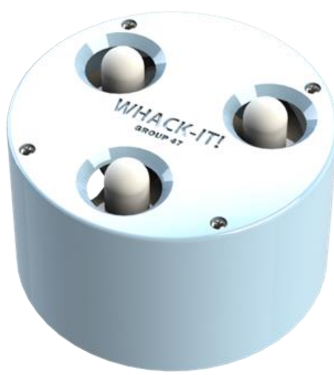
Department of Mechanical and Mechatronics Engineering

ME100: Whack-It! Design Report



A Report Prepared For:
Spin Master Ltd.
121 Bloor Street E
Toronto, Ontario, M4W1A9

Prepared By:
Alex Trinh, Muhammad Haris, RJ Masse, Yusuf Tunc
Department of Mechanical and Mechatronics Engineering
University of Waterloo
200 University Ave W.
Waterloo, Ontario, N2L 3G1
December 5, 2022

Department of Mechanical and Mechatronics Engineering

University of Waterloo
200 University Ave W.
Waterloo, Ontario, N2L 3G1

December 5, 2022

Mollie Jameson
Spin Master Ltd.
121 Bloor Street E
Toronto, Ontario, M4W1A9

Salutation,

This report, entitled ME100: Toy Design Project Report, was prepared as our design project submission for ME100: Introduction to Mechanical Engineering Practice I. The intent of this report is to provide you with the concept that we have selected, and to outline the progress we have made towards developing this product.

ME100 is a 1A course in mechanical engineering at the University of Waterloo that focuses on teaching engineering design, communication, and professionalism. This is the first complete engineering design project of the course, where we have been tasked with designing a toy for Spin Master LLC. Whack-It is our devised solution, a competitive tabletop game for children. In essence, it is a whack-a-mole game with a rotating base that makes the traditional game more challenging and fun.

This work was completed entirely by the undersigned and has not been submitted for credit at this or any other institution. Thank you for taking the time to review this work. If you have any questions or concerns, please do not hesitate to contact either of us.

Best Regards

Alex Trinh	RJ Masse	Yusuf Tunc	Muhammad Haris
1A Mechanical Engineering	1A Mechanical Engineering	1A Mechanical Engineering	1A Mechanical Engineering

Table of Contents

Table of Figures

Summary

Whack-It is a competitive game concept designed for Spin Master LLC, it is a twist on the whack-a-mole game with a base that is rotating. The rotating base makes the traditional whack a mole game more challenging and fun. The project is mixture of two products which takes Whack-A-Mole's mole hitting aspect and Let's Go Fishing's spinning feature.

Whack-It subsists of two main functions. The first is lifting the moles out of the base periodically. Players will be challenged with timing their hit to as soon as the moles come out. The second function which makes the design unique as opposed to a traditional whack a mole game is the spinning base. The base will spin with the moles inside it. This makes the game more challenging for players and will require hits to be precise. The constraints of this design concern rotations per minute of the base, speed of the mole lifting mechanism, solidity of the top plate, and the size of the toy. In addition, adding an extra function such as score registering system and improving the safety are considered as the criteria. Safety concerns regarding the design are mainly the pinch points. It can occur in the mole raising mechanism as well as where the power is transmitted to spin the carousel (the rotating wheel). Another concern is burn hazard caused by friction if the rotating speed reaches higher than expected.

The selected solution for the mole raising function is the use of elastics or springs to provide the upwards force and a trigger to the hold the mole within the base. For the spinning carousel the solution is the use of a slewing bearing to provide a stable axis of rotation. A friction drive is a simple way to provide the rotational motion to the carousel. The current functions of the toys have been designed and prototyped for. As of December 5, 2022, the toy works on a functional level in a way that the toy moves in all degrees of freedom (rotationally and translationally) as expected. The biggest remaining challenge associated with the design is implementing the entire system together, assembling the pushing mechanism with the spinning component in conjunction.

1.0 Introduction

Whack-it! is a new interpretation on how Whack-A-Mole is played. It is a competitive game for kids. The age range of the toy is intended for children from the ages six to twelve. More details about the toy will be discussed in the following sections.

1.1 Play Pattern / Age Range

The Whack-It! Toy is a novel approach to the traditional Whack-A-Mole (Figure 1). The toy implements more range of motion by adding a spinning element to it. The play pattern of the toy would be considered a competitive table-top game. The toy can be played with up to three players and has a recommended age range of 6-12 years of age. The maximum suggested age of 12 was determined based on the expected force during play so that they would not break the toy. It is not advisable for children under the age of 6 to play due to spinning components that may potentially pose to be hazardous under operation. To further validate the suggested age range, comparable Whack-A-Mole products suggest a starting age of 4, without a rotating element [1] . Firstly, the toy starts by spinning around for a random amount of time and once it stops, three moles are simultaneously ejected from the carousel. The first player to hit the moles wins the round!

Figure 1 Whack-A-Mole [2]

1.2 Comparable Products

The idea of the design is a mixture of Whack-a-Mole (Figure 1) and Let’s Go Fishing by Pressman (Figure 2), both of which are products that can be found in every toy store. However, there are no toys that have the features of both. In technical terms, the spinning aspect was inspired from Let's Go Fishing, while the physical aspect was taken from Whack-A-Mole, bridging the gap between the toys.

The spinning feature of Let's Go Fishing is one of the most important aspects of its gameplay. Whack-It uses a similar function as the toy will start rotating to make it more difficult and more involving while hitting the mole.

Figure 2 Let's Go Fishing [3]

1.3 Objective

The objective of this report is to prove the feasibility of Whack it. It will be done by discussing the constraints and criteria, going over what solutions were considered, and describing the technical progress. The technical progress explains what the solutions are and how they work.

2.0 Problem Definition

The focus of this project is to recreate the whack a mole toy concept and add additional functions to it. Whack a mole toy consists of mole shapes that are quickly lifted periodically to be whacked with a hammer. The additional function entails adding a rotational component that will allow the toy to spin. The main challenge is finding a way to implement these two functions into one design.

2.1 Functions

With the concept of the toy in mind, functions were determined to define what the toy should do and how it would operate. As the toy similarly follows the design of a traditional Whack-a-mole, one of the primary functions consists of being able to lift the moles—meaning they move translationally up and down. To distinguish the toy from the traditional Whack-a-mole, the secondary function facilitates rotation of the toy. The secondary function adds an extra degree of freedom by adding a rotational element to the translational motion of Whack-a-mole. Combining the primary and secondary functions is vital for proving the feasibility of the toy. Other functions of the toy, although not required to prove the functionality/feasibility of the toy include detecting which mole is whacked first and tallying the score for each player.

2.2 Constraints and Criteria

For this toy design to be successful it must meet the following constraints: the spinning carousel must spin at or above 60 rotations per minute, the moles raise in less than 1 second, the top plate must withstand 500 Newtons of force in the downwards direction, and the total diameter of the design must not exceed 30 cm. The carousel must spin faster than 60 rotations per minute so that the player cannot track their assigned mole while the machine is spinning. The moles must raise in less than 1 second so that they can raise fully before players are able to react and make contact. The force of 500 newtons that the top plate must withstand is to ensure that the forces players may exert on it during play cannot break the toy. The product needs to be smaller than 30 cm in diameter so that it is portable and able to fit onto tables.

Criteria that the design should aim for are registering which of the moles is hit first, recording, and displaying the score, minimizing cost, and reducing safety concerns. A system to register which mole gets hit first and a system to record and display the score would improve the playability of the toy. These systems would reduce disputes between players when deciding who won. By minimizing the cost of the toy design, it becomes more viable as profits would likely be higher. The safety considerations below should be addressed for the final design of the toy.

2.3 Safety Considerations

Safety must be considered in this design as the moving parts could increase the risk of injury. The main areas for concern on this toy are pinch points where power is transmitted to the spinning carousel and in the mole raising mechanism as well as issues associated with having an exposed spinning object. The pinch point where power is transmitted can be addressed in the final designs with a guard covering this area. Since the mole raising mechanism is contained within the part, this pinch point will not be accessible. A safety issue from the exposed spinning surface is the potential for friction burns. To prevent this, the speed of the carousel should be kept as close to the targeted speed as possible and a material with low friction should be selected for use on exposed areas such as smooth plastic. Also, the holes that the moles come out of should not allow fingers to get caught while spinning.

3.0 Technical Progress

In this section the process of reaching the final prototype will be discussed in detail. It will include what solutions have been chosen and then move on to explain how they work and what they do, what kind of materials/methods were used, and the challenges were faced. Lastly, it will be concluded with discussing the progress made and the remaining challenges.

3.1 Solutions

Devised solutions for our toy design were split based on the required functions of our toy. One of the functions required the toy to be able to lift and emulate the translational motion like a whack in mole. The second function focused on implementing the spinning elements and how it would all be housed in. The last technical problem involves implementing the motor which entails the necessary electrical and software components to operate.

3.1.1 Lifting Mechanism

The lifting mechanism in this design must provide linear motion in the upwards direction. This can be done with the use of linear actuators (mechanical or pneumatic), a rack and pinion system, or using springs/elastics and a release mechanism. Issues with using mechanical linear actuators and rack and pinion systems are the forces from players hitting the moles could wear the teeth and provide too much resistance to players. Pneumatic actuators can be configured to solve the issues stated above, but they are expensive and complex as a system including a pump and valves would be necessary. Using springs or elastics to provide the upwards force is the best option since they are cheap and simple. This solution requires a channel or rail for the moving part to restrict motion to only the vertical direction and a release with the basic design shown in Figure 3.

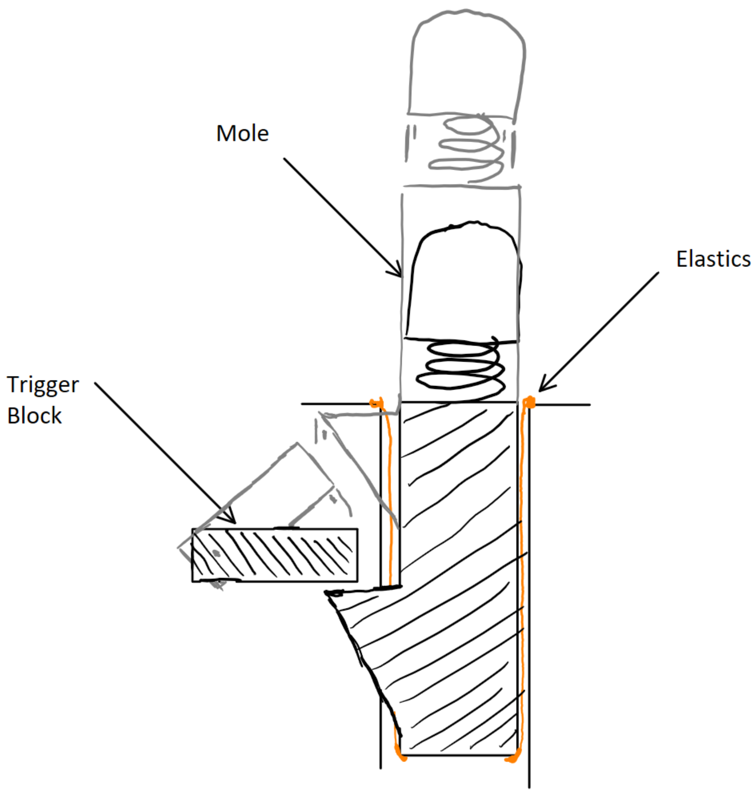


Figure 3 Mole Raising Concept

3.1.2 Spinning Mechanism

To determine how the spinning mechanism should be designed, two factors were considered; how the mechanism would spin, and what would be spinning it. The initial consideration was having a shaft along the center of the carousel (the housing of the spinning component) (Figure 4). An issue arose with having the housing being solely supported at the center of the piece since it would be exposed to non-uniform loads on the sides when it is being whacked. It would resultantly cause instability in the housing and increase likelihood of failure (particularly fracture around the center by the axis) during play.

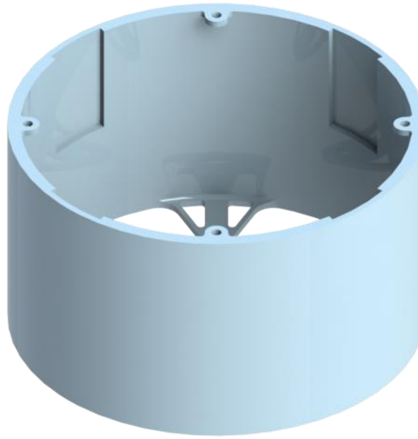


Figure 4 Carousel Component

To uniformly stabilize the carousel housing as loads are being applied to its top, slewing bearings were a feasible solution. Slewing bearings or Lazy-Susan's (interchangeable in principle) operate similarly to ball bearings with the benefit of having a significantly large diameter, with its main purpose being for the use of turn tables (Figure 5). With the bearing in mind, it would be possible to mount the carousel with fasteners while maintaining stability during operation and play. The selected bearing was purchased and measured such that the components would be able to fit with respect to it (Figure 6). In addition to implementation in CAD, the holes needed to be machined with a counterbore and tapped to facilitate screws so that they would be able to securely hold the carousel. In a static analysis of the assembly, the toy can withstand 1000N of load with less than 2.2mm of deflection, well within the expected load of the suggested play range (Figure 7).

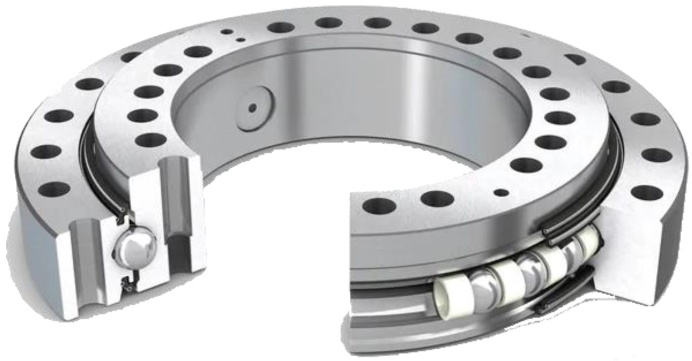


Figure 5 Slewing Bearing [4]

Figure 6 6-Inch Aluminum Alloy Turntable [5]

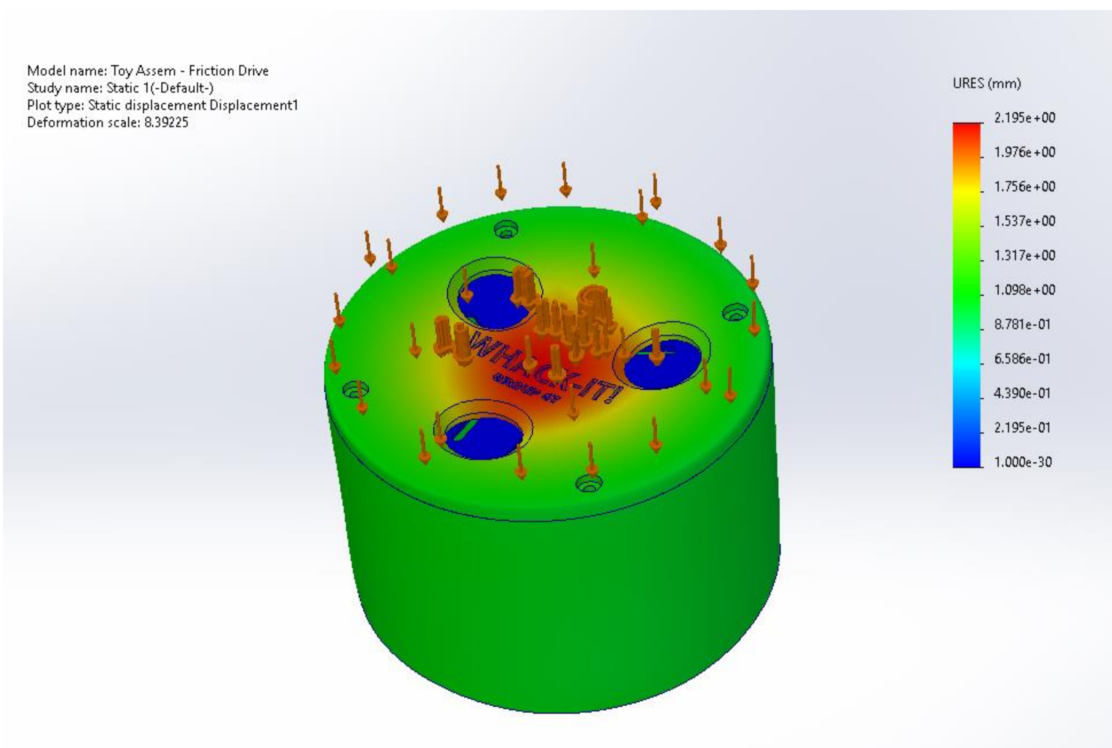
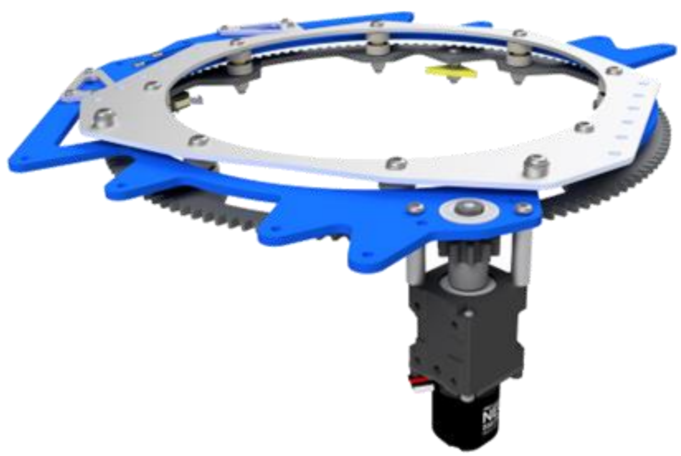


Figure 7 Displacement of Toy Assembly Under 1000N of Load

After finding the means of mounting the housing, options for automatically spinning the housing were considered. To spin a housing, a mechanism needs to be devised in way that takes the rotational motion output of the motor and transmits it to the housing. Various implementations were considered as to how It could be approach. The first method entails using gears to transmit rotational motion. However, without having a shaft output holding the gear in place for the shaft, a sprocket/gear plate would have to be designed so that it would fit on the bearing or carousel (Figure 8). Secondly, timing belts could be used to run the carousel and would provide similar results to using gears (Figure 9). The aforementioned methods are both viable for accomplishing the task, however, require more extensive mechanical design on the toy that would increase time for fabrication. Hence, the most approachable method of spinning the carousel would be by housing a friction drive. The friction drive entails having a wheel tangentially aligned with the carousel. As the motor spins the wheel it would consequently spin the carousel. This would simplify the need to configure the precise gear ratio to achieve the targeted RPM.



8 Sprocket/Gear Driven Plate [6]

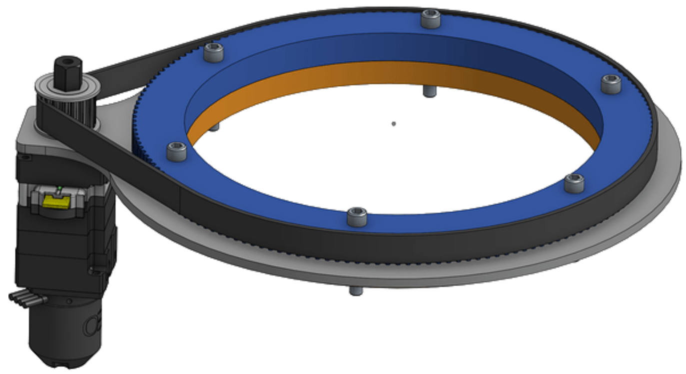


Figure 9 Timing Belt Plate [7]

For manufacturing, all the parts were designed using CAD so that they would be able to be manufactured using 3D printing and laser cutting. The parts were designed for assembly in a way that would be able to securely fit with each other and reduced the assembling time to less than a minute. The assembly is comprised of the main components: the top plate (Figure 10), mole plate (Figure 11), and carousel.

Figure 10 Whack-It! Top Plate

Figure 11 Whack-It! Mole Plate

The mole plate was laser cut from 1/8" high-density fiberboard wood (HDF wood) (Figure 12). This material was selected over ¼" or 1/8" acrylic as the materials share similarly high yield strength and Young's Modulus. However, HDF is inherently less brittle than acrylic and would be able to handle repeated impact from getting whacked. The top plate was 3D printed with polylactic acid (PLA) and the carousel with acrylonitrile butadiene styrene (ABS). The materials were determined by the 3D printers that were accessible and the filament that was available.

Figure 12 HDF Laser Cut Mole Plate

Figure 13 Carousel Assembled with Mole Plate

Figure 14 Completed Assembly of Whack-It!

3.1.3 Embedded Software and Electrical

The motor needs to be electrically powered and programmed in a way that operates properly. The toy uses several components to operate the motor accordingly to our play which includes: the motor, transistor, diode, microcontroller, breadboard, and switch (Figure 15). The motor is controlled using a microcontroller that provides directives for the motor to operate. The Raspberry Pi and Arduino were considered as the main options due to accessibility. Ultimately, Arduino was used to simplify programming tasks and setup. The components are attached onto the breadboard that allows current to be distributed between wires, creating a circuit. The button sends an input to the Arduino when pressed to send an output to the motor. The transistor amplifies and controls the output from the Arduino, redirecting it to the motor. Alternatively, a microcontroller could be used in place to remove the intermediary process of creating a circuit using a breadboard.

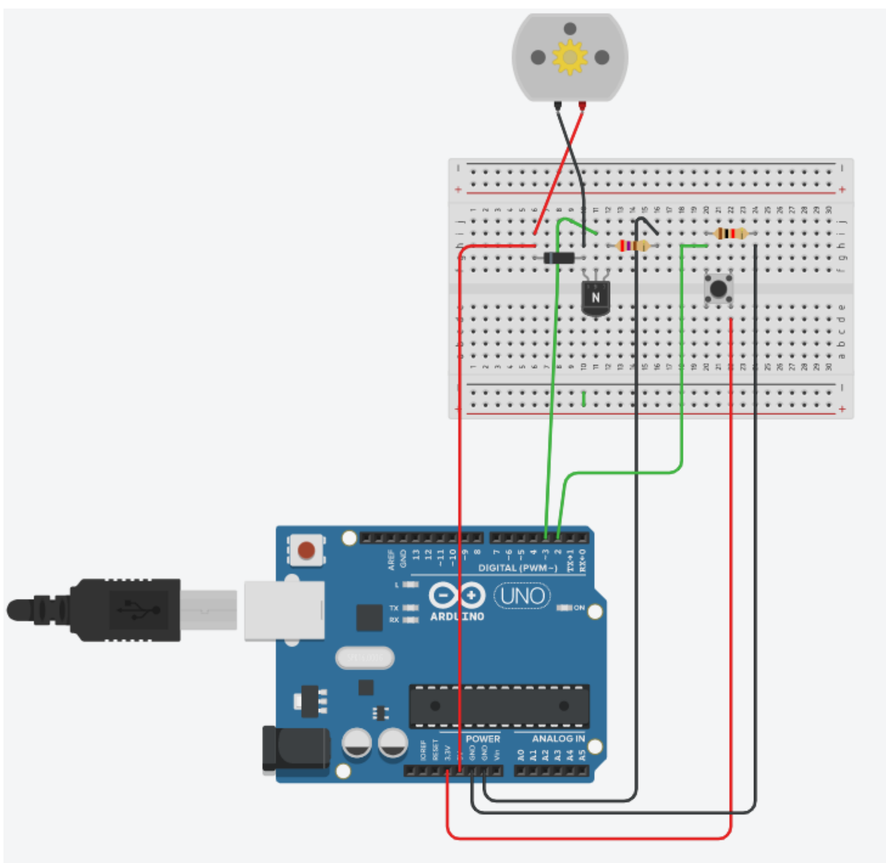


Figure 15 Electrical Schematic of Circuit [8]

Once the electrical components were arranged, the directives for the toy were determined. When the button is pressed, the motor will spin for an arbitrary amount of time between 5-10 seconds. Then, the motor stops and the lifting mechanism ejects the moles. The program then waits 1 second to mitigate the chance of failure/error when the button is pressed immediately. Figure 16 illustrates the pseudocode written using Arduino with respect to the constructed circuit. The code is deployed onto the Arduino and while powered, runs on a continuous loop detecting any input from the button to run the program and start play.

```
int motorPin = 3;
int buttonPin = 2;
int buttonState = 0;
long randNumber;

void setup() {
  Serial.begin(1000);
  randomSeed(analogRead(0));
}

void loop() {

  buttonState = digitalRead(buttonPin);
  if (buttonState == HIGH){
    randNumber = random(5000, 10000);
    Serial.println(randNumber);
    digitalWrite(motorPin, HIGH);
    delay(randNumber);
    digitalWrite(motorPin, LOW);
    delay(1000);
  }
}
```

Figure 16 Code for Arduino

3.2 Progress to Date

As of December 5, 2022, all required functions have been achieved and integration of the functions is ongoing. As shown in Figure 17 the prototype of the spinning function is complete and the motor spins the carousel at just over 1 rotation per second. The carousel houses a plating for the moles that allows them to rotate radially and permits translational motion when the lifting mechanism is applied. Additionally, moles were printed and attached onto the plate. The initial prototype for the lifting mechanism, shown in Figure 18, proves that the moles can be raised in the required time using an elastic and trigger mechanism. The second prototype of the lifting mechanism, Figure 19, fits inside the carousel and can move up using the elastics, however in the current state there is too much resistance in the actuation of the trigger so it cannot be activated when placed inside the spinning carousel.

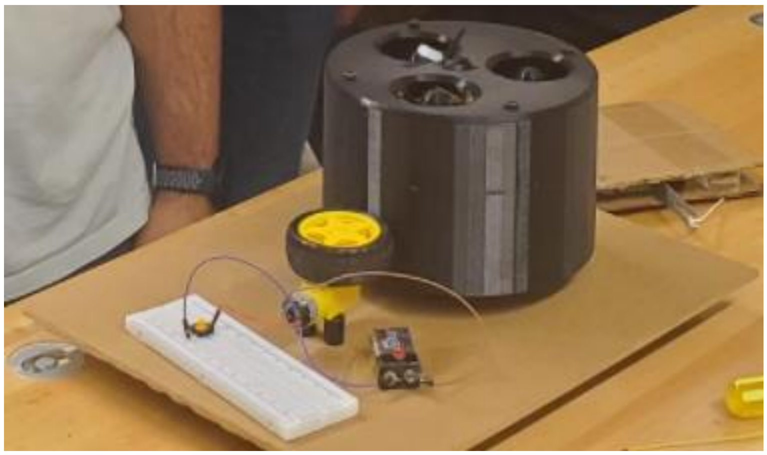


Figure 17 Completed Spinning Prototype

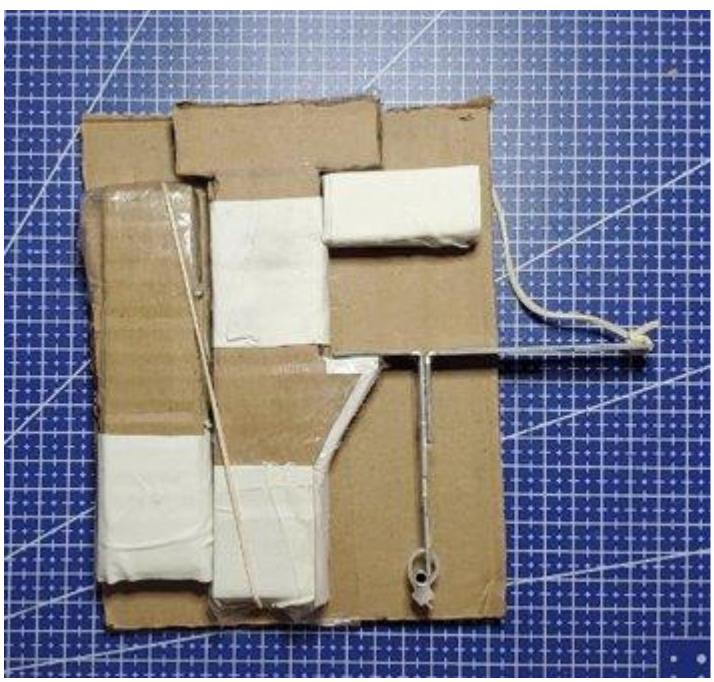


Figure 18 Initial Mole Raising Mechanism

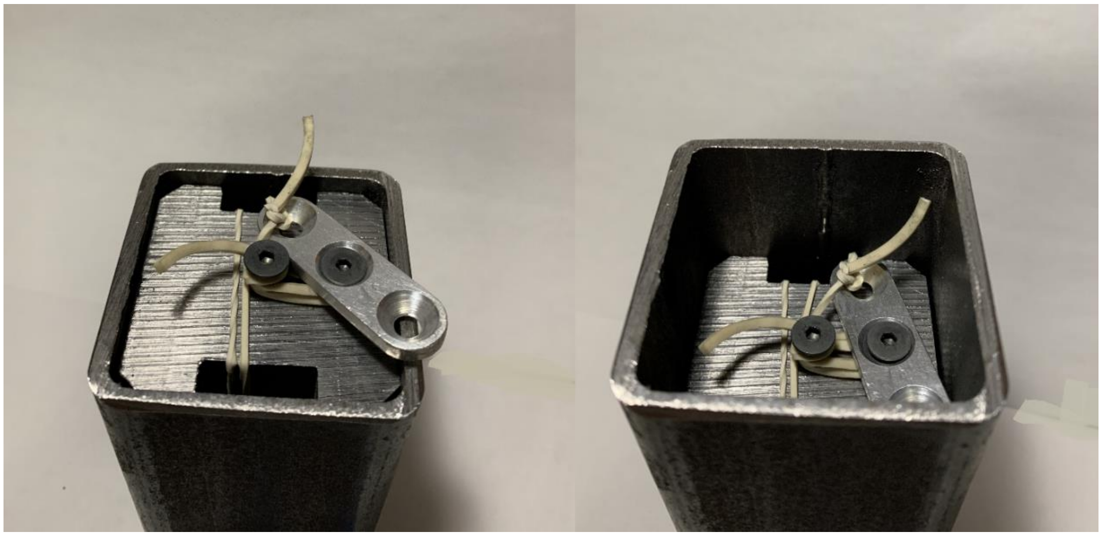


Figure 19 Mole Raising Mechanism, (left is moles down, right is released)

3.3 Remaining Challenges

The main challenges associated with the design project have been established and planned accordingly for completion. The overall challenge is implementing all the components of the toy into a single assembly. With the current state of the project, most of the components have been constructed to work as a single functional toy. However, one underlying challenge was enabling the motor to be controlled with the microcontroller. The current state of the toy uses a button that must be held down to run the motor, however, idealistically should be able to be operated with a microcontroller removing the need for manual operation. Additionally, the mole lifting mechanism mounts onto the toy but requires improvements to eject the mole plate. Overcoming the challenge will require efforts in machining the mole raising mechanism further to reduce internal friction and incorporating an automatic means of ejecting the mole (using an actuator to eject the mechanism which could be controlled with the microcontroller).

4.0 Conclusions

The final view of the design process will be discussed as well as the recommendations to improve the design.

4.1 Conclusions

The Whack it! Toy concept is a feasible toy concept. Prototypes show that the constraints can be met. The mole raising mechanism prototype can be raised in less than a second. The carousel spins smoothly and the speed that it spins at when powered by the motor is above the minimum speed required. A static analysis of the top of the toy shows that the toy is strong enough to withstand the expected forces from game play. The size of the latest prototype, which contains all required functions, is within the 30cm size constraint.

4.2 Recommendations

Looking forward, there are further implications and considerations for the toy if it were to be expanded. For instance, additional features of the toy can be explored such as implementing a score detection system. One way to implement means of tracking and scoring is through using sensors, particularly, an infrared sensor. When the mole plate is ejected the sensor will detect when the mole has been hit and based on which sensor receives the reading first, reward a score to the player. Additionally, further implementations for driving the carousel could be considered. Whack-It currently uses a friction drive, but a gear driven arrangement could be explored. This would be done by mounting a pinion to the motor and designing a gear plating on the carousel that could be laser cut. The benefits of having a gear arrangement would allow for precise configuration of torque and speed (RPM) of the toy. Rather than using a breadboard and circuit to power the motor, a motor shield can be used to simplify the need for redundant electrical equipment. Aspects of the toy can be leveraged to improve the toy for market deployment.

References

[1] "toysrus," [Online]. Available: https://www.toysrus.ca/en/Whac-a-Mole/94860969.html.

[2] "bobsspaceracers," [Online]. Available: https://www.bobsspaceracers.com/Whac-A-Mole--SE-Arcade-Games--10-348648.html.

[3] "thediscoveryhut," [Online]. Available: https://thediscoveryhut.com/products/0055_gm-lets-go-fishing.

[4] "Slewing bearings," [Online]. Available: https://www.skf.com/group/products/slewing-bearings.

[5] "6-Inch Alumium Alloy Turntable," [Online]. Available: https://www.aliexpress.com/item/32856984127.html.

[6] "helios," frcteam2637, [Online]. Available: https://www.frcteam2637.org/2021-2022.html.

[7] "ARMABOT Turret Drive Instructions," [Online]. Available: https://manuals.plus/armabot/turret-drive-manual#axzz7meGqevYB.

[8] "Circuit," [Online]. Available: https://www.tinkercad.com/things/cQrt45bXwnV.