Portable Dog Ball Launcher (FetchIT)

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Executive Summary

An autonomous portable ball launcher, named FetchIT, is designed and constructed by Evan Priadi and Robert Cheng Bao with Dr. David Jones and Jon Nakane as project sponsors. Only materials from the project lab are used to construct FetchIT.

The goal of this project is to build a launching system that uses a spinning wheel to accelerate balls of various sizes that dog owners usually use for their dogs. The system uses a spring system that is similar to the suspension of a car to accept balls of various sizes. The system is able to recognize if the dog have retrieved the ball or not before launching again by using a contact with. It also allows the user to adjust the launching distance for the ball, by changing the pre-set speed levels with a single power button. The safety system is able to detect objects up to any distance up to 6 meters in front to prevent injuring people or dogs using a sonic sensor.

FetchIT is able to launch a tennis-sized ball up to 10 metres and the smaller 56mm diameter ball up to 2 metres in front for about 30 minutes, with continuous use. The shooting distance can be improved further with more development time. One way to improve the system would be adjusting the suspension system and rail.

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1. Background and Motivation

Humans have domesticated hundreds of species of animals. Out of all of them, dog has become so close to us and was given the nickname "Man's best friend." Throughout centuries, dogs have performed many important duties for men, from hunting and protection to assisting the visually impaired and companionships. Many dogs have a natural urge to retrieve objects and return to their owners. Playing fetch keeps the dog alert and energetic. This game provides dogs a good chance to exercise and have fun. Exercising is crucial in keeping a dog healthy. Some dogs end up not getting enough exercise, because their owners do not have the time to exercise them. This report includes our methods for a portable dog ball launcher that can keep dogs happy and healthy when nobody can play with them.

Currently, there are commercially available dog ball launchers that one can use to manually throw a ball.

Figure 1: Triple Crown Farflung Launcher (Amazon.com)

Using this kind of launcher still requires a person's time and effort. Other automatic dog ball launchers have also been seen online developed by dog owners. Most of those launchers requires a power outlet and are huge and bulky to carry around.

Our goal is to develop a portable dog ball launcher that enables dog owners to exercise their dog without human input. This device would save dog owners time to exercise their dog. We will make sure that the launcher is safe to use and portable.

2. Discussion

This section discusses our project objectives, theory, the design implemented on FetchIT, and the results obtained.

2.1 Project Objectives

We designed and construct the dog ball launching system to achieve the following objectives:

1. Able to launch different kind of balls (5 to 7 cm in diameter) about the same size a tennis ball (6.7 cm diameter).
2. Allow user to set shooting range from 5 meters to 30 meters.
3. A safe and easy for dogs to put down retrieved balls.
4. Safety features that prevent dogs or people from getting shot.
5. Keep the entire system under 50cm x 40cm x 30cm and portable.

2.2 Theory

In this section, we present the calculation and the primary concepts used on FetchIT to satisfy the objectives.

2.2.1. Pulse Width Modulation (PWM)

This technique is used to control the speed of the spinning wheel, so that FetchIT can be launched at various distances.

PWM uses a square wave pulse that switches between on and off to control the amount of voltage applied to the DC motor. This rapid switching between the two states causes the motor to “see” a range of voltage proportional to the duty cycle of the square wave. Modifying the voltage seen by the motor will change the speed the motor turns at. For a 12V DC motor, 50% duty cycle provides 6V to the DC motor.

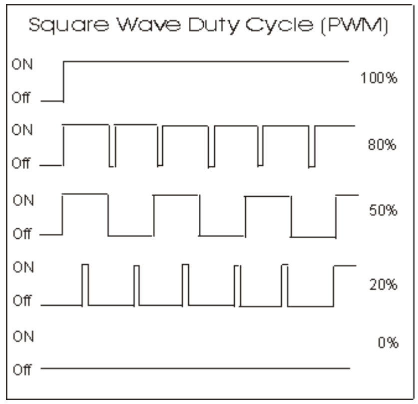


Figure 2: Square Wave Duty Cycle

http://www.imagesco.com/articles/nitinol/07.html

2.2.2. Range Calculation

The ball is launched at 45° to maximise the range of FetchIT. We know the motor draws at the current of about 4A with the belt attached. From the datasheet we can determined the revolutions per minute of the wheel.

From the data sheet,

RPM = $5100\ rpm$

Diameter of the wheel = $0.154\ m$

Radial velocity at the surface of the ball = $\frac{1}{2} \times \pi \times 0.154\ m\ \times \frac{5100}{60} = 20.5\ m/s$

Air time = $2 \times \frac{20.5 \times \sin 45°}{9.8\frac{m}{s^2}}$ = $2.96 secs$

Range = $20.5 \times \cos 45° \times 2.96\ secs = 42.9\ m$

The ball without any losses to friction and total velocity transfer is expected to go up to 42.9 metres.

2.2.3. Safety Detection Range Calculation

This section calculates the safety detection range required for the sonic sensor to sense. The ball launches at a height of approximately, 0.21m above ground.

Time when maximum height is achieved = $\frac{2.96}{2} = 1.48\ secs$

Maximum height obtained= $(1.48 \times 20.5 \times \cos 45°) + 0.21m = 21.67\ metres$

We want the height that is safe is above 2 metre.

Vertical distance travelled by the ball = $2m - 0.21m = 1.79\ metres$

$$s = ut + \frac{1}{2}at^2$$

$$1.79 = (20.5 \times \cos 45°)t + \frac{1}{2} \times 9.8t^2$$

$$t = 0.119\ or - 3.08\ secs$$

Safety Range Detection= $0.119 \times (20.5 \times \cos 45°) = 1.72\ metres$

The safety detection range of the sonic sensor should be within 1.72 metres.

2.3 Final Design

This section presents the final design of our computer controlled dog ball launcher -- FetchIT. The system has three major parts: Mechanical, Electrical and Software Design.

2.3.1. Mechanical Parts

Below describes the mechanical design of FetchIT to meet the goals of this project.

2.3.1.1. Structural Frame

FetchIT is made from 2 major materials: wood and modular 80/20 aluminum frames. These materials have low density and should keep the weight as light as possible. The support frame holding all the components is constructed using 80/20 aluminum beams. These beams are versatile to use, and can mount other structures easily on the slots. The cover for FetchIT is made from a thin walled plywood. A cover is needed to prevent anyone or the dog from touching the spinning wheel or the circuitry.

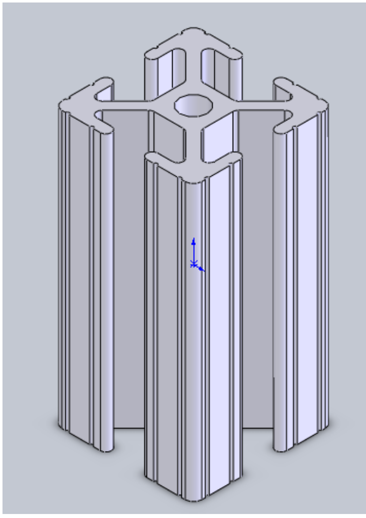
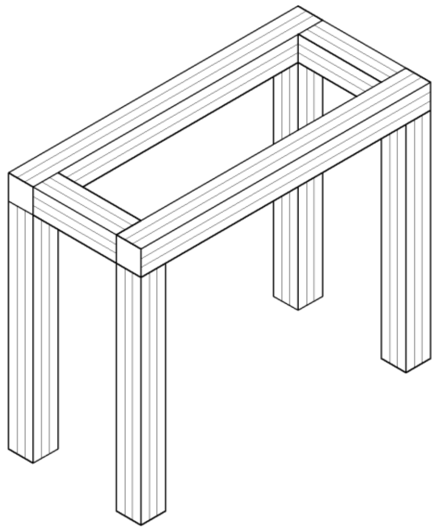


Figure 3: 80/20 Aluminum Beam

Since there are vibrations from the motor spinning and the wheel, rubber stud legs are added onto a wooden platform which the support frame is secured on. This is to prevent the vibrations from disorienting FetchIT, and to dampen the vibration.

The net weight of the overall system is 7300 g.

The 12-V battery weighs about 620 g.



m

Figure 4: Support frame for other mounts

2.3.1.2. Launching System

Crucial requirements for the launching system:

- Able to receive various sizes of balls
- Able to detect that the launcher is loaded
- Able to release the ball into the spinning wheel
- Dampen vibrations caused from the spinning motor
- Repeatable
- Safe to use

The launching system can be divided into 4 major sections. The rail, the belt drive, the motor, and the linear actuator gate system.

2.3.1.2.1. Rail

The rail consists of 2 wood pieces separated by about 1 inch. The separation provides a guide for the ball so that it will only move in the direction of the rail. The two wood pieces are connected by two U-shape braces at the front and back.

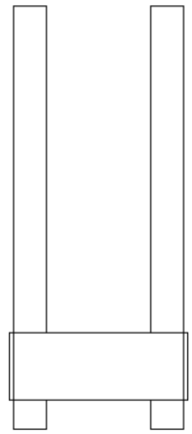


Figure 5: The Rail

In the beginning of the project, it was not clear what would be the optimum design of the rail. One possibility is that the spinning wheel we are using is much heavier than the balls to be launched. The ball may be accelerated with only a brief contact with the wheel. The other possibility is: if the wheel contact with the ball too long, friction may even slow down the ball.

Therefore, before selecting the rail profile, we made 3 versions of the rail profile, with the exit angle of 45°. The profiles are listed below:

1. Full contact of the ball and the wheel from -45° to -135° position.
2. Impulse contact of the ball and the wheel at -90°.
3. Full contact of the ball and the wheel from -45° to -90°.

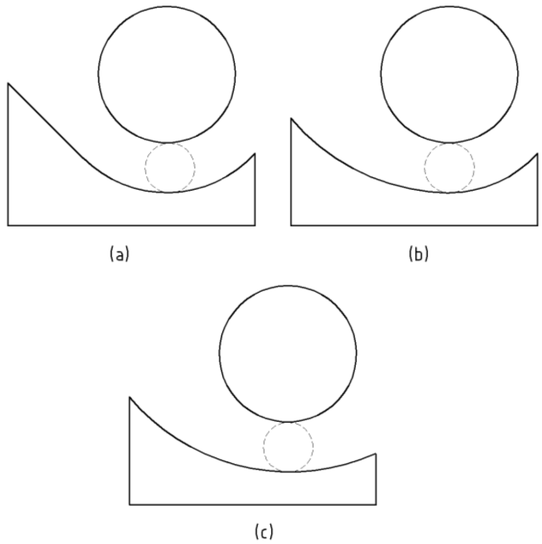


Figure 6: (a) Full contact of the ball and the wheel from -45° to -135° position. (b) Full contact of the ball and the wheel from -45° to -90°. (c) Impulse contact of the ball and the wheel at -90°

After testing all three rail profiles, the rail profile that had the most contact went the furthest. The distance that it travelled was about 10 metres, while the rest of them were significantly shorter.

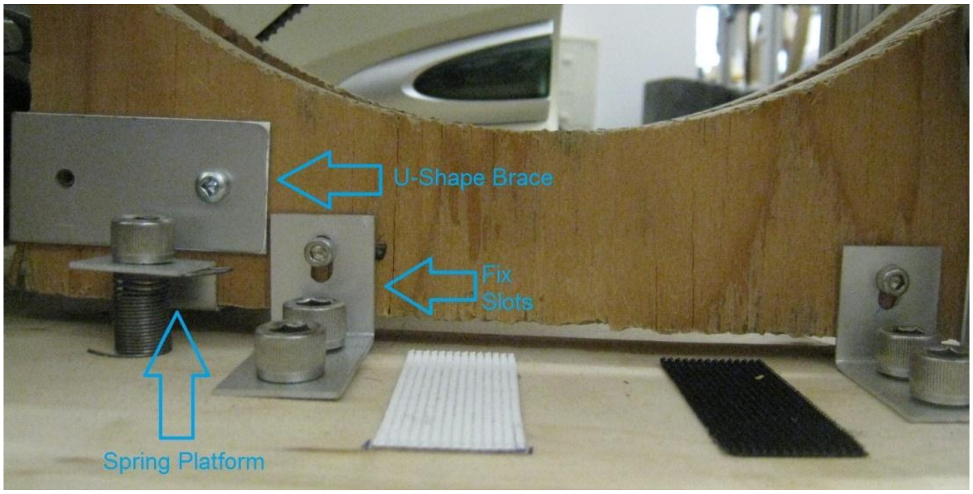


Figure 7: Spring System

Inspired by the suspension systems of cars, the rail is also placed to a spring system which makes the launcher to be able to accept different ball sizes ranging from 5.6cm diameter to 6.27cm. The spring system consists of 4 fix slots, and 2 spring suspension platforms.

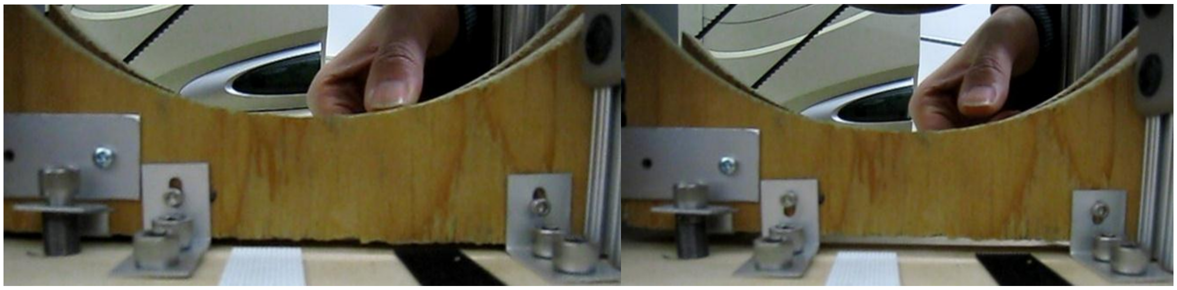


Figure 8: Rail Compressed vs. Released

The suspension platform help to suspend the rail, however, it does not prevent the rail from shearing forward away from the spring platform. Therefore, the 4 fix slots are placed to help guide the rail only up and down, and prevents it from shearing away.

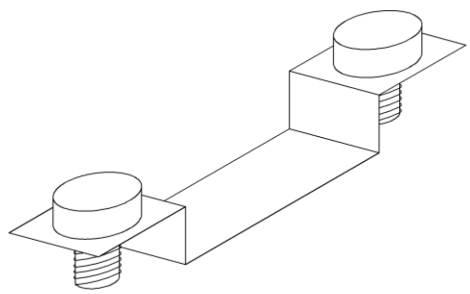


Figure 9: Spring Platform

2.3.1.2.2. Belt drive

In our initial design, the motor was directly connected to the wheel. However, using a belt system would provide a thinner profile, and easier to change the motor or wheel if needed. Thus, we separated the motor and the spinning wheel, added a pulley system, and changed the spinning wheel to be belt-driven. A ball bearing is wedge in between the axle plate and on stationary part of the wheel hub to reduce friction, which might cause a lot of noise during fast revolutions.

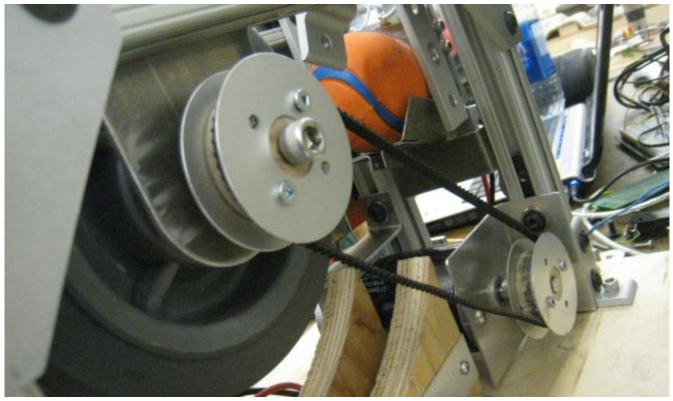


Figure 10: Belt and Pulley System

The belt drive is made using a wood pulley with aluminum walls to prevent the reversed timing belt from derailing. We used the smooth end of timing belt as the belt because it is the only component that we can use in the lab that is that the right diameter. To attach the wood pulley to the motor shaft and wheel axle, we used a clamp that is screwed on the wood pulley. This makes changing the wheel or the motor easily.

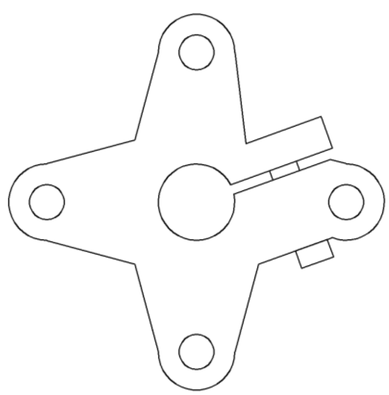


Figure 11: Clamp Piece Screwed on Wood pulley

2.3.1.2.3. Motor

The motor is mounted to the frame using 2 braces. Initially, only one motor brace is attached to the frame. (See picture below).

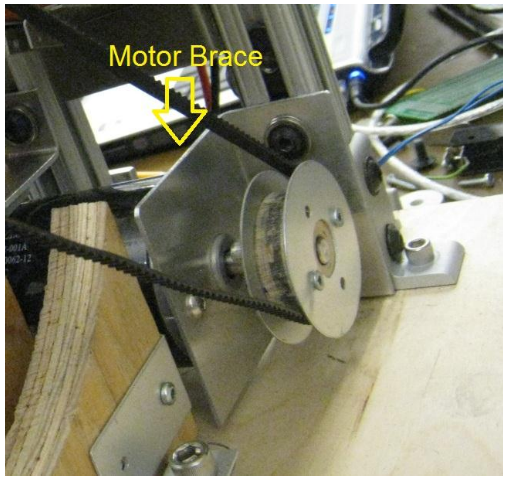


Figure 12: Initial Motor Brace

However, at certain motor velocities, the motor will vibrate a lot causing a lot of rattling noises and causing the whole platform to vibrate away slowly. We decided to place a second bracing to hold the motor securely to dampen the vibrations.

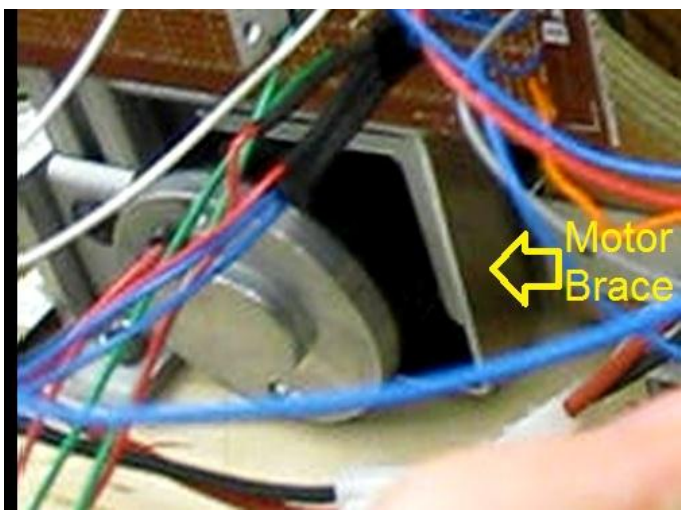


Figure 13: New Motor Brace

2.3.1.2.4. Gate System

To feed the ball into the spinning wheel, we use a gate system that drops and guides the ball into the entry of the spinning wheel and drives the ball between the wheel and the rail. The gate system consists of: a solenoid actuator, a pivot strip, a contact switch, and a back buffer.

The gate latch is made from a linear solenoid actuator that has a strong spring around the shaft to keep the rod normally extruded, and the gate attached to shaft. When the solenoid is not energized, the gate is being pivoted around a wall strip, causing the gate to slope up, holding onto the ball. At the tip of the gate, a contact switch is attached to sense if a ball is present. The contact switch is oriented in such a way that the contact lever is easily pressed, when the ball is dropped. To prevent the gate mechanism from collapsing inwards on strong impacts by the ball, we added a modular 80/20 strip to function as a ``back buffer`` in between the solenoid mount platform and the structural frame. This adds rigidity to the gate upon impact.

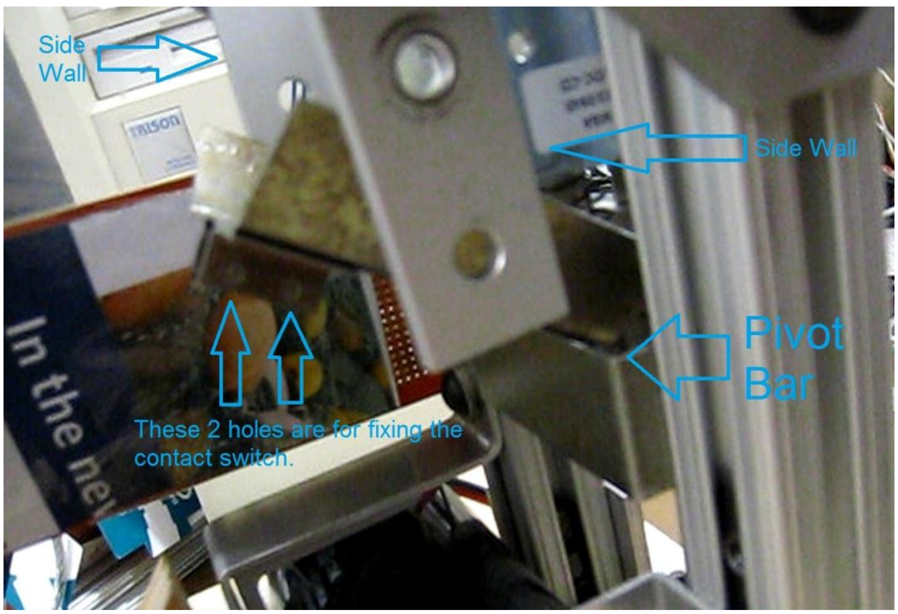


Figure 14: Gate System Solenoid OFF

Figure 15: Gate System Solenoid ON

To release the ball upon sensing that the ball is present, the solenoid is energized and the solenoid rod contracts, bringing the connected end of the gate upwards. This causes the gate to slope down, feeding the ball in between the spinning wheel and the rail. Once the solenoid is finished energising, the spring brings the rod back out again, causing the gate to slope up again, ready for the next launch.

<u>Calculations for Spring System:</u>

Spring Strength Measured: 4cm to support 400g.

Estimated Weight of The Rail: 500g to 600g

Natural Length of Springs: 3.5cm

Length of Spring When Fully Compressed: 1cm

Weight to Be Supported by each spring: $\frac{600g}{4}$= $150g$

Length of Spring with Rail: $3.5cm - \frac{150g}{100g\ per\ cm}$ = 2cm

Thus, ideally, the spring system can accept balls whose diameter vary up to 1 cm, i.e., 5.7cm to 6.7cm.

2.3.1.3. Retrieval System

The retrieval system consists of: the top buffers, 2 side walls, and top cover.

The requirements for the retrieval system are:

- Cheap and light weight
- Easy for a dog to reload and to learn

To make it easy for the dog to reload, we want to have a mechanical system that would guide the ball to the gate mechanism for launch once the dog has dropped the ball into the opening. To achieve that, we placed some modular 80/20 z-frame on both sides of the top beam structure to act as top buffers that would guide and reduce any strong impact of the ball being drop, acting as a buffer. This helps to prevent gate from sloping downwards upon impact. To prevent both the ball and the gate from going to the side opening, we placed more 80/20 strip frame to act as side walls, and also guide the ball to the gate, with contact switch.

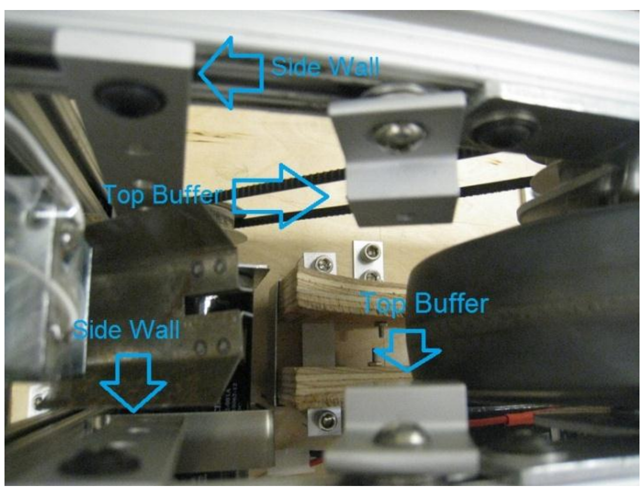


Figure 16: Internal Structure of The Retrieval System

The top frame plywood cover will have a square opening that directly leads to the gate system. With some training, the dog can learn to just drop the ball into the opening, and the launcher will be loaded. The gate system also allows rapid reloading.

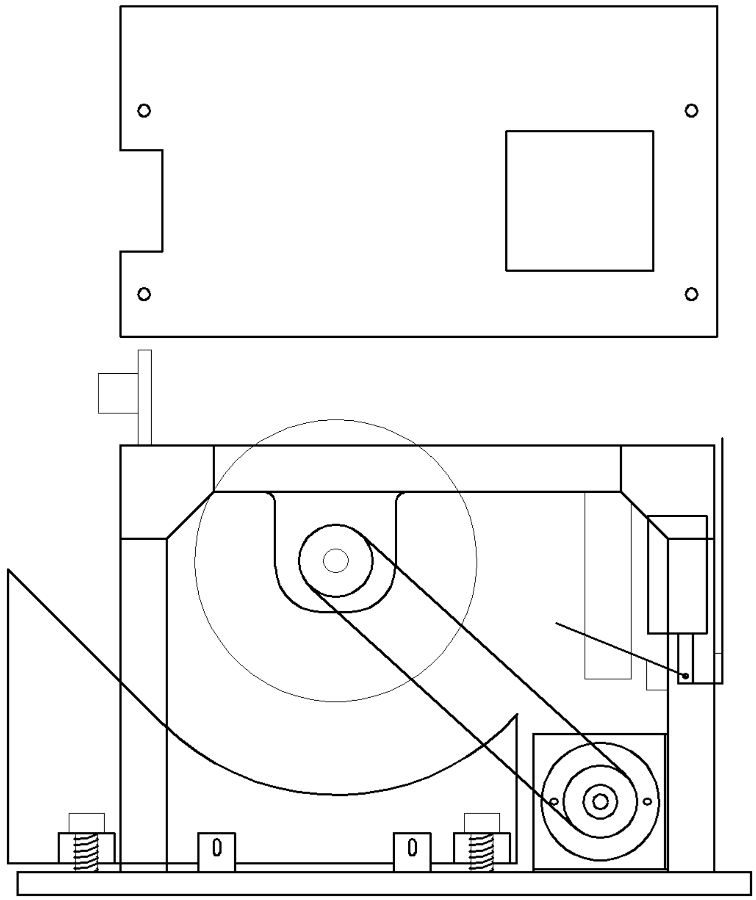


Figure 17: Overall look of FetchIT with Top Cover hole horizontally aligned

2.3.2. Electrical Circuits

The electrical circuits are used to generate input signals for the Arduino board, and operate motors. Electrical circuits and components that are used to generate analog input for the Arduino board are: power button, ultrasonic sensor, and contact switch circuit. Circuit that use output signals of the Arduino board are: Main Motor Control, LEDs (power system and safety system), and Solenoid Motor Control.

The entire system is powered by one9-V battery and one 12-V battery. The9-V battery provides power to the Arduino board. Circuits for the power button, ultrasonic sensor, contact switch circuit, and all LEDs all use the +5V on the Arduino board. Circuits that use the 12-V battery are the main motor and solenoid motor.

2.3.2.1. Motor Control: Power Button, Motor Power LED, & Motor Control

The motor used for this project is FR801-001 whose typical performance is at 12-VDC. We implemented the motor to have 4 major states of the main motor: OFF (0% voltage), LOW (50% voltage), MEDIUM (75% voltage), and HIGH (100% voltage). Different percentages of voltages are achieved by changing the ratio of High and Low of a PWM. The motor goes through these 4 states as the user presses the power button.

When the button is not pressed, the power button circuit is an open circuit. When it is pressed, it becomes a closed circuit. Thus, each time the button is pressed it sends a Low-High-Low pulse to the Arduino allowing it to change motor states by counting the pulses sent from the power button.

Then, PWM signals are generated by Arduino and sent through a Digital Output. In our case, channel 10 is used. An LED is also connected to the same output so that it would have different illumination in different states.

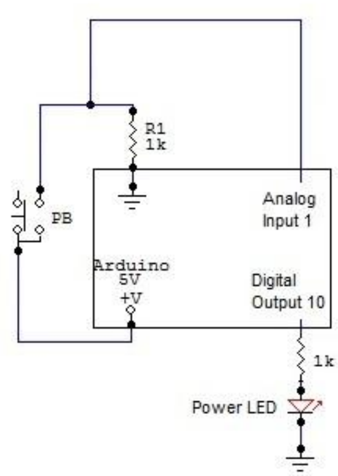


Figure 18: Power Button Circuit

Since we only need the motor to rotate in one direction, only one MOSFET, instead of an H-bridge, is used to power the main motor. Signals sent from Arduino will turn the MOSFET on and off using PWM.

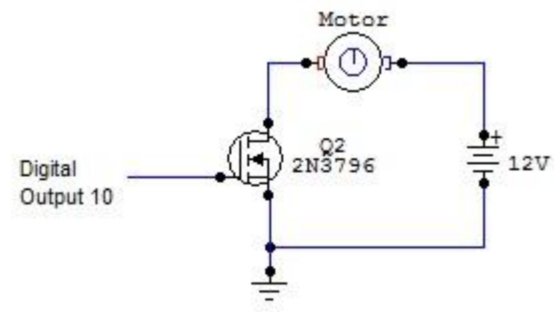


Figure 19: Motor Circuit

2.3.2.2. Safety System: Ultrasonic Sensor & Safety LED

To make the system safe to use, we used an Ultrasonic Range Finder - Maxbotix LV-EZ1. The range finder is used to detect if there is any objects within a specified safe distance. It has a detection range of up to 255 inches (0 to 6.45m), and can be used by directly connecting corresponding pins to the Arduino's +5V, GND, and an analog input.

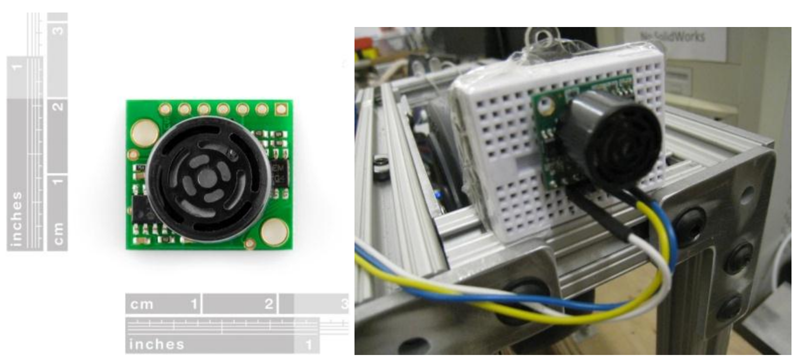


Figure 20: Ultrasonic Range Finder - Maxbotix LV-EZ1

Then, a pair of LEDs will be used to indicate whether it is safe or not. When safe, the Arduino will output a Low signal at output channel 7 and turn on Blue LED. If there are objects within safety distance, channel 7 will be set to High, and Red LED will be turned on.

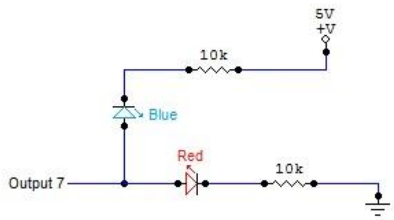


Figure 21: Circuit for Safety System LEDs

Another method to detect objects could be using an IR sensor. Our team tested both an IR sensor (Infrared Proximity Sensor Long Range - Sharp GP2Y0A02YK0F) and an ultrasonic sensor that would potentially be useful for this project. Through testing, we found that the ultrasonic sensor is much more stable to use. When using the IR sensor, the Blue and Red LEDs would flick even though there is no objects in front of the IR sensor. Also, the range of the IR sensor is only up to 150 cm, which won't be able to meet our requirements.

Figure 22: Infrared Proximity Sensor Long Range - Sharp GP2Y0A02YK0F

2.3.2.3. Launching System: Contact Switch & Solenoid Motor

The electrical part of the launching system consists of a contact switch and a solenoid motor. The circuit for solenoid motor is the identical to the main motor. But, the Gate of the MOSFET is fed by another digital output channel of the Arduino board. The circuit of the contact switch is shown in the figure below.

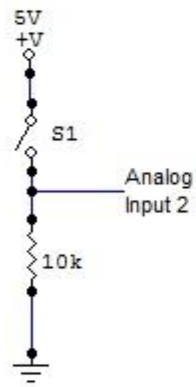


Figure 23: Circuit for Contact Switch

The analog input 2 of the Arduino board will detect High when the contact switch is closed. Using this, we can detect whether the ball has been fed into the right position ready for launching. If the ball is present, and it is safe to launch, a signal will be sent from Arduino to the MOSFET that controls the solenoid motor.

2.3.3. Software

An Arduino board is used to read inputs from the electrical circuits, then generate signals, and control the motors. The software of the system is programmed using the Arduino programming language. The analog inputs come from a power button, a contact switch, and an ultrasonic range finder. It generates PWM for our main motor, controls the solenoid motor and all the LED lights of the system.

2.3.3.1. Motor Control: Power Switch and Main Motor Control

Parameters: PWM frequency = 100 Hz

Input: analog input from power switch

Output: PWM signal for MOSFET that controls the main motor

The speed of our main motor is controlled by one button. The motor has 3 different rotation speeds: Low, Medium and High, thus, providing close, medium and long shooting distances. In order to control the speed using one button, we use the button as a counter to change the state of the motor. Eight states are assigned: Off, LowPending, Low, MediumPending, Medium, HighPending, High, and OffPending.

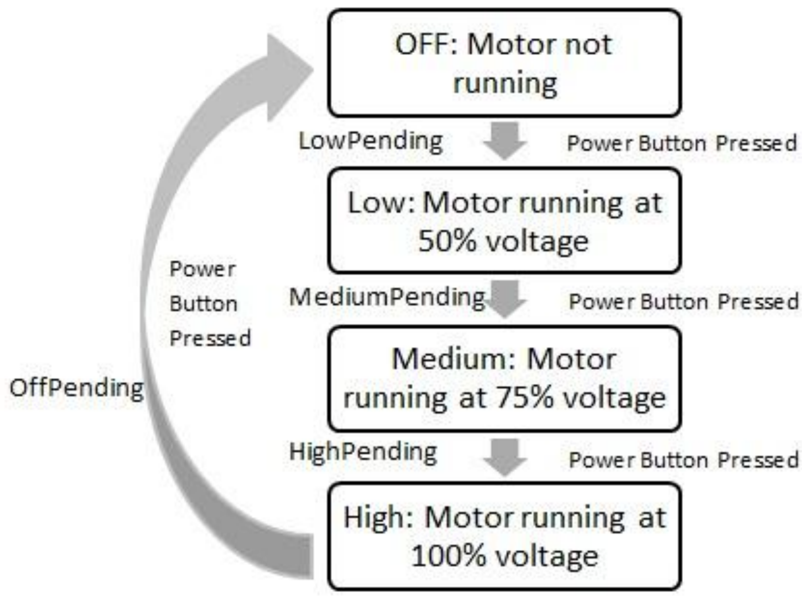


Figure 24: Motor Operation States

As shown in the figure above, when the 12-V battery is connected, the motor will initially be in Off state. When the button is pressed, the analog input of the power switch detects a high voltage, the Arduino then changes the state of the motor to LowPending state. When the button is released, the analog input detects a low signal from the circuit and the motor is changed to Low state. Thus, starting from idle, the motor will be in Low, Medium, High states by pressing the power button three times consecutively.

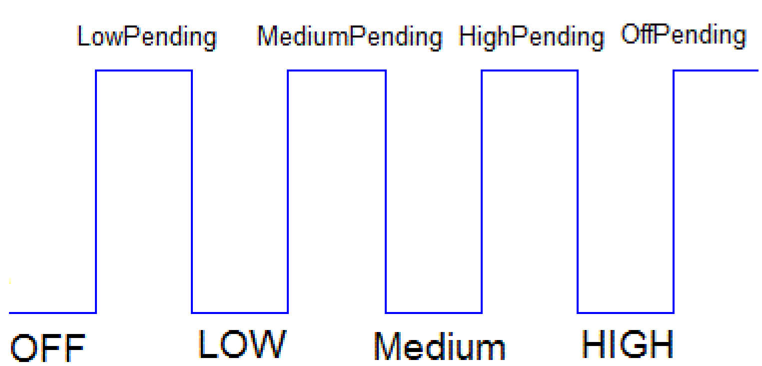


Figure 25: Power Button Signals

The motor speed: 50%, 75% are achieved by using PWM. For example, in Low state, the MOSFET that controls the motor would be turned on for 50% of the duty cycle then turned off for the remaining 50% of the duty cycle.

Another method for motor control could be achieved by using a potentiometer. Potentiometer was our initial chose of motor control. However, we found that it is easier to place the power button onto the frame, and, it is also more user-friendly to press a button than turning a knob.

2.3.3.2. Safety System: Ultrasonic Sensor & LEDs Control

Parameters: Safe Distance = 3 meters.

Input: Analog input from Ultrasonic Range Finder

Output: Digital output for the safety LEDs: Red and Blue.

The safety system has two states: safe and unsafe. The ultrasonic sensor is placed in the front of the system. If objects are detected within a specified safe distance, it is unsafe to launch the ball. (For safe distance calculation, refer to section 2.2.3)

When objects are detected within 6.45 meters in front of Ultrasonic Range Finder - Maxbotix LV-EZ1h, its analog output generates 10 mV per inch, i.e., 0.3937 volt per meter. The range 0 ~ 255 inches corresponds to 0 ~ 512 of the analog input. Thus, the distance of objects detected would be AnalogInput × 6.45 ÷ 512.When the distance of object is greater than the safety distance, it is safe for launching. The corresponding digital output channel sends a low voltage which turns on the Blue LED and turns off the Red LED. When objects are detected within the safety distance, the Red LED turns on and the system will not permit launching.

2.3.3.3. Launching System: Contact Switch & Solenoid Motor Control

Parameters: First Time Delay = 10 ms

Second Time Delay = 0.7 second

Input: Analog Input from Contact Switch

Output: Signal to Trigger Solenoid Motor

Two conditions must be met for launching a ball, as shown in the figure below:

1. No objects detected within safety distance.
2. A ball is detected by the contact switch.

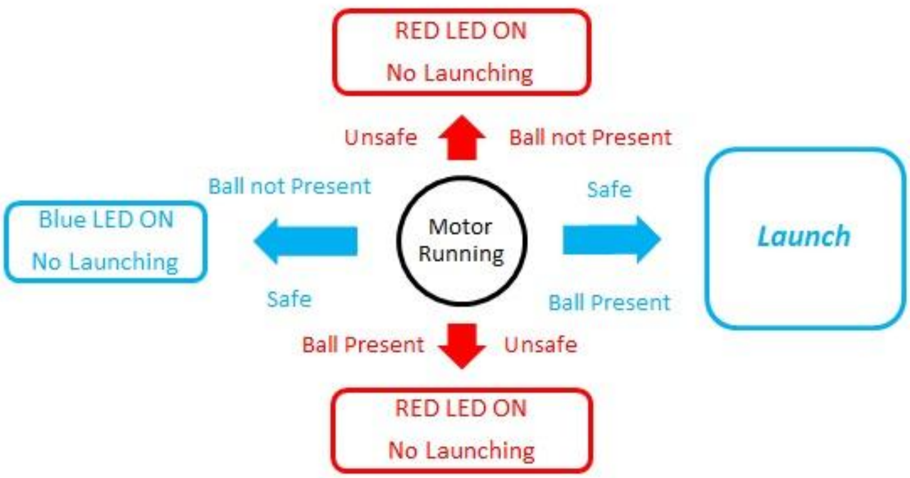


Figure 26: Ball Detection and Safety System Logic

The presence of the ball is detected by a contact switch. When a ball is fed into the system and dropped on the contact switch, the analog input of the contact switch changes from low to high.

The launching process consists of three steps as displayed in the figure below.

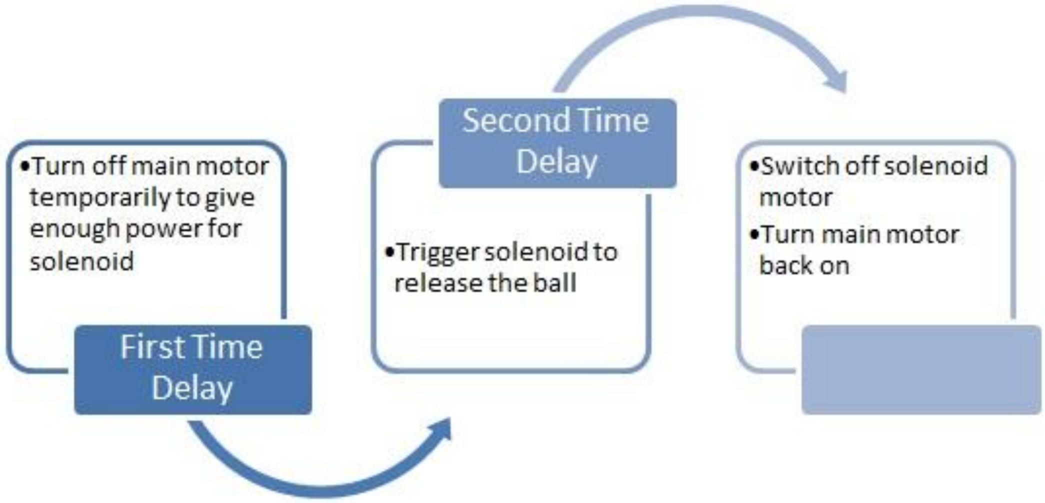


Figure 27: Launch Operation of Solenoid and Main Motor

Through testing, we found out that the 12-V battery is not able to operate the solenoid motor and the main motor at the same time when operating at full speed. Thus, the main motor would be turned off temporarily to allow enough power for the solenoid motor when it is safe to launch. To prevent the spinning wheel to lose momentum when the ball launches, the solenoid motor is triggered 10 ms after the main motor is turned off. At launching, the solenoid motor would be turned on for 0.7 second to ensure that the ball has been fed into the rail before the main motor is switched on again. After the solenoid motor is switched off, the main motor would be turned back to the state it was in before the launching process.

2.4 Testing Results

The performance of the machine is measured by:

1. the distance between the initial landing point of a launched ball and the system
2. the safety range
3. power consumption

All testing was conducted inside the Hennings building at the University of British Columbia.

2.4.1. Shooting Distance

During testing of FetchIT, we found the maximum range of the tennis sized ball to be 10 metres, while the maximum range of the smaller 5.6cm diameter ball to be less than 3 metres.

2.4.2. Safety Range

When testing the safety range of the machine, we set the safety range to be 2 meters. One of our 1.73m in height team member stand at the edge of the detection range of 2 metres holding up a chair to guard against incoming ball, and the large ball managed to miss the team member entirely.

2.4.3. Power Consumption

During the course of testing, we also found the play time to be about 30 minutes. The 12-V battery ran out of power after 30 minutes and the motor speed reduced significantly. For the9-V battery which powers the Arduino and the circuits, it can be used for a long time. One9-V battery can power the circuits for months.

2.5 Discussion of Results

This section discusses the results from testing and the sources of errors and limitations.

2.5.1. Shooting Range

The 10 metres shooting range for the tennis ball is a lot shorter than the calculated value of 42.9 metres. There are several factors that can affect the shooting range:

1. Rail friction.

   The rail we are using is made of wood. The surface where the ball touches the rail is pretty rough. There are huge losses to friction between the ball and rail, and the rail having a long take-off ramp. Having the ball to travel along the take-off ramp after leaving the wheel contact point for a long time will probably cause the take-off velocity to be reduced severely.

2. Motor Powering

   During testing, we found out that that the 12-V battery is not able to provide power for the solenoid motor when the motor is running at full speed. Thus, to supply enough current to the linear actuator solenoid, the main motor has to be temporarily powered down. This reduction in speed would reduce the range of FetchIT.

3. Contact Distance and Compression

   The contact time of the smaller ball is slightly reduced compared to the bigger ball. This causes the maximum range to be reduced for the smaller ball.

   Spring selection is another factor that is affecting the shooting range. When the ball is fed into the rail, it would compress the springs. The friction that accelerates the ball is proportional to the compression force. If the springs are too strong, the rail would not be compressed for bigger ball. Thus, it would not go into the rail. Smaller ball is lighter, and requires less compression to speed up. However, if the spring is too weak, there won`t be enough compression force between the rail and the smaller ball. This might be one of the reasons why the shooting range of the bigger ball is much longer than the small ball.

4. Ball Selection

   The smaller ball has only the maximum range of less than 3 metres. This is partly due to the ball having a smooth surface and thin outer shell. Even though the surface of the ball is smooth and greatly reduce the amount of friction between the ball and the rail, the spinning wheel might be slipping on the surface of the ball. Having a thin outer shell also makes the smaller ball compressible, further reducing the amount of traction between the spinning wheel and the ball. This slippage causes the wheel to not properly transfer velocity to the ball.

   Some losses affecting the larger ball also affect the smaller ball, such as the rail having a long take-off ramp, and the motor powered down to supply enough current to the solenoid. The combined effect of these factors makes the small ball unsatisfactory to use for the system so far.

2.5.2. Safety Detection Range

The safety detection range seems to be successful, even though the range of FetchIT is a lot shorter than calculated. However, the test was conducted when the battery is fully charged. If the battery voltage starts to fall, the trajectory of the ball at 2 metres away from FetchIT might be shorter than 1.7 metres high, possibly causing injury to the people who happen to be standing in front of the machine while it is operating.

2.5.3. Operating Time

The 30 minutes play time of FetchIT seems to be decent if the dog plays it continuously. The dog should be exhausted by the time the battery weakens significantly. Since the battery is rechargeable, the user should be able to use the system in a few hours.

3. Conclusion

In this project, the work is done to design and construct an automatic dog ball launcher. The project objectives are concerned with shooting range, portability of the system, and safety.

Currently, similar systems were made by hobbyist and most of those launchers requires a power outlet and are huge and bulky to carry around. One of the objectives is to reduce the size of the machine. The system constructed has a frame about the size of a shoe box 40cmx33cmx29cm. The net weight of the system is 7.3kg. Our system is powered by 2 batteries: one 12-V battery and one9-V battery. Therefore, allowing an average adult to be able to carry it around.

Similar to a tennis ball launching machine, our system uses a spinning wheel to accelerate the ball. The final design of the system uses a belt-driven system in which the motor and the wheel is connected by a pulley system.

In order to achieve long shooting range, different rails were tested during development. Testing results showed that the one with maximum contact distance for the spinning wheel and the ball has the longest shooting range.

Our system has 2 major sensors, 2 motors, and 2 LED sets: an ultrasonic range finder, a contact switch for ball detection, a main motor that drives the spinning wheel, a solenoid motor to feed balls into the rail, a power LED to indicate motor speed, and 2 LEDs for the safety system.

Both IR and sonic sensor are commonly used in projects for object detection. To ensure the safety of the system, different range finders were used. The final design uses an Ultrasonic Range Finder - Maxbotix LV-EZ1 that has a higher range and stability than an IR range finder, Infrared Proximity Sensor Long Range - Sharp GP2Y0A02YK0F. LEDs of different colors are used for safety. When the Red LED is turned on, it is unsafe to launch balls, and the system won't shoot. Only when no objects were detected within a safe distance, 3 meters, in front of the machine, will it launch the ball if the contact switch is detects the ball in the ready-to-launch position.

To test the effectiveness of the final system, tests were run to evaluate the shooting distance, safety distance, and power consumption. For the shooting distance, bigger balls with diameter around 6.5 cm are the best for the system with more than 10 meters of range. However, for smaller balls with diameters around 5.5 cm, the system cannot launch the ball far enough. The tests showed that the safety distance meets the objective successfully. The power consumption results show that each play time would be restricted to 30 minutes.

4. Project Deliverables

4.1. List of Deliverables

We will provide the following deliverables to the project sponsor:

1. FetchIT Prototype
2. Both big rubber ball and small plastic ball
3. Project Report
4. User Manual

4.2. Cost Estimation

The table below shows the rough cost estimation for FetchIT. Cost is estimated by finding out the known prices on the web. For this project, all electrical and mechanical parts are provided by the project lab.

Part	Estimated cost
80/20 beam	$30
80/20 screws n nuts	$20
Aluminum Parts	$30
Motor	$28
Arduino w/ protoshield	$50
Wooden parts	$32
Total	$190

Figure 28: Table of Cost Estimates

5. Recommendation

The following actions may be taken in the future to improve the shooting range, energy efficiency, and portability of our automatic dog ball launching system developed in this project:

1. Reduce the takeoff ramp after leaving the wheel contact point so that the friction would be reduced, thus, providing a longer shooting range.
2. Find a better material than wood for the rail to increase shooting range.
3. Increase the vertical range of the 4 slots used for the spring system to allow more room for the rail to move up and down. This may improve the compression for the smaller ball.
4. Find more springs that would be able to support the rail but not too strong to prevent balls with diameter 6.7 cm to enter the rail.
5. Add surface material for the spinning wheel for better grip with the ball.
6. Custom make or find a spinning wheel that is a lighter to reduce the weight of the system but heavy enough to accelerate the ball within the contact distance.
7. Construct a new platform for the system. Current platform is made of a thick piece of wood with dimensions 40cmx33cmx5.5cm, which adds on a lot of weight to the system.
8. Add wheels at the bottom of the system so that it can be pulled by the dog.
9. Make a waterproof cover for the system to allow usage in wet conditions.

Appendix A – FetchIT User Manual

A1. Introduction

Congratulations on acquiring your new automated dog ball launcher -- FetchIT! Please take the time to get well acquainted with your machine by reading this user guide. The more you know and understand about your robot, the greater the safety and pleasure you and your dog will enjoy.

For more information on FetchIT, you can contact our project team members at the following addresses:

- Evan Priadi evan.priadi@gmail.com
- Robert Bao imrobert_bao@hotmail.com

A2. Instrument Cluster

9-V battery connector: connector for 9-V battery which powers the circuits and Arduino board.

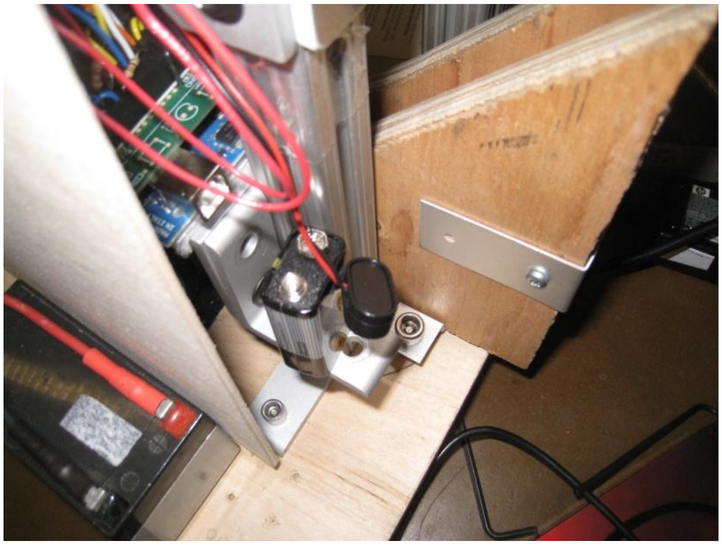


Figure 29: 9-V Connector to Power Arduino

Safety LEDs: indicates the safety state for launching. Blue indicates safe. Red indicates unsafe.

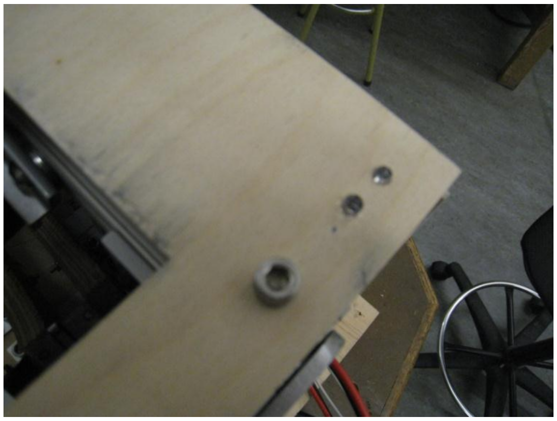


Figure 30: LED Safety Indicators

12-V battery connector: connector for 12-V battery, powers the main motor and the solenoid.

Figure 31: 12-V Connector to power Motor and Solenoid

Power LED: indicates motor state. Turns off when motor is off. Turns on when motor is on.

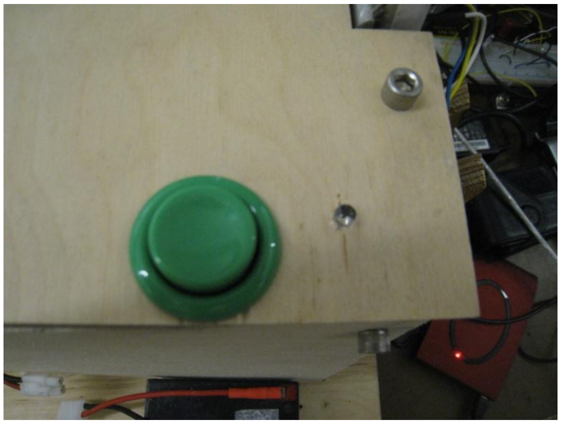


Figure 32: Power Switch with LED Indicator

Square Slot on Top of The Machine: where the ball is fed into the launcher

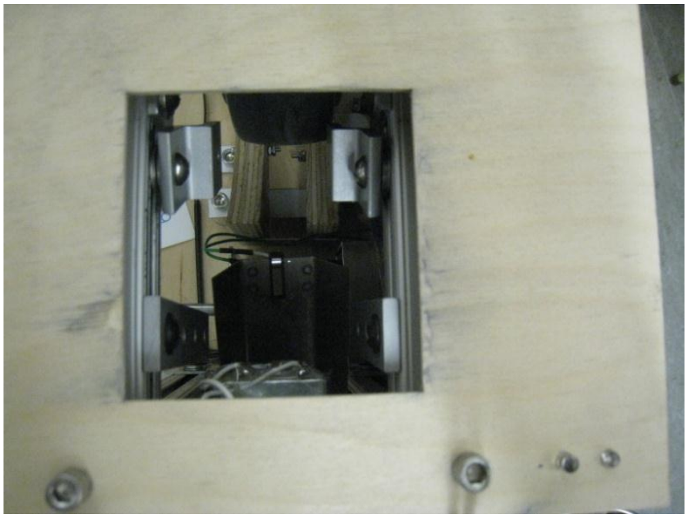


Figure 33: Top Loader Location

A3. System Setup and Checking

1. Place the machine on a relatively flat surface, i.e., slope of the surface within 20 degrees to horizontal.

   ! Warning: Placing the machine at an angle greater than 30 degrees can prevent the launcher from launching or make incorrect safety range estimations.

2. Connect a 9-V battery to the connector to Arduino board.

3. **Check the Safety System** by placing an object in front of the sonic sensor. If the LEDs at the back of the top surface turns red when there are objects within 2 meters of in front of the sonic sensor, and turns blue when there is no object in front of the machine, move to the next step.

   ! Warning: The problem sometimes can be caused by simply a loose wire. But, operating when the safety sensor is not working can cause injury to human or dog.

4. Connect the 12-V battery to the 12-V battery connector.

   ! Warning: If the motor starts running automatically at this point, please disconnect the battery. It usually indicates a blown MOSFET or wire.

5. **Check Motor Operation** by pressing the power button. The motor should start running, and the power LED in the front part of the top frame should light up.

6. **Finish Pre-Operation Check** by pressing the power button 3 more times. The motor should speed up for the first two times and show down when for the third time. Power LED turns off.

A4. Operation

1. Make sure both batteries are connected to the system.

2. Set the motor to the speed you want by pressing the Power Button:
   - Pressing once give Low speed which is intended to be used in an area where the ceiling is less than or around 3 meters.
   - Pressing twice give medium speed which gives around or less than 10 meters of shooting range.
   - Pressing the power button three times give full speed which can shoot the ball upto or more than 10 meters.

   ! Warning: Do not place a ball inside the machine before the motor is running.

3. (This step can be performed by a dog or person.) When the motor is running, place a ball into the square slot on top of the machine. If the front of the machine is clear, the ball will be launched.

   ! Warning: If the safety LED at the back of the machine is blue and the ball does not launch, turn off the motor. This may be a problem of the solenoid or ball detection problem.

4. After play time, turn off the motor by pressing the power button until the motor is turned off. Charge the battery for next play time.

5. Check if there are any screws or nuts on the ground below or near the machine after operation. It is very common for the system to have vibrations during operation. Please collect and fix the loose screws or nuts to their original position, or contact our project team.

   ! Warning: Operating a loose screw may cause operation failure.

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