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TNT Board: An Interactive Electronic Board Game

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Tanzeena Karim received the B.Sc. degree in Computer Science with double minors in Mathematics and Writing in 2020 from Middle Tennessee State University (MTSU). She currently works as an SAP Support and Development Engineer at a tax consulting firm and volunteers as a Web Developer for the literary publication, "Shift," at MTSU. She has worked as a Research Assistant and Frontend Android developer intern at a startup company, branched from Vanderbilt University's Robotics & Autonomous Systems Lab (RASL), contributing to a digital platform for robust early screening of Autism Spectrum Disorder (ASD) in toddlers. Her experiences also include working as a content creator and social media manager intern at the MTSU English Dept., Student Technology Assistant (STA) at the Adaptive Technology Center at MTSU, providing hands-on assistance to assisting students with disabilities to efficiently utilize various adaptive equipment, such as utilizing braille embossing tech to create accessible textbooks, etc. She is CITI (Basic Collaborative Institutional Training Initiative Program) certified by the IRB, Certified Microsoft Office Specialist, a TBR SERS Grant recipient, received Excellent Scholar Award in 2014 from her high school in Dhaka, Bangladesh, her written formal essay was chosen to represent MTSU at the Southern Literary Festival Undergraduate Writing Competition, and has received multiple scholarships as an undergraduate namely, MT Diversity, Lottery Hope and Hope Supplemental, Lottery Aspire, has been a part of the TLSAMP (Tennessee Louis Stokes Alliance for Minority Participation) program, and was a finalist for the Robert C. LaLance Jr. Achievement Award. Her volunteer activities also include participation as a mentee in the WiTT (Women in Technology of Tennessee) mentor program, volunteer at the EYH conference (Expanding Your Horizons), etc

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The TNT Board: An Interactive Electronic Board Game

Abstract

In summer 2020, a research and enrichment program funded by a Student Engagement, Retention, and Success (SERS) grant from the Tennessee Board of Regents took place in the form of online/remote delivery. The goal of the program was to improve the GPA and retention rate of underrepresented and minority students by engaging them in multidisciplinary and collaborative summer projects. This paper presents the project carried out by one of the student groups, in which two students in Mechatronics Engineering and one student in Computer Science worked together remotely and designed and implemented an interactive board game using Arduino Mega and various other electronics and mechanical parts. The board consists of six games and is fun to play for all age groups. All student participants had no prior experience with Arduino, but with the help from the faculty mentor, they were able to learn it quickly and complete the project within 4 weeks. Although each student was primarily responsible for two games, the project was a true multidisciplinary collaboration: the computer science student led the efforts of setting up GitHub for software programming and source management whereas the mechatronics engineering students conducted mechanical design for the board. In this paper, we will present the mechanical, electrical, and software design of the board game. The bill of materials and the details of remote collaboration will also be included.

On the educational front, we discuss a couple of efforts that helped the students: *(i)* We designed an introductory training lesson to introduce Arduino to them and *(ii)* We utilized project-based learning techniques to encourage them to learn new things along the way.

1. Introduction

This paper presents a summer research project conducted by three undergraduate students in the College of Basic and Applied Sciences (CBAS) at Middle Tennessee State University (MTSU). The project was part of a summer program that aimed at engaging minority and underrepresented freshman and sophomore students in CBAS via multidisciplinary and collaborative research activities. Specifically, we were hoping that the summer experience would increase the retention and GPA of the participants and eventually help them succeed at MTSU. Basically, it was a 4-week summer program took place in July 2020 in which the students worked 20 hours per week and no coursework was involved. The summer program was funded by the Tennessee Board of Regents (TBR), and a separate paper detailing the recruitment and scheduling can be found in [1].

There were totally four projects completed in the summer program. Two of them were mostly computer science related projects and do not fit into the scope of Multidisciplinary Engineering Division. In another project, one of the participants wanted to commercialize the final product and did not wish to disclose the details of the design. Therefore, in this paper, we concentrate on the technical aspects of one of the projects in the summer program: the TNT board, which was named after the combination of the first letters of the three creators' first names. The board is essentially an electronics board game, powered by Arduino and various other components.

Arduino is a very popular microcontroller for hobbyists, thanks to its open-source hardware and software platforms. Using Arduino in engineering education has been well-studied. In [2], the authors used Arduino to motivate students and promote their interests in project-based learning. Several activities, including summer camps and LAB design for high school students, advanced studies for Electrical Engineering majors in the industrial setting, were reported. Arduino has been widely used for teaching junior and senior level controls [3]-[9] and microprocessor courses [10], computer engineering capstone projects [11], and communication systems courses [12].

Arduino has also been widely used in lower-division courses. For freshman engineering students, Arduino was used as a platform to teach programming, design, and measurement [13]. In this work, the authors transited the *Living with the LAB* curriculum, which used the Boe-Bot mobile robotics and the Basic Stamp microcontroller, to the Arduino platform. In [14], Sullivan et al. used Arduino in an Introduction to Mechanical Engineering course where freshman students designed and implemented a cornerstone project "Potato Cannon". Belfadel et al. [15] designed a fundamentals of engineering course using Arduino for freshman engineering students. The goal was to use hands-on activities to promote students' critical-thinking and problem-solving skills. [16] describes a freshman engineering design course for ECE students using Arduino. [17] presents another introductory course to programming and problem-solving using Arduino-based LABs. In [18], Arduino was incorporated into a design course for sophomore Mechanical Engineering students where they were introduced to mechatronics systems involving sensors and actuators. In [19], Parikh introduced sophomore students in a Digital Systems course to Arduino. Project-based learning was adopted, and the students were asked to not only use the libraries provided by the Arduino community, but also develop their own using low-level registers. There were a few LAB modules, and the final course project was assigned by the instructor.

In addition, Arduino has been used in an online Introductory Engineering Design course [20] where freshman students could choose to take self-guided Arduino training modules. The students got evaluated regularly, and they could also use Arduino in their final course projects. In [21], Arduino was used as an interdisciplinary project development platform for experimental learning in an undergraduate research project where a group of engineering students designed and implemented an Exoskeleton Suit.

In [22], Arduino-based Sparkfun Inventor's Kit (SIK) was used in a 5-day summer camp to teach high school students circuit construction and programming. In the first half, the participants completed a designated project after they were introduced to 16 experiments that involved LEDs, an LCD, and various sensors; in the second half, they selected projects freely based on their interests, and the topics ranged from digital clocks with alarm functions, to wireless control of a small mobile robot, to a multi-function calculator with memory.

The project discussed in this paper differs from the previous works in the following aspects: *(i)* The project idea was proposed by the participants; *(ii)* The team members were from both Mechatronics Engineering and Computer Science, and the project was carried out in a multidisciplinary and collaborative setting; and *(iii)* Project-based learning was utilized, and the team members learned Arduino programming and hardware interfacing along the way. Compared with [22], our project has the following differences: (*i*) It was truly multi-disciplinary, i.e., it

involved not only circuit construction and programming, but also mechanical design; *(ii)* The participants of our project were college students who had taken at least one high level programming course; and *(iii)* The student collaboration was mostly carried out remotely.

The organization of the rest of the paper is as follows: in Section 2, we discuss project preparation and project idea selection; in Section 3, we specify the 6 games the team designed; we describe in detail how the project was carried out in Section 4; finally, we conclude in Section 5.

2. Project Preparation and Project Idea Selection

The summer program took place in July 2020. Before the project started, the faculty mentor provided an ELEGOO Uno Project Super Starter Kit for each participant. The kit costed $36 on Amazon, and it came with 22 lessons. In the last week of June 2020, the team members were asked to complete all the lessons as a team. Before they started working on these lessons, the faculty member gave a training lesson over Zoom, explaining the basics of microcontrollers and Arduino programming. In order to clearly and effectively demo the hardware interfacing, the faculty mentor used a Canon EOS M50 Mirrorless Vlogging Camera and Sigma 16mm f/1.4 DC DN Contemporary Lens, mounted on top of a desk by an Arkscan MCM5 table clamp mount. By using Canon's EOS webcam utility, the camera appeared on a PC as a webcam and streamed Ultra High-Definition video of the setup over Zoom. The following topics were covered in the training lesson:

(1) Introduction to Microcontrollers and Arduino
We covered what Micro Controller Unit (MCU) is, its applications, and why Arduino is popular. We explained the purpose of the anti-ESD bag and how to handle the board to minimize the chance of having it damaged due to short circuits and electrostatic discharge. We also showed how to power the Arduino Uno and how to connect it to the computer.

(2) Arduino Programming Basics and Arduino IDE
We introduced the Arduino IDE to the students, including the menu items. We explained what a "sketch" is and discussed the purpose of the "setup" function and the "loop" function required by all Arduino programs. We showed the participants how to compile programs and upload binary files. We also covered the c++ syntax since some students only learned Python.

(3) I/O pins and modes
We went over all the I/O PINs on the Arduino Uno, including the power (3.3V/5V), the ground, the analog PINs, and the digital PINs. We emphasized that the power sources on the Arduino cannot be used to power devices that require lots of currents. We discussed the three modes of the digital I/O PINs: INPUT, OUTPUT, and INPUT_PULLUP.

(4) Using Arduino libraries
We first discussed what Arduino libraries are. Then, we showed the students how to use the Library Manager and how to import .ZIP libraries.

(5) Demo of selected built-in Arduino examples including the LED light, buzzers, and the temperature sensor

Finally, we demonstrated some of the built-in examples to show the process of Arduino programming, how I/O works, and how to troubleshoot issues. To make the demonstration more interesting, we also modified the examples and let the students predict what would happen before we actually tried the new code on the board.

After the training lessons were over, each team member completed the ELEGOO Uno Project Super Starter Kit lessons prior to July 2020. In the first week of July 2020, the team was asked to come up with two ideas that involve Arduino, sensors, motors, and digital displays. The faculty member then discussed the ideas with the team and helped the team members select the topic. The final project topic of this team was "The TNT board", where "TNT" is the combination of the first letter of the first name of each team member. The project essentially was to design and implement an interactive electronics board game that consists of six games.

3. Description of the Six Games

The board game consists of six games or challenges, and they can be implemented based on the lessons came with the kit and the included parts. These games would be fun to play for players in all age groups. The board could also be used for competition purposes: whoever completes all six challenges using the minimum amount time wins. The description of the six games/challenges are as follows:

Game 1: Direction Matters

"Direction Matters" is a game module that involves two main components: an analog joystick and a Liquid Crystal Display (LCD) screen. In this game, an LCD screen lights up and randomly displays a series of directions to the player. The player will need to quickly input the directions using the analog joystick. For example, if the player sees a prompt "Up", then he or she will need to push the joystick up. The next direction is displayed if the direction is input correctly in the previous round. If the player does not input the correct direction fast enough, the game fails and the players will have to try again.

Game 2: Perfect Height

"Perfect Height" is a game module involving an ultrasonic sensor and an LCD screen. The ultrasonic sensor is used to measure distance, and this game's objective is to achieve a specific height between the sensor and the player's hand. Specifically, the LCD screen displays a randomly generated height for the players to achieve, and the player need to raise or lower his or her hand from the ultrasonic sensor to reach the designated height for the game. There is a time limit: if the player takes too long to achieve the proper height, then the player fails and has to start over; otherwise, he or she continues to the next game.

Game 3: Math Guru

The game referred to as "Math Guru" utilizes a membrane keypad and an LCD screen. It requires the player to solve a series of math problems within a specific amount of time in order to advance to the next game. If too much time is taken or the wrong answer is typed in, then the game ends with a failure and the player has to start over. The math problem is different in each play.

Game 4: Angle Challenge

Unlike the other challenges, the “Angle Challenge” game requires three components: a rotary encoder, a servo motor, and an LCD screen. As always, there is a time limit requiring players to act swiftly. With this challenge, a randomly generated angle will appear on the LCD screen, requiring the player to turn the rotary encoder to match the specific angle. Specifically, the encoder controls the servo motor movement, which is used for the game to check whether the challenge is completed successfully or not.

Game 5: Memory Game
This game module utilizes a series of buttons and an LCD. The LCD will display a series of asterisks, one at a time, to the player. The player needs to memorize the pattern and then press the corresponding buttons in the right order to match the display. The players will do this several times and clear the randomly generated patterns in order to move on to the next game.

Game 6: Collision Avoidance
The final game is the “Collision Avoidance” challenge. This challenge works slightly differently from the other games. In this challenge, the LCD screen will display a little “runner” looking character on the left of the screen as an obstacle, and the other runner on the right will be running towards the obstacle. The objective is to press the button that causes the runner to jump and avoid a collision. The player must achieve a fixed number of scores by jumping over the obstacle at the right time to pass the challenge and move on.

The six games and how to play them are summarized in Table 1.

Table 1: The six Games and how to play them

Game Name	How to play the game
Direction Matters	A list of directions is displayed, and the player must input the direction commands
Math Guru	Solve a series of math challenges
Perfect Height	Establish a specific distance between the player’s hand and an ultrasonic sensor
Angle Challenge	Control a servo motor to turn a specific angle
Memory Game	Memorize the pattern on the display and press the corresponding buttons to match it
Collision Avoidance	Jump at the right time to avoid collision with an obstacle on the running path

4. Project Design

4.1 Bill of Materials

After designing the six games, the team finalized the Bill of Materials (BOM), which is shown in Table 2 below. Most items were included in the Arduino kits with a few exceptions: *(i)* The plywood board and the spray paint were purchased from a home improvement store and *(ii)* The

Arduino Mega Microcontroller was purchased from Amazon (it was necessary because the Arduino Uno board came with the kit does not have enough number of I/O pins).

Table 2: Bill of Materials

Item	Quantity	Purpose
Plywood board	1	Base for board game and holds all electrical components
Assorted Jumper Cables	100	Wiring for all electrical components and microcontroller
Arduino Mega	1	Microcontroller used to control all sensors/modules
Basic 3D Printed Parts	7	Housing for different sensors and wiring
Rotary encoder	1	Used in Angle Challenge to control servo motor
Servo Motor	1	Used in Angle Challenge to turn the right angle
Ultrasonic Sensor	1	Used in Perfect Height to detect distance
Analog Joystick	1	Used in Direction Matters to input direction commands
Membrane Keypad	1	Used in Math Guru to input answers to math problems
Buttons	5	Used in Memory Game and Collision Avoidance as inputs
Motor Driver	1	Used to regulate Servo Motor
Liquid Crystal Display (LCD)	2	Used to display prompts and challenge requirements throughout the different games
Potentiometers	2	Used to control brightness/contrast on the LCD screens
9V Battery	1	Power Source
Spray Paint	1	Used to give a more professional finish and coordinated color

4.2 Mechanical Design

The first step in creating the board game was to create a mechanical design using Computer Aided Design (CAD) software. In particular, designs were made by creating small structures to mimic each component used in the board game. These models were then used to determine how each component would be laid out on the board with the most logical and intuitive design. Fig. 1 shows the 3D model of the board. The mechanical design was primarily done by Mechatronics Engineering students.

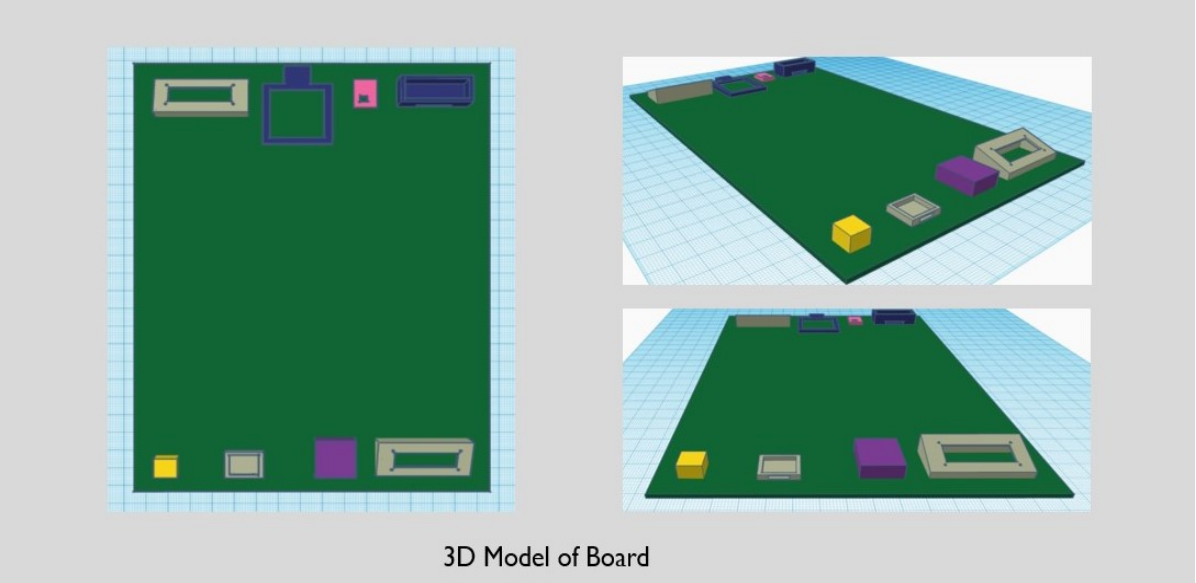

Figure 1: 3D model

4.3 Electrical Design

Once the mechanical design of the board was completed, the next step was to begin working on the electrical design. A few more CAD models were created to contain some electrical components for a cleaner and more professional look. The overall electrical design is completed in multiple steps. First, the design of the six game modules was divided equally among the three team members so that each student was primarily responsible for two games. To ensure that the overall system worked properly, the modules were designed as if they were standalone modules: this would allow for a clear understanding of how the sensors, actuators, and the microcontroller were operating correctly with the proper connections; otherwise, it would become harder to tell when a device was wired incorrectly or if any sensors were malfunctioning. Fig. 2 is the circuit diagram generated by the Fritzing design tool showing how the components of all six games are interconnected.

4.4 Software Design

The software and electrical designs were conducted concurrently in order to test and verify each game. The first step in software design was to break the programming task into six individual game modules as if they were standalone. This would ensure that the coding process is smooth and the source code is easier to develop and maintain. The code was written based on the lessons provided by the Arduino kit. One important step taken was to generate “randomness” during the game play using pseudo-random number generators. The randomness was used to determine the sequence of the game modules the players would encounter as well as randomized challenges in all six games. See Fig. 3 for the flow chart used to code each game module. Finally, unit testing and debugging were performed for each game module to resolve technical issues and to

guarantee that it worked as intended. Figures 4 and 5 show the code of the setup function and the loop function, respectively. The code of one of the challenges is shown in Figure 6.

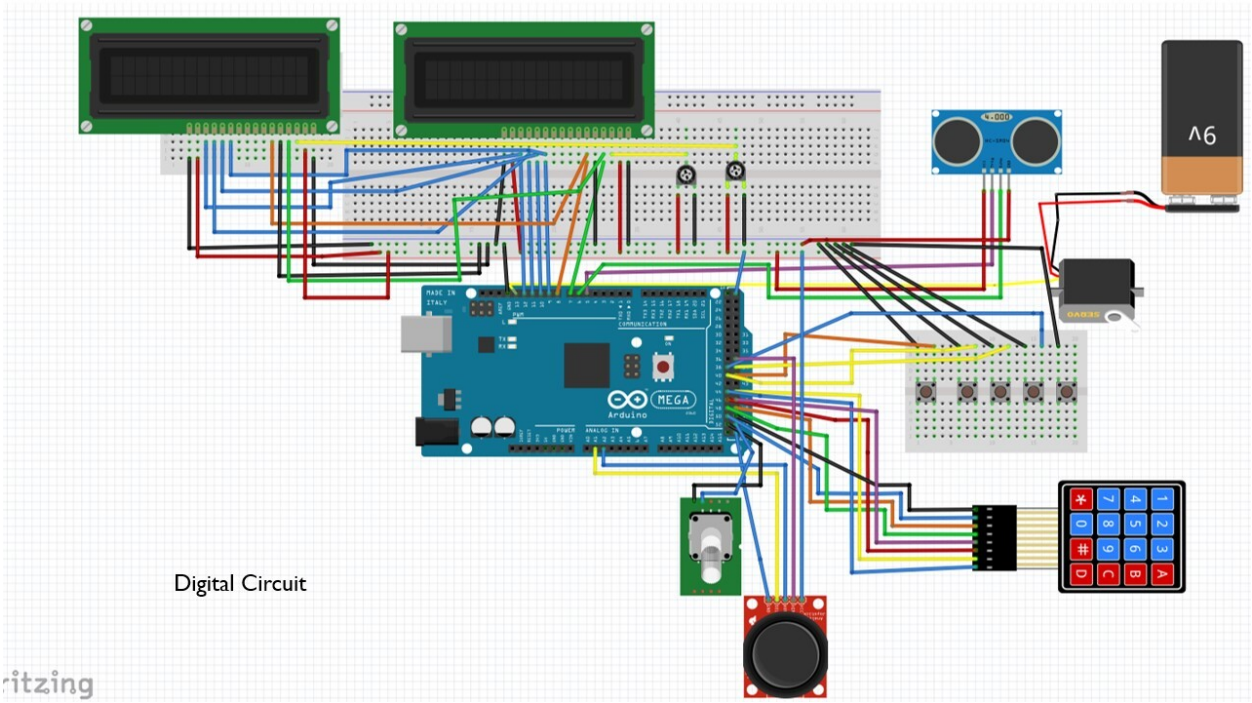

Figure 2: Circuit Diagram

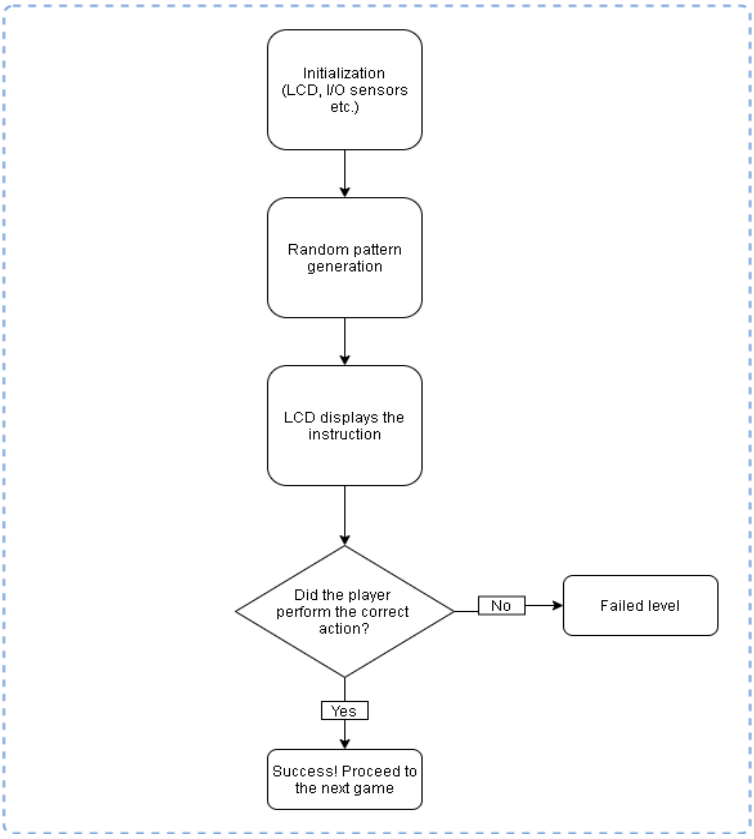

Figure 3: Flow Chart of Game Module design

```
void setup() {

  // Servo/Encoder setup
  pinMode (inputCLK,INPUT); // Set encoder pins as inputs
  pinMode (inputDT,INPUT);

  //set up ultrasonic
  pinMode(trigPin,OUTPUT);
  pinMode(echoPin, INPUT);

  Serial.begin (9600); // Setup Serial Monitor
  pinMode(btn,INPUT);
  analogWrite(9,35); //adjusting contrast without the potentiometer (6 is pin, and 35 is contrast)

//set up for Runner module
  Serial.begin(9600);
  pinMode(btn,INPUT);
  lcd.begin(16,2);
  lcd.createChar(0,runninl);
  lcd.createChar(1,runnin2);
  lcd.createChar(2,jump);
  lcd.createChar(3,defl);
  lcd.createChar(4,def2);
  lcd.createChar(5,slide);
  buttonState=digitalRead(btn);

  myservo.attach(13); // Attach servo on pin 9 to the servo object
  previousStateCLK = digitalRead(inputCLK); // Read the initial state of inputCLK Assign to previousStateCLK variable
  andomSeed(analogRead(0));  // setup generate random number

  pinMode(43,OUTPUT); // turn on and off membrane LCD Screen

  pinMode(42,OUTPUT); // turn on and off joystick LCD Screen

  lcd.begin(16,2);

  digitalWrite(43, HIGH);
  digitalWrite(42, HIGH);

  lcd.print("TNT Board");
  delay(3000);
  lcd.clear();
}
```

Figure 4: The setup function

4.5 System Integration

The system integration was performed in the very end after each game module was correctly wired, programmed, and tested. The plywood was first cut to the right size and painted. The 3d painted parts were then mounted onto the board, making it ready for the electronics components. The six modules were added to the board, one at a time. Once this step was completed, the six individual programs were compiled and condensed into a single one, with some modifications throughout so that the entire system operates properly without issues. Because the games were initially developed using Arduino Uno but the final product used Arduino Mega, a number of I/O pins had to be reassigned and the program had to be modified. Fig. 7 shows the working games before the system integration, and Fig. 8 shows the completely integrated system.

```
void setup() {

  // Servo/Encoder setup
  pinMode (inputCLK,INPUT); // Set encoder pins as inputs
  pinMode (inputDT,INPUT);

  //set up ultrasonic
  pinMode(trigPin,OUTPUT);
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//set up for Runner module
  Serial.begin(9600);
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  lcd.createChar(0,runninl);
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  lcd.createChar(5,slide);
  buttonState=digitalRead(btn);

  myservo.attach(13); // Attach servo on pin 9 to the servo object
  previousStateCLK = digitalRead(inputCLK); // Read the initial state of inputCLK Assign to previousStateCLK variable
  randomSeed(analogRead(0));  // setup generate random number

  pinMode(43,OUTPUT); // turn on and off membrane LCD Screen

  pinMode(42,OUTPUT); // turn on and off joystick LCD Screen

  lcd.begin(16,2);

  digitalWrite(43, HIGH);
  digitalWrite(42, HIGH);

  lcd.print("TNT Board");
  delay(3000);
  lcd.clear();
}
```
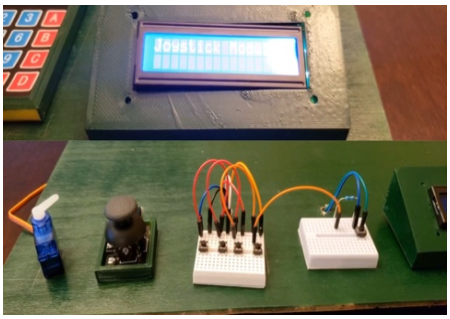

Figure 5: The loop function

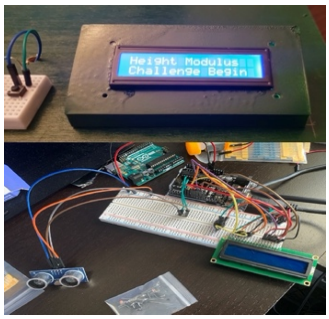
```
void joystick() {

  if(individualSetup == 0) {

   digitalWrite(43, HIGH); // switch lcd Screens
   digitalWrite(42, LOW);

   pinMode(SW_pin, INPUT);
   digitalWrite(SW_pin, HIGH);

   randNumber = random(0,3);  // generate random number between 1 and 3
  //set up LCD
   lcd.begin(16, 2);
  //Display challenge module
   lcd.print ("Joystick Modulus");
   delay(3000);
   lcd.setCursor(0,1);
   lcd.print ("Challenge Begin");
   delay (3000);
   lcd.clear();

   lcd.setCursor(0,0);
   lcd.print("Up");
   ++individualSetup;
  }
  if (randNumber==1)
   {
     version1Joystick();
   }
  if (randNumber==2)
   {
     version2Joystick();
   }
  if (randNumber==3)
   {
     version3Joystick();
   }
```

```
void version1Joystick()
{
  if(currentProblemJoystick == 0 && analogRead(X_pin)==0)
  {
    lcd.clear();
    ++currentProblemJoystick;
    lcd.print("Down");
  }
  if(currentProblemJoystick == 1 && analogRead(X_pin)==1023)
  {
    lcd.clear();
    ++currentProblemJoystick;
    lcd.print("Left");
  }
  if(currentProblemJoystick == 2 && analogRead(Y_pin)==1023)
  {
    lcd.clear();
    ++currentProblemJoystick;
    lcd.print("Right");
  }
  if(currentProblemJoystick == 3 && analogRead(Y_pin)==0)
  {
    lcd.clear();
    ++currentProblemJoystick;
    lcd.print("Up");
  }
  if(currentProblemJoystick == 4 && analogRead(X_pin)==0)
  {
    lcd.clear();
    currentProblemJoystick = 0;
    lcd.print("Success");
    individualSetup = 0; // prepares setup for next challenge
    timerReset = 0; // prepares timer for next challenge
    ++challengePassed; // starts next challenge
  }
}
```

Figure 6: The code of the Angle Challenge

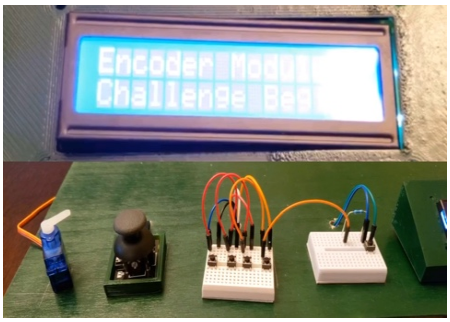


Direction matters

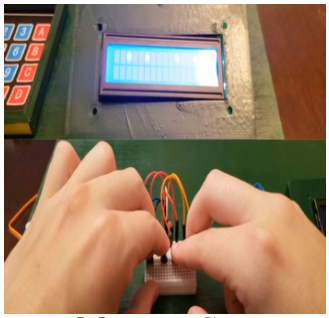


Perfect Height

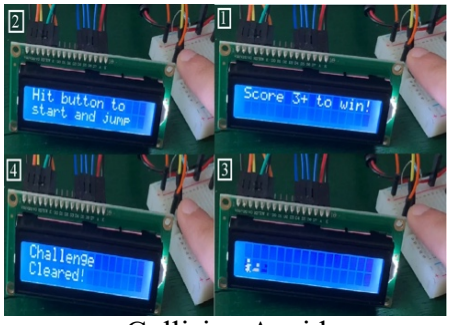
Math Guru



Angle Challenge



Memory Game



Collision Avoidance

Figure 7: Functioning Games

4.6 Teamwork and Collaboration

OU campus was closed in summer 2020 due to the COVID-19 pandemic, and undergraduate students were not allowed to be on campus. As a result, the project members only met 2 times in person to distribute and exchange supplies; they met roughly 10 other times via Zoom. Asynchronous discussions and document sharing were done using Slack, and the revision control of the source code was done using a Git repository hosted on GitHub.

To evaluate the effectiveness of teamwork and collaboration, we asked the team members to do a self-assessment survey using the criteria provided in [23], and the team rated the highest across all four:

1. *Team members actively participated in the task or project to accomplish a common goal?*
   Team members had an extensive project management plan that outlined which accomplished tasks, needed resources, and assigned aspects to various members with anticipation for future needs. The team also engaged in regular activities as follow-up to monitor progress and provided feedback.
2. *Team members participated in decision-making process?*
   All members proposed set of ideas and negotiated a fit between personal ideas and ideas of others, using contrasts to spark and sustain knowledge advancements of the entire team, and acknowledged that each members had a significant role to play and responsibility in the decision making.

3. *Team adjusted to unforeseen circumstances?*
   Team members knew that working to achieve goals require flexibility in thought and action, being creatively adaptive, “unbreakable” in the face of challenging problems and changing situations.
4. *Team members used their diversity to build strength?*
   Team members recognize each other as legitimate contributors to the shared goals; they build on each other’s ideas and take responsibility for the overall advancement of knowledge of the team. They see diversity as a strength that helps to strengthen the overall outcomes. Team members encourage diverse points of view, openly negotiate emerging understandings and provide and accept specific feedback to and from each other to improve team processes and project outcomes.

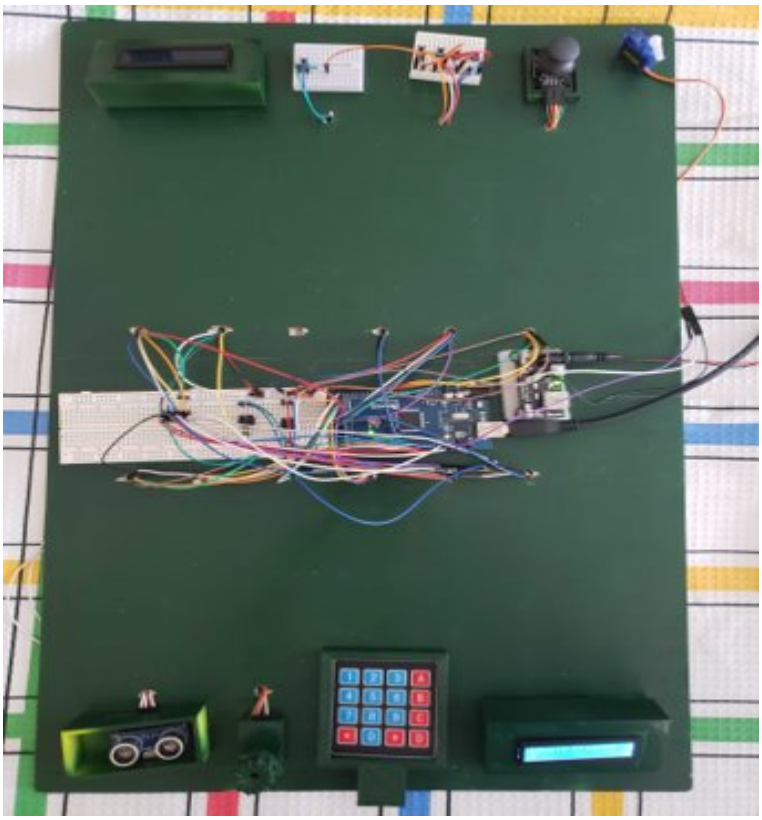


Figure 8: The finished game board

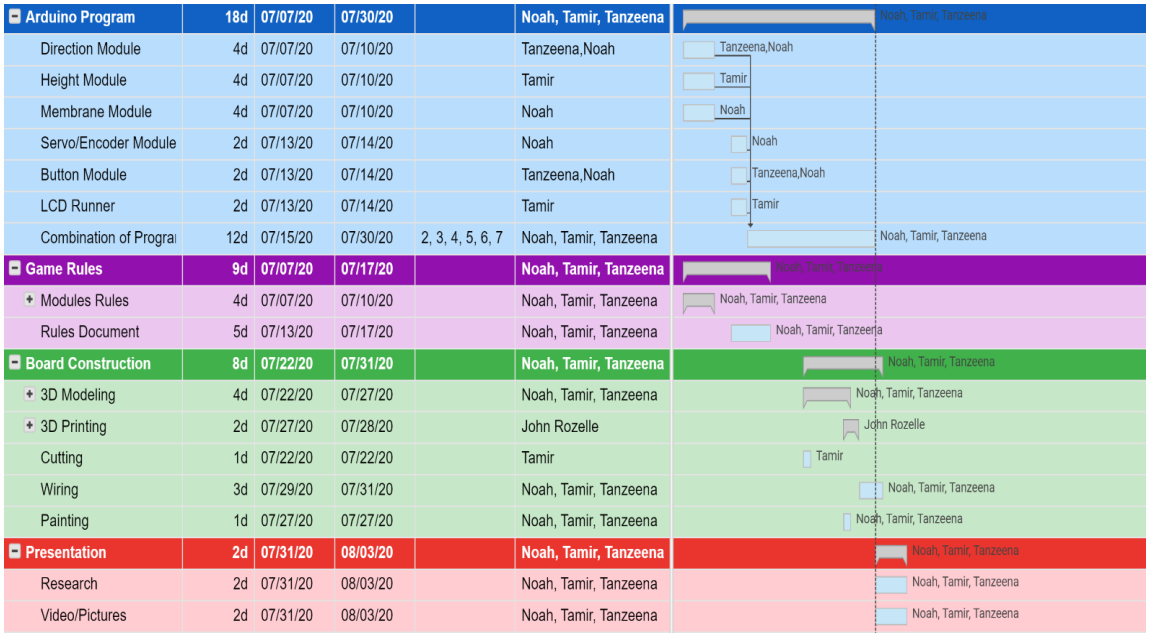


Figure 9: Gannett Chart for Project Timeline

All team members were responsible for different design aspects of the TNT Board. Although each member primarily focused on the design of two games, every person was involved in deciding the modules to be included, the BOM, and the overall design. In the beginning of July 2020, the team members created a viable schedule for the project, which is shown in the Gannett chart in Fig. 9. It greatly helped the team keep the time frame in mind, which was crucial since the summer project only had 4 weeks.

4.7 Project-based Learning and Project Outcome Assessment

The summer program utilized project-based learning to encourage the students to learn new things along the way. In particular, we used game-based learning to motivate the students. In order to not only play, but also design the 6 board games, they studied the lessons provided by the Arduino kit and learned how to connect and program various components, such as keypads, LCD displays, sensors, motors, and buttons.

The assessment of the overall outcome of all four projects is stated in details in another paper accepted by the Minorities in Engineering Division of the 2021 ASEE annual conference (a reference with the title and author details will be provided). For this specific project, the retention rate of the participants was 100%, higher than that of all freshman and sophomore students in CBAS, which is 69.1% from Fall 2019 to Fall 2020. As the delivery method of most courses offered by MTSU switched to Remote, Online, or Web-assisted in Fall 2020, many students had financial difficulties, mental health related issues, and difficulty adjusting to the new learning methods. As a result, there was a significant negative impact to the students' GPA in Fall 2020, caused by the COVID-19 pandemic. Therefore, we did not see an improvement over the participants' GPA. However, among the participants in this project, the median GPA

difference between Fall 2019 and Fall 2020 is -0.016, which is less than -0.043, the median GPA difference of all freshman and sophomore students in the same major.

5. Conclusions

In this paper, we present an interactive electronic board game designed and built by three undergraduate students at MTSU: two from Mechatronics Engineering and one from Computer Science. The students did not have prior experience with Arduino, but with the help from the faculty advisor and more importantly, from other team members, they were able to collaborate remotely and successfully put together a complicated product within 4 weeks. The result was a showcase of a multidisciplinary collaboration among individuals from two different fields of study, although further improvements can be made to conceal the wires and provide a fully furnished look. All team member learned Arduino programming and hardware interfacing with various components using project-based learning. The final product and the teamwork and collaboration assessment showed that the summer project was completed successfully. The project outcome assessment data on retention rate and GPA also showed that the summer project positively affected the participants' future study at MTSU. We hope that this effort will give insights to other multidisciplinary projects that involve students from different disciplines, especially in an online setting.

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References

[1] Miao, L. and Li, C. "Engaging Minority and Underrepresented Engineering Students to Fight "Sophomore Slump" through a Summer Research and Enrichment Program (Research)", 2021 ASEE Annual Conference & Exposition, Virtual Conference, July 2021

[2] Wood, B., and A. Ganago. "Using Arduino in Engineering Education: Motivating Students to Grow from a Hobbyist to a Professional." *ASEE Annual Conference and Exposition, Salt Lake City, Utah*. 2018.

[3] Hopkins, M. A., and Kibbe, A. M., 2014, "Open-source hardware in controls education," ASEE Annual Conference, Indianapolis, IN.

[4] Parker, J. M., and Canfield, S. L., 2013, "Work-in-progress: using hardware-based programming experiences to enhance student learning in a senior feedback controls lecture course," ASEE Annual Conference, Atlanta, GA.

[5] Parker, J. M., Canfield, S. L., and Ghafoor, S. K., 2014, "Using hardware-based programming experiences to enhance student learning in a junior-level systems modeling course," ASEE Annual Conference, Indianapolis, IN.

[6] Candelas, F., Garcia, G. J., Puente, S., Pomares, J., Jara, C. A., Pérez, J., Mira, D., and Torres, F., 2015, "Experiences on using Arduino for laboratory experiments of automatic control and robotics," IFAC-PapersOnLine, 48(29), pp. 105-110.

[7] Reguera, P., García, D., Domínguez, M., Prada, M., and Alonso, S., 2015, "A low-cost open source hardware in control education. Case study: Arduino-feedback MS-150," IFACPapersOnLine, 48(29), pp. 117-122.

[8] Sobota, J., Pisl, R., Balda, P., and Schlegel, M., 2013, "Raspberry Pi and Arduino boards in control education," IFAC Proceedings Volumes, 46(17), pp. 7-12.
[9] Ishikawa, M., and Maruta, I., 2010, "Rapid prototyping for control education using Arduino and open-source technologies," IFAC Proceedings Volumes, 42(24), pp. 317-321.
[10] Bird, Nathaniel. "Use of the Arduino Platform for a Junior-Level Undergraduate Microprocessors Course." *American Society for Engineering Education*. American Society for Engineering Education, 2011.
[11] Minaie, A., and R. Sanati-Mehrizy. "Capstone projects in a computer engineering program using Arduino." *Proc. ASEE Annu. Conf. Expo.*. 2016.
[12] Underwood, H., "Telemetry Project For An Introductory Communications Systems Course", ASEE Mid-Atlantic Section Spring Conference, Washington, District of Columbia, 2018
[13] Recktenwald, Gerald W., and David E. Hall. "Using Arduino as a platform for programming, design and measurement in a freshman engineering course." *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*. 2011.
[14] Sullivan, Gerald, and J. M. Hardin. "Revitalization of an Intro to ME Course Using an Arduino-Controlled Potato Cannon." *ASEE Annual Conference & Exposition, New Orleans, Louisiana. http://dx. doi. org/10.18260*. 2016.
[15] Belfadel, Djedjiga, et al. "Use of the Arduino Platform in Fundamentals of Engineering.", *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, Tampa, FL, 2019.
[16] Berry, Carlotta, D. Chang, and C. Miller. "From LEGO to Arduino: Enhancement of ECE freshman design with practical applications." *ASEE Annual Conference & Exposition*, New Orleans, LA, 2016
[17] Daugherity, M., "Introducing Programming and Problem Solving with Arduino-based Laboratories", *ASEE Annual Conference & Exposition,* Tampa, FL, 2019
[18] Bedillion, M., Muci-Kuchler, K., and Nikshi, W., "An Arduino-Based Hardware Platform for a Mechanical Engineering Sophomore Design Course", *ASEE Annual Conference and Exposition, Salt Lake City, Utah*. 2018.
[19] Parikh, Chirag. "Introducing Arduino Platform to Sophomore's using an apt recipe." *Proceedings of the 2014 ASEE North Central Section Conference*. 2014.
[20] Schmidt, Jillian Beth. "Work in Progress: Development and Implementation of a Self-guided Arduino Module in an Introductory Engineering Design Course." *ASEE Annual Conference & Exposition*. 2018.
[21] Zhang, L., et al. "On the Design of Exoskeleton Suit: An Interdisciplinary Project Development Platform for Experiential Learning in Engineering Education." *ASEE Annu. Conf. Expo., ASEE, Columbus, USA*. 2017.
[22] Post, John E. "An arduino-based summer camp experience for high school students." *Proceedings of the 2016 ASEE Annual Conference*, New Orleans, LA, 2016.
[23] https://www.galileo.org/tips/rubrics/t-c_rubric.pdf