Senior Design Project I MDR Report: A Revision of System Performance of Tablo

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***Abstract*—In this work, we present the results of the system prototype of our project to be named "Tablo". Tablo is a gaming system that uses camera detection to allow users play board games without the anxiety of losing game pieces and makes the gaming experience of board games more convenient. This project has been in the making from the start of the Fall 2018 semester; the ideas and implementations of this project has been evolving ever since. The goal of Tablo was to make the experience of playing real life table games more convenient and accessible, however, this idea proved too ambitious, thus we formulate a new goal that is more feasible. The current goal of Tablo is to now improve the gaming experience of board games such as: chess, checkers, and more creative games of our making. We have developed a sensing mechanism that can track the motion of specifically colored objects, namely we use red for our color detection. We have been successful to demonstrate the essentials of playing a game through this system by being able to track a red-colored cloth in moderately dim light to interact with objects moving around in our central computer. Our hope now is to be able to display the motions of the game through a projector while the player uses the colored controller on top for a more intuitive experience, with a more robust sensing mechanism.**

***Index Terms*— Arduino, Camera detection, Board Games**

I. Introduction

In this work, we present our gaming system, Tablo, that can help to improve the experience of playing board games. Board games have many small components and pieces, thus people face the issue of losing these pieces or have difficulties storing several of their board game sets. The digitization of these board games via Tablo will aid in removing the anxiety of losing pieces, as well as enabling the user to store numerous board games in one, compact set. Tablo can also offer players many more features to traditional board games, since all the games are digitized, we can add new features that can further customize the game settings and appearances. For example: we can change colors of the game pieces, add unique scoring systems, provide tutorials on how to play the board game, etc.

This problem has a very large market, according to Ref[1], sales of board games have been rising every year for the past decade. Board games have been increasingly becoming more and more popular as friends and families are attracted to the notion of being able to bond and connect with each other face-to-face around a table. Studies shown in Ref[2] support the notion that board games can enhance children's abilities to learn and grow to be adaptive. The visual graphics and hand-eye coordination allows for children to grow their critical thinking capabilities, and families have a more affinity to buy their children board games. Board games in general come with strategies and requires wits and logical reasoning to win against your opponents in any board games at any age.

The gaming industry has involved 1.2 billion people around the world, and there are tens of millions of people playing board games who would love for their gaming experience to be enhanced. Many attempts are made to digitalize board games for enhanced experience, however these digital versions of board games allow for only one game. This is to say that there is no database for multiple board games that can be saved in one system, in lieu that each board game has its own requirements and uniqueness to it such that one interface cannot accommodate for all types of board games. This is also to say that board games cannot have electronic features to them; bard games are not only limited to just plastic pieces with no dynamics. In a paper proposed by Melissa J. Rogerson et al, Ref[3], many implementations for digitalizing board games is explored. These techniques used are for the sole purpose to make board games exist in the digital world, not necessarily to make the experience of playing board games easier or more convenient.

Fig. 1. Depiction of our gaming system. Projector and camera will be hung over user's table, about 5 feet to 6 feet above their table. The control box, where our PCB board will be used, is mounted on the edge of the table to allow users to perform necessary functions such as: pausing the game, resetting the game, or switching the amount of players in the game, just to name a few.

Our solution is to propose a more user-friendly environment in which anyone of any age can use the gaming system we propose to make playing board games more accessible and easy to play. The gaming system we call Tablo, a spin-off from table games, will store board games in one interface and will use camera detection to track user interactions to allow the user to play several hundreds of types of games in one sitting. We envision the users playing at a normal table in a regular household, with a small, light-weight camera overhead, and the users being able to see a projected view of the game they play on the table before them, with a control box that utilizes the printed circuit board (PCB) to switch form one game to another.

This will have major impact on the community since board games can help children learn and expand their critical thinking abilities, as well as help families and friends bond over face-to-face interactions around a table in the comfort of their homes. This gaming system will strengthen the board game community and have a positive impact for players as this system shall remove the anxieties of losing game pieces and save players the hassle of storing numerous boxes containing their games, as opposed to one electronic gaming system.

Table 1

Requirement	Specification	Value
Portability	camera weight	< 5 ibs.
	PCB control	Mountable to table edge
	Projector weight	< 20 ibs.
Response	Delay	< 100 ms
Safety	Projector	Mountable up to 6 feet above table
User Compatibility	Number of players	1-4
	Display area	$2ft^2$ *to* $6ft^2$
	Control box	Adjustable gaming interface

Table 1. System specifications table for project Tablo. Qualitative and quantitative values listed. The power dissipation of the PCB should be no more than 50 mW.

The system specifications table reveals our goals for our project. We want a safe way to mount the projector over the table that users will be playing on, this will be above player's heads, so the weight of the projector must be minimal. We would like to have an adjustable display such that users can adjust the projection of their game onto their table, as different people have different table sizes. The control, where we shall implement our PCB board, will allow users to simply perform functions necessary to facilitate a convenient way to regulate the games being played. Functions that the control box will iterate are: resetting the game, pause, adjust camera sensitivity by the lighting in the room, and change the amount of players allowed in the game, just to name a few. In this work, we revise the outcomes of our mid-year design review (MDR).

II. Design

Our design can be easily understood with our system block diagram, which depicts how each component communicates with each other and how our project will function.

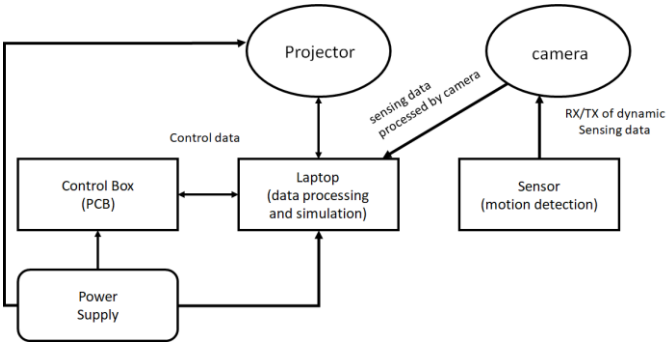

Fig. 2. System block diagram with communication mechanism labeled on arrow paths. Components that are hung over players' heads are in ovals, components that are used on the table are in rectangles. Player's laptop is made the central control for the entire system.

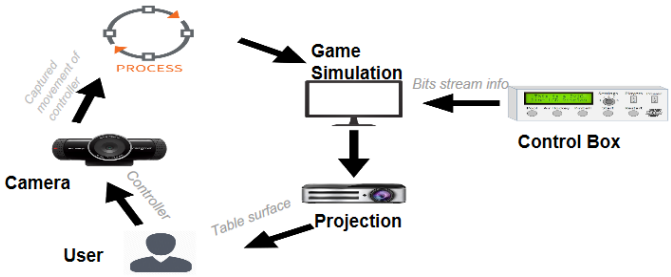

Fig. 3. With our system block diagram shown, we also show how the system works in real time. The projector will display the simulation on the table, from which the user can see how the game progresses, and then is able to use their controller that the camera can track. The camera then sends processed data to the game simulation in the user's laptop, which then reiterates the progression of the game on the projector. At any during this feedback loop, the user can turn on and off the game, or switch settings of the game via the control box.

The control, or the main computing component of our system is the user's computer/laptop. This is so that the gaming system is made a commodity that is convenient for anyone's use. The laptop is used for all computations, the user's laptop will take in information from the camera and process that data to track the motion of the user. The central control, the laptop, will store the numerous games users can play in a database, and will be able to send the simulation data to the projector onto the table. The central control will take in the motion tracking information and use this data such that the simulated objects within the game will react to the user's interactions.

The camera will be hung over the user's table, alongside with the projector This will allow for players to have an easy, intuitive playing experience on the table, however if the users wish, they can orient the camera and projector together to be able to play on a wall if need be. The camera shall track the user's controller, as of now, we use a color sensing, RGB mechanism to track the color red. Thus far, our controller is a red cloth that the users can use as a controller to interact with objects displayed form the projector. We choose color tracking because we believe this is the easiest mechanism for detection and will allow for minimal delay in sending data.

The sensor is the controller as discussed previously, the camera is programmed for color tracking, thus the sensor must be of a color that is not used by the user's table or clothing. We continue to explore other mechanisms and means for picking up data from the sensor, as we have come across issues with the color tracking, such as issues with the lighting within the room obscuring colors. A more robust means of motion tracking is currently being taken under consideration. We will test a way for the camera to take in data from the image of the user's hands themselves as the sensor rather than a colored object. This method seems more robust and convenient for the user, as the user may have a colored table cloth or clothes that are the same color as what the camera will want to sense. This mechanism is however more complicated than color detection, as the users will constantly move their fingers, this obscuring how the camera detects the hand. We have been testing the color tracking scheme with a red cloth tied to the end of a stick to act as the controller. If this method proves to be un-usable in certain lighting conditions that rooms usually have, then we would resort to the hand detection. The color tracking is functional for dim-lighted rooms, and we still have issues trying to keep the tracking consistent.

The projector will be store-bought, roughly $200.00 is the estimated, maximal cost. The projector will be hung above the player's table just like with the camera so the projection is over laid on top of where the camera is picking up motion.

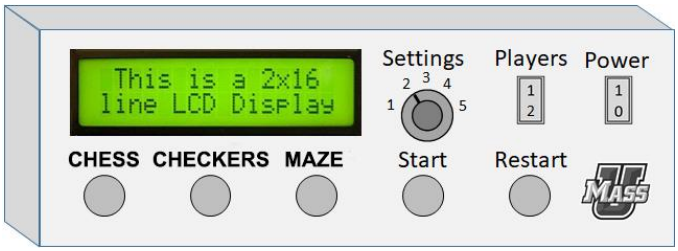

Fig. 4. Depiction of control box, finished product. Finished product is depicted as a box that is able to be mounted on the edge of user's table, with many buttons for many functions that the user can adjust easily without having to resort to their laptop.

Plans are still being taken further for fabrication of our PCB board. We implement our proof of concept with the Arduino UNO PCB to communicate with the laptop to adjust gaming settings. Code has been written to read in voltage values from potentiometer that we use as analog switch to adjust the display screen of the projector, such that low voltage values will decrease projection surface area, and larger voltage values will increase the projection surface area. We are waiting to fabricate our PCB board as we are soon finalizing which exact functions we want it to implement. Ideas include a potentiometer switch to adjust display surface area, and have photo-resistors to detect the ambient light in the room, which can signal the camera to adjust how it senses the colors for motion tracking. The PCB is an integral part to the system, and we are taking cautious, preemptive measures to design the board before we request to fabricate it. Three-dimensional printing will be used to encase the PCB board for aesthetics and protection purposes. The Arduino circuit uses the ATMega32-8P microcontroller, the schematic of which is shown in figure 5. We shall use this in fabricating our PCB board in addition to the other components we are using, such as buttons and linear elements (resistors, capacitors, and inductors) and nonlinear elements (potentiometer, transistors, and amplifiers) to be added to the microcontroller. The PCB is expected to dissipate no more than 50 mW.

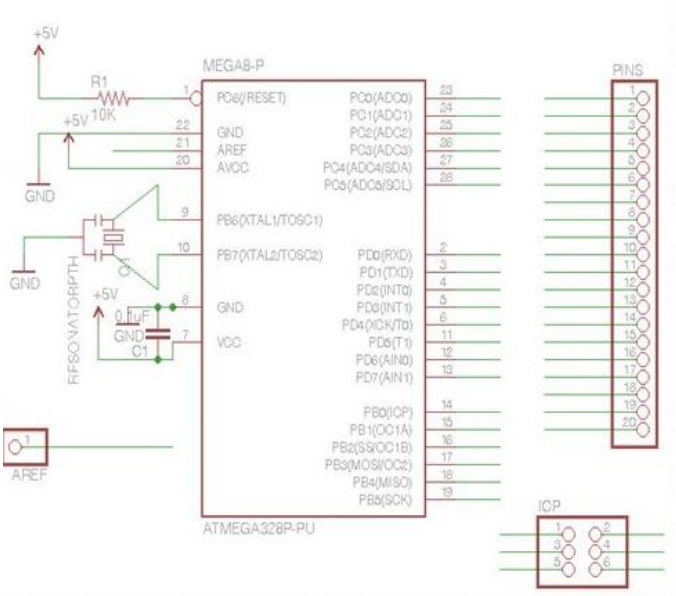

Fig. 5. Pin layout of ATMega32-8P microcontroller that shall be used for our PCB board. This microcontroller shall take in 5 V supply from a battery.

We intend to produce a minimal apparatus for displaying our project for the final week of presentations. We envision a bar that is raised by two support beams on either side of the table we demonstrate our project on, with the camera and projector hanging from the middle of the bar. This should be sufficient and a safe means to display our final product at the end of next semester.

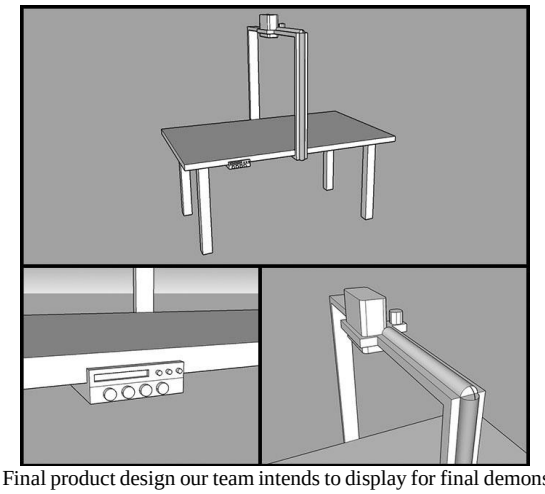

Fig. 6. Final product design our team intends to display for final demonstration. Top figure shows entire apparatus, bottom left figure shows the mountable PCB board, and bottom right shows where the camera and projector will be hung. We intend to have wired connections running along the side beams to communicate the projector and camera to the PCB and laptop.

III. Project Management

Table 2		
MDR Deliverables	**Status**	**Next Steps**
Functional camera detection	Completed	Refinement of color detection
One functional sensor input	Completed	Second functional sensor input
Detect interactions between user controller and simulated objects in real time	Completed	Allow users to pick up and drop objects in simulated game
Display simulation of game on laptop	Completed	Projection of game on table
PCB control commands outlined	Completed	Prototype on breadboard and outline in CAD software

Table 2. Table of MDR deliverables with status and next milestones listed next to each deliverable. The items listed in the "Next Steps" column are our final goals for the project.

We believe we have been able to meet our MDR deliverables, concerning the basic essentials of our project's functionality. The downside to this is we have yet to build the circuit that will be used as useful, user-friendly tool for players. The motion tracking mechanism that utilizes color detection is currently under revision. We aim to make this sensing mechanic work better to be error-free and more robust. However, alternative plans are being considered, such as shape tracking or hand detection. These alternative methods pose even greater risks however. The hand detection may be more difficult as users will constantly move their fingers in various ways, which can obscure how the camera will detect the user's hand. The shape tracking poses an inconvenience as there are inevitably many kinds of shapes that will appear on the board game, such as squares and circles for checkers, thus our controller cannot take the form of a simple shape that would be mistaken as an actual game piece.

The lighting issue poses troubles as well, if a room is too dark, the controller's red cloth appears as black and the camera will not detect anything, and too much light saturates the camera, thus rooms of only dim light are preferred. This makes having the projector on top of the filed where the camera will detect a potential problem. We intend to solve this problem with our PCB, by implementing photo-resistors to send feedback to the camera on the lighting of the room, so the camera can adjust its sensing at any time, for example if users want to play games at night or in the morning.

With our second functional sensing input we aim to add to our project, we should be able to allow users to play a greater variety of games that enables them to place objects arbitrarily. Our first sensing input, the color detection, allows for users to move around within the game. If we are successful to implement a secondary input to be processed by the laptop, we can allow users to not only traverse the gaming field, but also have more interactions with the objects within the game. We envision some kind of switch that the user can press, which will correspond to turning on and off a light-emitting diode (LED) circuit that is safely and securely attached to the controller. The LED may send information in the form of infrared radiation (IR) which the camera can pick up and register the signal as the user holding an object. The user would have to continuously hold the switch to keep the IR LED circuit on, which corresponds to the user holding an object in the game, and the user would simply let go of the switch to let go of the object in the game.

We have designed preliminary commands and functions that the PCB will implement for our final product, we now must make greater efforts to have the PCB fabricated. We at least wish to have a prototype implemented on a bread board by CDR to demonstrate users can perform basic functions such as turning on and off the games.

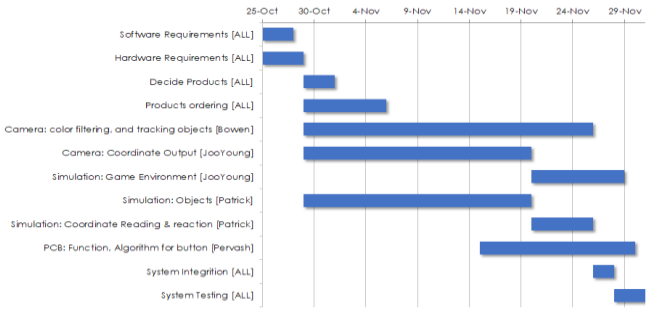

Fig. 7. Gantt chart displayed with each group member's individual responsibilities. Chart shows how tasks have been split up during set time periods.

The Gantt chart displayed in figure 7 shows how each team member has contributed to the project. The tasks are broken up by each team member's expertise. Bowen and Joo Young have been using their programming knowledge in C to as well as expertise in image processing to create the video tracking software. Patrick has been using his previous experiences in gaming to create the gaming simulations, as well as developing means to edit current games and produce new games. Pervesh, the electrical engineer major of the group, has been testing LEDs that are bright enough to be used as a secondary functional input, as well develop pin layout plans for the fabrication of the PCB.

The means of giving each other aid within the group stems from independent research. Each team member is assigned a task and then is free to execute that task as they see fit. Occasional issues arise within each group member's task, thus team meetings are set up over weekends to revise and resolve issues. Each team member is able to offer their own expertise in helping another team member's issue. For example, Pervesh has had troubles developing Arduino code to send data to the laptop, Patrick and Bowen were able to provide aid in developing code for the circuits' commands. Another case where Patrick and Bowen wanting to test which LEDs would suffice in motion tracking, Pervesh was able to create circuits to make sure the LEDs were biased properly to ensure current flow was in the correct direction with sufficient voltage supply.

Our two main methods of communications are a group text and multiple google docs. The group text allows us to always keep each other updated on how our tasks are going gives us an easy way to ask each other quick questions, and the google docs allow us to all access the information the other members have gathered and share things with each other that we think might be important information in the future.

With everyone being in different classes and working with complicated schedules, putting things in the google docs allows everyone to work on presentations and reports when the have the opportunity, instead of struggling to figure out when and where everyone can meet to work on things.

Aside from doing our own tasks individually on our own time, we meet regularly as a group to make sure all of the separate components still work and communicate correctly with each other. We also meet weekly with our advisor Professor Kelly to discuss the status of the project as a whole and to make sure timeline is still as close to our proposed schedule as possible.

IV. Conclusion

Our project is underway for success, as we have demonstrated our proof of concept. We have shown that our system has the makings to be able to implement board games. Our camera detection works up to 1.72 meters, approximately the 6 feet height that we are aiming for our projection and camera to operate at above from the table. We have been able to demonstrate the camera is in fact able to track the motion of the color red in dim lighting up to 1.72 meters. We have been also able to program simple games that users can interact with, such as in one game, users appear as a red ball and can chase a yellow ball, and if they acquire the yellow ball, they earn points, but if they hit a black ball on the field, they lose the game and must restart. Figure 8 shows the game simulation that has been presented at MDR. The camera was oriented to face a wall, from which users could use the red cloth on to act as the controller to move the red circle around in the game simulation.

We are only able to display the simulation of the game on a laptop. Our hopes are to have the projector fully running and able to display the game on a table. We would like the camera to be mounted on the projector so the users can have intuitive playing experience by playing the board games on the table. Another goal is to create a more robust mechanism for the camera being able to detect motion in order decrease delay and have an easy way for users to interact with the gaming system. Our current idea is to track the hand of the users themselves, this poses the best way for users to have the best, intuitive way to play digitalized board games. The hand detection, along with shape detection are ideas being considered as back up plans if the color detection proves unsuccessful in refining for better computational performance.

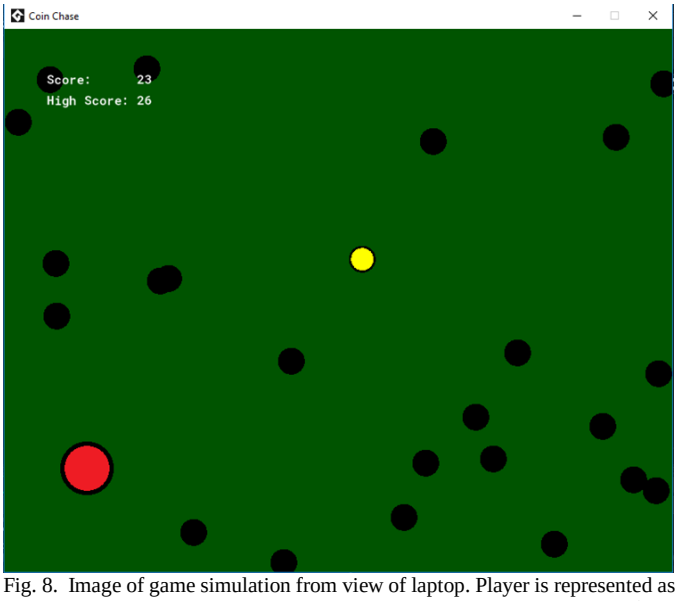

Fig. 8. Image of game simulation from view of laptop. Player is represented as a red circle, and the goal is the yellow circle, obstacles that prevent you from advancing the game are black circles.

As for our PCB board, work is still underway to have it fabricated, we have yet to purchase the software necessary to draw out the schematics of the PCB board. This goal however, is relatively straightforward, once we finalize which functions we want the control box to have separate from the user's laptop, we can draw out the circuit schematic and have it sent to the Altium company and have it fabricated within two weeks. We implement basic functions on the Arduino UNO PCB board for proof of concept. We have shown we can read in voltage values from the Arduino circuit, these voltage values will be used to send the laptop information to execute several functions. Some of the functions we absolutely would like to implement is being able to adjust the surface area of the projection's display, and being able to adjust the sensitivity of the camera's detection based on voltage values from the photo-resistors to aid in the motion tracking.

Our plans moving forward are to implement an LED circuit to be used as a secondary sensing input to provide users the ability to play a wider variety of games. This secondary input will allow users more types of interactions with objects as they would be able to pick up and put down objects in the simulation so they can play chess or checkers, for example. We plan to have our PCB drawn out on a CAD software and be ready to be fabricated, once final decisions on which functions the PCB should carry out are made. We shall work towards a prototype of the PCB using Arduino to implement basic functions in regulating how games are played. The tasks that are being worked on now are planning how many button switches will be needed for each function we want the PCB to implement. We need to devise circuitry for the buttons, we plan to use linear elements, such as resistors or capacitors, to make sure the voltages on the buttons are read correctly. After this process is done, we next would incorporate all these buttons and command functions on a breadboard as a prototype. Once the prototype is established as a fully functioning component, we can then draw out the schematic in a CAD software, such as Altium, and have it sent to be fabricated.

Our next task that we are currently working on is refinement of the color tracking. Our current issues are that the tracking will sometimes erroneously track other objects within the camera's view, such as the user's wrist or another inanimate object. We currently are working to revise this issue so the color tracking is always correct and reliable. Once we can enhance the color detection, the next matter is to display the game simulation on a table via the projector, so the user can play on the table alongside with what is happening in the game, as opposed to having to play against the wall and view the game on the laptop. Once we have our improved color tracking and PCB design, we should be underway for a successful milestone completion.

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