of digital tokens is set to 10 to match the touch point limit of the

touchscreen. The page performs a search for “Figtags” with “Display = yes” then sorts the list in order of most recently modified. Each token is paired to a “Figtag” based upon the index of the list. If the “Figtag” has the “Display = yes” then its “Character’s” photo will be displayed. The size of the token is dependent on the device displaying them: small, high resolution devices such as a tablet will have smaller tokens whereas larger monitors will have tokens closer in size to the 1” x1” standard. The search function for determining the tokens allows new figures to be added without altering the identity of the tokens. The “initiative” value is set before encounters begin so the figures already established in an encounter will not be modified until the next encounter. In the future another field will be added to “Figtag” to allow for a separate display toggle for the tokens. This will allow all figures to be added to the “Players” page before an encounter without being forced to display all of them on the external screen. This will allow the “HP” field to be actively adjusted for each “Figtag” during combat and have the value saved without interfering with the identity of the tokens.

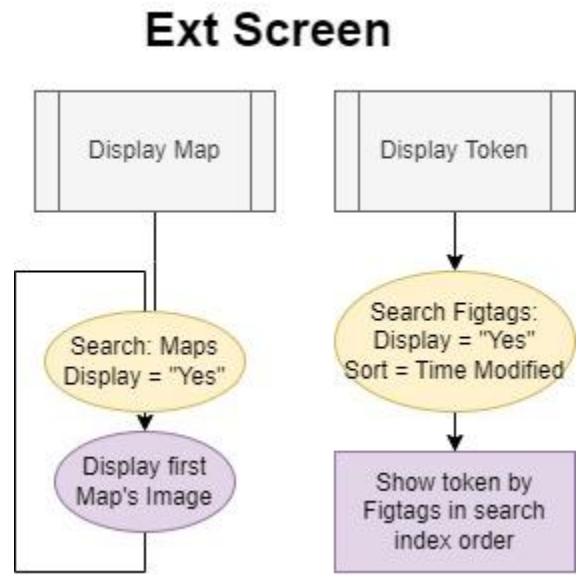


Fig. 16: Ext. Screen Workflow



Fig. 17: Ext. Screen Page

VIII. TEST AND RESULTS

The major challenge in this project is the integration of our many systems. First we must ensure that individual components work, then we connect modules together, resolve issues again and this cycle repeats. This section will follow a similar format where we talk about how stand alone components work, and issues faced when combining components together.

First, we will talk about the RFID scanner. When testing its base functionality of reading RFID tags, it was largely successful. Using terminal applications like the one built into the Arduino IDE, we were able to read the RFID tags consistently between scans, with only ever so often running into a stray character that would lead the rest of the ID. Then when connecting the reader to the bubble.io app, we ran into scanning consistency problems. This led us to compensating by adding more functionality to the app when adding characters as described in the Library section of the Design chapter. Although we had to make this adjustment, we were able to meet our requirement (Table 1, requirement 5) on being able to reliably recognize a figure.

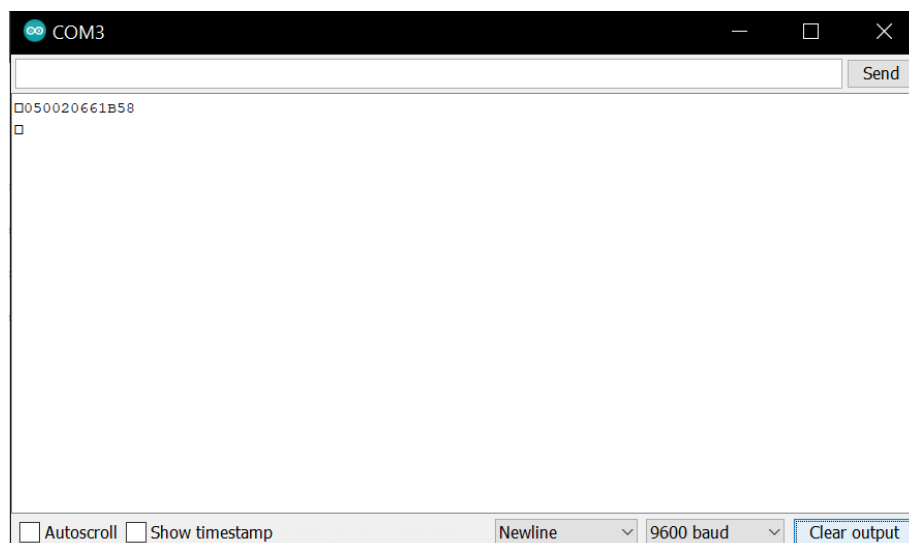


Fig. 18: Arduino Serial Monitor Showing RFID Tag Being Read

The computer we used for this project was very appropriate. On its own, it is a small portable fanless PC that works like most conventional desktops and importantly allows us to connect to the internet. It has the exact amount of USB ports needed for our purposes; we can connect a mouse, keyboard, the RFID scanner, and the touch sensor data from the display. It is able to connect to the internet and allows us to use our app with little to no major slowdowns. Using this device, we were able to satisfy our requirement on a quick and responsive system as seen in Table 1, requirement 3.

The touchscreen display worked well as a display. We had no problems when trying to show anything from the computer or other devices and it is large enough as a play space to conduct the game. Since it is a digital display and can be played on displays of many different sizes, the map can be adjusted to fit the size of the figures which are conventionally 1in x1in. This allows us to satisfy the first requirement in Table 1. The challenges arose when trying to use the touchscreen functionality when trying to locate the figures. Using the touchscreen with our fingers was easy and natural as expected. Then we tested using silicon rubber nibs on the screen and at first that seemed successful as well. However when attaching the nibs to the bottom of figure bases and then trying to use the figure as an alternative touch method, consistency of touch dropped considerably. Most times we were unable to get a touch signal to be recognized, and the ones we did seemed erratic. Although we were not able to achieve the touchscreen functionality we imagined, we are still able to use figures or digital tokens to denote the location of characters which allows us to fulfill the requirement set forth in Table 1, requirement 4.



Fig. 19: Display Board with Map Set to 1in x 1in Boxes

When combining all of these components together with the bubble.io app, we get the Smart Game Board. Overall, the app developed works well for our purposes and the Mini PC we have been testing it on. As described before, the flexibility of the app allows for us to make up for some of the lack of performance we expected from other components in the project. There is room for improvement in the app we developed. Major and Important components work well but could be fine tuned. There are some things like how you are able to scroll off the map page when using a figure token that shouldn't happen. However this app allows us to condense and organize a lot of relevant game information, and therefore satisfies our last requirement set forth in Table 1.

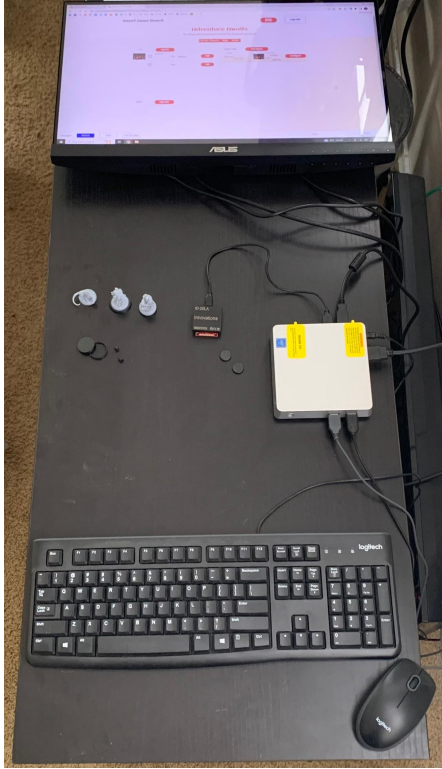


Fig. 20 & 21: Smart Game Board - Fully Built & Game Session

IX. CONCLUSION

The Smart Game Board is an internet based application that utilizes an RFID scanner, RFID tags, computer, and an additional monitor in order to provide digital tools for Dungeons and Dragons players. The original concept was built on three main criteria: collect information, locate pieces, and a digital display. The SGB satisfies the first objective as it recognizes the RFID tags and successfully identifies and displays the information of figures within its database. However, this area could be improved since the current iteration does not consistently read the full RFID tag value. In order to improve this functionality we could build a new serial monitor plugin for bubble or transition to a new app development tool. Locate pieces was the most challenging objective to implement in this design. There are not a lot of tools within Bubble to have users manipulate the position of an element on the screen. Digital tokens (currently a max of 10) can be dragged across the screen but it cannot be done with a figure. Capacitive touch screens require a discharge path in order to operate; in order to add figure functionality we would need to provide a conductive path on the base of the figures. There are two simple solutions for this: metallic figures with a conductive ball tip that descends below the base with a plastic base plate to house the RFID tag. This approach limits the conductive contact point to a single location while providing a path to the player through the metallic figure. The other method is to place a conductive line from the bottom base of a figure to the outer ring where players must hold while placing the figure. The SGB may use tablets, monitors, or almost any display that can connect to the internet as a digital display. The image on the external player's screen is configured to fit on almost any display size, best results are on 20" or larger displays.

Bubble is a very effective tool that made it possible to satisfy most of our core objectives within this time period; however, there are other more powerful methods that would allow for

more freedom in design. There is currently only one option for implementing a serial monitor within Bubble as well as element position manipulation. These facets gave inconsistent results and were difficult to deal with. In order to improve this current iteration “Figtags” need to have a separate display toggle for digital tokens. The current iteration will run into difficulties when encounters have combatants that enter the map in waves.

An external monitor and the scanner could be built into a single housed product but that would increase the cost of the project and it would increase the environmental impact of the project since customers may already own suitable equipment to act as displays.

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XI. APPENDIX

ANALYSIS OF SENIOR PROJECT DESIGN

Project Title: Smart Game Board

Student's Name: Conner Sima, Nathan Jagers, Jacob Barnes

Student's Signature:

Advisor's Name: Dr. Nayeri

Advisor's Initials:

Date:

1. Summary of Functional Requirements

- a. Describe the overall capabilities or functions of your project or design. Describe what your project does. (Do *not* describe how you designed it).

This project stores and organizes information provided by a user. It provides a simple interface to quickly retrieve requested information by the user. It provides a means for the user to display information to others.

This project makes it easier to host games of Dungeons and Dragons 5E. It shifts the complexity of the game into the preparation stage rather than the active play stage. This project provides an easy reference to critical game information in order to help the flow of complicated situations.

Users can create digital tokens and manipulate their position above a user uploaded background. Detailed character information is displayed by scanning an associated RFID tag.

2. **Primary Constraints**

- a. Describe significant challenges or difficulties associated with your project or implementation. For example, what were limiting factors, or other issues that impacted your approach? What made your project difficult? What parameters or specifications limited your options or directed your approach?

The primary difficulty associated with this project was building a software interface. The hardware involved with this project was easy to acquire and didn't need adjustment. The bridge between inputs and display was the hardest to build. Our group was forced to learn a lot about building applications and multiple methods were attempted. We ran into the time constraint in the end due to the substantial amount of time spent learning how to build the application well. Ultimately, it was the time constraint that kept us from accomplishing all of our original objectives as initially imagined. There were some technological hindrances and economical as well since touchscreens have a touch point maximum and ultra-high frequency, multi-read RFID scanners are expensive but those were easily worked around.

3. **Economic**

- a. What economic impacts result? Consider:
 - i. Human Capital – What people do.

- ii. Financial Capital – Monetary instruments.
- iii. Manufactured or Real Capital – Made by people and their tools.
- iv. Natural Capital – The Earth’s resources and bio-capacity.

This project requires many electrical components, mostly in the form of monitors/displays. This means lots of copper, silicon, and many more harmful agents used in PCB creation. The chemicals used in creating wafers for the electronic components are extremely hazardous as are the fumes from melting the gold and copper from the e-waste at the end of the life cycle. This project requires use of smart devices that can connect to the internet. Most people already own capable devices which means it is not necessary to purchase the most expensive elements to this project in order to utilize it. Households that already own a computer and an extra monitor or tablet will only need approximately \$60 more to use this product. This project is mostly app development and would not require a production phase if launched; this front loads the human effort put into the product. Once the app has been launched human effort would be spent in small bursts to keep the application updated and maintained.

- b. When and where do costs and benefits accrue throughout the project’s lifecycle?

The majority of the costs are up front. It takes time to develop the app and to test the entire system but once it is satisfactory the cost to maintain the application is significantly less. Customers also have an initial purchase and time investment before they begin reaping benefits since the efficiency of the application increases with the size of its database. Primarily the cost of the project is in its development

and in the initial purchase of the equipment since there are little maintenance costs; however, more costs can occur due to technological advancement and obsolescence. Computers are beginning to shift from USB-A to USB-C which necessitates the use of adapters or other part integrations for RFID scanners.

- c. What inputs does the experiment require? How much does the project cost? Who pays?
- i. Original estimated cost of component parts (as of the start of your project).
 - ii. Actual final cost of component parts (at the end of your project)
 - iii. *Attach a final bill of materials for all components.*
 - iv. Additional equipment costs (any equipment needed for development?)

The project has external information and power inputs. Information is given and organized within a library which is later retrieved once a familiar RFID tag value is put into the system. Power is used to operate the computer, monitor, and scanner.

The development costs for this application were approximately \$320 for the components and \$8,415 for labor. The launch and maintenance cost would be approximately \$32/month for the site and \$7200/year for labor. Calculations are based upon a \$30/hr rate.

- d. How much does the project earn? Who profits?

In order for the project to earn money the total expenses must be overcome. This can be done either by selling page space to advertisers or by charging users a fee.

Assuming a goal of 240 new users a year a one time fee of at least \$32 would allow the project to start earning money. This breaks down to approximately \$2.67/month if implemented via subscription. A subscription based system would compound the overall benefits each year so long as the subscriber base remains consistent. Those that launched the application and bubble.io are the primary entities that benefit

e. Timing

- i. When do products emerge? How long do products exist? What maintenance or operation costs exist?

The SGB application costs \$32/month for the domain at the lowest tier on bubble.io. Customers may choose their own suppliers for 125kHz scanner, external monitors and computers; however, for the products used in our development the average power consumption is approximately 70W while operating. The approximate maintenance cost for the application is \$32/month for the domain cost and \$7200/year for site maintenance labor.

This project is designed around Dungeons and Dragons 5th edition. This is currently the most popular TTRPG on the market; however, this will not always be the case. Wizards of the Coast is currently working on the next system which was stated to be compatible with 5th edition so that would not conflict with the current state of the project but in the future this project will need to adapt to the latest TTRPG system.

Since this project's development was largely software, and the components required for its physical construction, such as the RFID scanner and touchscreen display, are purchasable directly from manufacturers, this product could be very quickly produced, manufactured, and released immediately after development is fully completed. Assuming normal use, this product should receive minimal wear and tear on its physical components, with only light physical contact on the display screen, and low heat buildup in its electrical components. Therefore it is reasonable to expect this device to have a many-year lifespan comparable or better than other contemporary electronic devices. Physical maintenance, and therefore maintenance costs, should only be required to this device if it is damaged outside of the boundaries of normal use, such as being dropped or a liquid being spilled onto it. Software updates and upkeep of that nature would not incur costs on the consumer. The only cost associated with the usage of this product beyond the initial purchase investment would be the power required to charge or run the device.

- ii. Original estimated development time (as of the start of your project), as Gantt or Pert chart

4. If manufactured on a commercial basis:

- a. Estimated number of devices sold per year

Roll20, a major VTT vendor, currently has 8 million subscribers, so we know there is a large market. A moderate goal would be 240 units for the year which averages out to 20 sales per month.

- b. Estimated manufacturing cost for each device

It cost roughly about \$350 to make this device with the monitor, PC and RFID scanner being the bulk of the costs. Then to keep it up and running there is the \$32 /month fee to pay to Bubble for its services.

- c. Estimated purchase price for each device

If we want a 20% profit from this operation, we will require a 20% markup from the manufacturing costs. This means we would expect the initial total to be about \$460. In other words \$420 for the physical device and a recurring \$38/month.

- d. Estimated profit per year

\$16,800 from the 20% markup numbers.

- e. Estimated cost for user to operate device, per unit time (specify time interval)

Operating this device requires about 70W. Assuming a single, typical Dungeons and Dragons group that meets once a week for four hours in California, this would cost about \$0.22288 per month. In addition, the operation of this device

requires a subscription to our service, at \$32 per month, and an internet connection, which appears to average around \$50 per month at starting price in California. In total, the monthly cost of operating this device averages around \$82.22. This cost assumes only 16 hours of use during the month however, meaning that for this scenario the hourly cost is \$5.14. However, most of these costs are flat rates per month, and do not depend on how often or long the device is used, the only component of this cost that is determined by use is the power, which is also the factor that contributes the least to this cost, so a user that uses this device more than 16 hours per month will drastically reduce their per hour cost.

5. Environmental

- a. Describe any environmental impacts associated with manufacturing or use, explain where they occur and quantify.

Since this product is largely electronic devices, the environmental impact of manufacturing this product comes from the manufacturing of PCB's: the collection and refinement of precious metals such as copper, the refinement of silicon into semiconductor chips; and the use of petroleum products such as plastic for housing. These processes are known to be capable of releasing harmful fumes into our atmosphere, especially when some of these materials are reclaimed from e-waste at the end of the product's lifecycle. In use, the environmental impact of this device is limited to its energy consumption, which depending on

the infrastructure in the user's area can have widely varying environmental impacts e.g. the difference between burning coal or harnessing solar.

- b. Which natural resources and ecosystem services does the project use directly and indirectly?

This product uses precious metals, silicon, plastic, and glass in its physical construction, and depending on the power infrastructure that the user makes use of this device may also consume resources such as coal or natural gas to provide the power requisite for its operation.

- c. Which natural resources and ecosystem services does the project improve or harm?

Since this product is an electronic luxury device for human entertainment, it is unfortunately not designed to directly improve natural resource consumption or ecosystem services, however, since users no longer require physical maps and terrain pieces, being replaced by the display of the device, it does reduce paper consumption, and given a long enough lifespan may end up reducing the amount of plastic consumed in terrain pieces by more than the device itself uses.

- d. How does the project impact other species?

This product supports industries such as electronics manufacturing, power generation, and e-waste reclamation; all of which can impact other species as well as humans with airborne pollutants resulting from those processes.

6. **Manufacturability**

- a. Describe any issues or challenges associated with manufacturing.

Since this project was primarily software, which fortunately does not need to be redone for each individual device, manufacturing is relatively simple. The most prominent possible challenges to manufacturing this device would be sourcing components, and updates to the design as relevant technological advancements are made or a particular component is made obsolete.

7. **Sustainability**

- a. Describe any issues or challenges associated with maintaining the completed device, or system.

Since the completed device should not receive much or any wear and tear during normal operation, maintenance should be very simple, if not entirely unnecessary. Throughout the lifespan of the device it could receive software updates however, either driven by necessity, such as an unforeseen security vulnerability, or simply to improve the performance of the device.

- b. Describe how the project impacts the sustainable use of resources.

The production of additional electronic components for this device would impact the usage of materials such as copper, silicon, plastic, and glass, most of which are not particularly sustainable as-is. In addition, since it requires power for operation, it could increase the usage of resources such as coal and natural gas for

power generation, which are not sustainable at this time. On the other hand, since this product makes the usage of physical maps and terrain objects unnecessary, it reduces the consumption of paper and plastic products over its lifespan. Additionally, as power generation continues to shift towards making sustainable use of resources such as solar and wind, this product's impact will shift along with them.

- c. Describe any upgrades that would improve the design of the project.

There were several upgrades to the design that would have been implemented in the original development if not for the time constraint. The original design was close to implementing a more effective tool for adding new characters. It is possible to populate the "Character" fields automatically once a user uploads a PDF, spreadsheet, or external webpage. The ability to share "Character" or "Figtag" across "Users" while maintaining security and privacy of a personal library would be another way to quicken database development. It can be time consuming to manually enter all the details when adding a new character. Ideally this project would create a physical product in the form of a figure base snap-on cover. This cover would house the RFID tag and provide a conductive path such that a nib could interface with the touchscreen.

Additional upgrades to the design of this project could be technological advancements, such as more power efficient displays and RFID readers, data transfer cables with better transmission, touchscreens with higher detection resolution and touchpoint capacity. Also, an upgrade that could be made to this

design would be if we were able to use an Ultra High Frequency (UHF) RFID reader and tags, which would allow us to place the reader beneath the display out of sight and the device would be able to scan multiple figures simultaneously and while they are in their proper positions on the map, as opposed to having to scan the figures in on the separate reader and then placing them on the map. The system is currently designed to work with Dungeons and Dragons 5th edition, another potential upgrade would allow for other game compatibility.

- d. Describe any issues or challenges associated with upgrading the design.

The primary challenges with upgrading the design are time and knowledge. Web application development is a skill that was acquired for this project. There are many software advancements that could benefit this project but it takes a significant amount of time to learn how to implement them effectively. This is also the case with hardware upgrades. The current system is designed around the 125kHz scanner that can only handle one tag at a time. The serial port plugin is not configured to work with the multi-read UHF scanner so the current system would need to be overhauled to work with the input the UHF scanner would give. The snap-on base cover could be developed through solidworks but that would involve contracting someone skilled or learning how to build a 3D model.

8. Ethical

- a. Describe ethical implications relating to the design, manufacture, use, or misuse of the project.

This product as it currently stands is restricted to individual users. There is no option to share information or to view other user's personal information. This does not fully prevent people from attempting to steal from other users. The only way to avoid charging customers while keeping profits is by giving space to advertisers. If there is a fee involved then there is a link to personal banking information that people could try to steal.

There is no current limitation on the language or content uploaded to the application. People are currently able to use this platform to offend others with language or images as it presently stands.

9. Health and Safety

- a. Describe any health and safety concerns associated with design, manufacture or use of the project.

The largest health or safety concern associated with this product would be the pollution resulting from the manufacturing of this product or the processing of it as e-waste at the end of its lifespan.

10. Social and Political

- a. Describe social and political issues associated with design, manufacture, and use.

This product was designed as a supplement to an increasingly popular form of entertainment, the tabletop roleplaying game. By the very nature of this genre and this device it promotes social interaction in a shared physical space; the use and

development of skills in critical thinking, teamwork and communication, planning and strategizing, problem solving, improvisation, social awareness, and imagination. This product will enhance the experience for the users by providing additional visual stimulus, as well as reducing the mental tax of keeping track of numbers and rules on the players, allowing them to devote more mental energy to the aforementioned skills and more importantly enjoying the game. By improving the experience for those who already engage in this activity, we are also encouraging those who do not already to also join, allowing them similar opportunities.

- b. Who does the project impact? Who are the direct and indirect stakeholders?

The consumers of this application are directly impacted by this project; the people who play the games that this device was designed to support. Another indirect stakeholder are the creators of the games that we are supporting, by increasing interest and engagement with their product. As game enthusiasts and the app creators we are direct stakeholders; we stand to benefit the most from this project. We will be the first to use it at the table and we stand to benefit from the profits once it is launched. Bubble.io is directly impacted by this project since it sells us access to the domain and their name is tied to this project. Cal Poly's name and funds are also tied to this project. They may not be involved with this project heavily when there is no issue but if something were to bring this project to court then Cal Poly would be an active party.

- c. How does the project benefit or harm various stakeholders?

The product improves the quality of the experience for the player, allowing them to have more fun while playing by taking away some of their mental load and providing more engagement with visual stimulus. This product has the capacity to drive up sales for the companies that own the games that we are supporting, by increasing interest and engagement it can bring new people to the market or encourage existing players to purchase more products such as supplemental rulebooks to have more options for their games or just as souvenirs or collectibles. The competitors such as physical map and terrain producers, Teburu, and virtual tabletops will have their sales reduced by having additional competition in the market that may appeal to an audience more than their product.

Bubble.io and Cal Poly both have their names intertwined with this project. The success and popularity of this project honors them and attracts audiences to them. This could drive creators to bubble.io for future projects and this could translate to more new students or funding for Cal Poly. Dr. Nayeri would benefit from the success of this project as the advisor.

The current system is designed to work with Dungeons and Dragons 5th edition which is a property of Wizards of the Coast. Should this project increase the popularity of their product then they would stand to benefit. They have their own digital toolkit which could integrate with this project to create characters more effectively. They also have their own VTT in development which could be seen as a form of competition to this product which could cause a less favorable relationship with them depending on what else they have in development with their digital toolkit.

- d. To what extent do stakeholders benefit equally? Pay equally? Does the project create any inequities?

- e. Consider various stakeholders' locations, communities, access to resources, economic power, knowledge, skills, and political power.

11. Development

- a. Describe any new tools or techniques, used for either development or analysis that you learned independently during the course of your project. Include a literature search.

Bubble.io is the primary tool used to create this project. Bubble.io is an object oriented, visual programming tool that does not require coding. Prior to this project our group didn't have any knowledge of this tool or how to use it. The site has an extensive online manual as well as a Youtube channel with tutorials for app development. A significant amount of our time on this project was learning how to use this tool effectively.

Creating an app using Python was another implementation that was explored for the software portion of this project. Prior to this project the group generally had little experience with python. There are many resources online that can help you

learn to code with python and an extensive amount of pre-made libraries so you can do so many different types of work with python. Many of the resources online we explored were how to create a GUI in python and how this GUI would look.

BILL OF MATERIALS

BOM SGB			
Component	Qty	Price/unit	total
ASUS VT229H 21.5" Monitor	1	\$243.16	\$243.16
16mm 125kHz RFID Button	2	\$4.50	\$9.00
Sparkfun RFID USB Reader	1	\$27.95	\$27.95
Plastic Miniature Base Pack	1	\$5.43	\$5.43
RFID Reader ID-20LA (125kHz)	1	\$37.50	\$37.50
Scotch Removable Mounting Putty (2oz)	1	\$2.89	\$2.89
		total:	\$325.93

GANTT CHARTS

Attached below.