Squirrel

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Agenda

Project background and requirements
Project considerations
System Design
Prototypes & Demo
Testing
Conclusion

Project Requirements

Project Background - Problem Statement

Client: Bob Thompson

Problem: Bob has squirrels that chew on and damage his deck. The damage they cause is expensive to repair and loud noises, such as a barking dog, are not enough to scare the squirrels.

Project Background - Functional Requirements

- The device should start tracking and targeting squirrels as soon as it is powered on
- The product should launch a projectile that will scare squirrels off the deck without damaging the house
- The product should automatically retrieve the projectiles that are launched
- The device should be able to attach to the deck without damaging it.

Project Background - Non-Functional Requirements

- The product must be able to withstand poor weather conditions as it is in an unprotected outdoor area
- The device should be low in cost, and be produced within the budget provided for the course
- The device should be autonomous and require minimal manual intervention.
- The device should be simple enough that it can be reproduced and scaled to multiple devices that cover an entire deck
- The product should operate for long periods of time without maintenance

Project Background - Engineering Constraints

- Must be small enough to fit on deck or deck railing
- Must be possible to power in an outdoor environment
- Must be reproducible, i.e. our parts must be possible to manufacturer outside of our 3-D printed prototype
- Must be powered by a typical wall power outlet
- Cannot have any exposed wires that could be shorted or become a dangerous fire hazard.

Project Background - Solution

We should launch ping pong balls at squirrels using a turret system to deter them from chewing on the deck. There will be 5 main subsystems that will make up the turret:

- Targeting
- Launching
- Reeling
- Vision System
- Power System

Market Survey

There are currently no products on the market that are similar to our product

Some hobbyist products have been created that we can compare to.

Main difference is that hobbyists use disposable projectiles like water or air soft bullets.

Project Considerations

Technology Considerations - Vision System

Vision System

Technology	Jetson Nano + PI camera	Jevois camera + raspberry pi
Cost	$130	$115
FPS	0.3 sec	2 sec

Jetson + Pi Cam is the better option, it improves classification speed by 6.6x for only $15 more

Technology Considerations - Launching

Launching System

Technology	Pneumatics	Fly-wheel	Spring launching
Cost	$200	~$30 - $50	~ $30 - 40
Advantages	No moving parts	Many moving parts	Few moving parts
Disadvantages	Cost is to high	Easy to reload	Difficult to reload

A flywheel is the best option due to its low cost and ease of reload. While we anticipate some difficulty in implementation, the simplicity in reloading will allow us to incorporate it with the rest of the system easier.

Unit Cost

Part	Quantity	Cost
Jetson	1	$99
StepD-01	1	$14.95
Pi Camera	1	$29.33
Nano Power Supply	1	$7.50
SSD 64 GB	1	$14.99
Nema 17 Steppers	2	$27.98
DC Motors	2	$13.78
L298N H-Brige	1	$5.99
TB6600 Driver	2	$23.98
6 ' Power Cord	1	$6.16
3D-printing plastic	2	$40
Casing	1	$15
Power Supply	1	$20.77
Wirering	1	$20
Arduino	1	$15
Total		$354

Within budget of $600, but to be a viable product we could look for further reduction in costs by:

- Design a PCB board instead of using separate motor controllers.
- Power the Jetson, motor controllers, and Arduino from the same power supply

Risk and Mitigation

High risk - Mechanical system used in launcher and to move launcher. Mitigate by focusing on building these systems first, and their software later.

Low risk - Training YOLO model to detect squirrels in images. Past experience shows that this takes a lot of time. Mitigate by being aware of this issue and prioritizing the data collection and training

High risk - Reeling system has potential to get tangled and stuck. No mitigation has been determined and therefore this is deemed high risk.

Medium risk - Due to COVID-19 were are not able to work together on prototypes. Mitigate by splitting up the systems and working on them individually only meeting for integration.

System Design

System Design

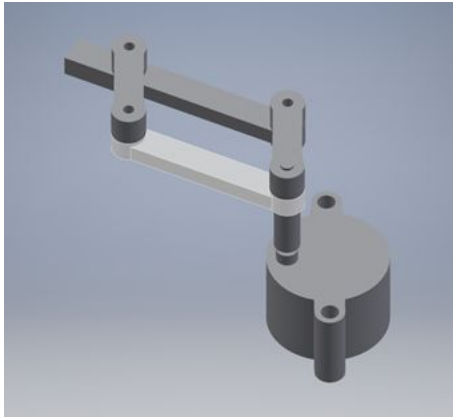
Subsystems

- Targeting
  - Moves gimbal
- Launching
  - Turns on flywheel
- Reeling
  - Reel in ping pong ball
- Vision System
  - Detect Motion
  - Check if squirrel is present
- Power System

Targeting

Fuhable on Thingiverse

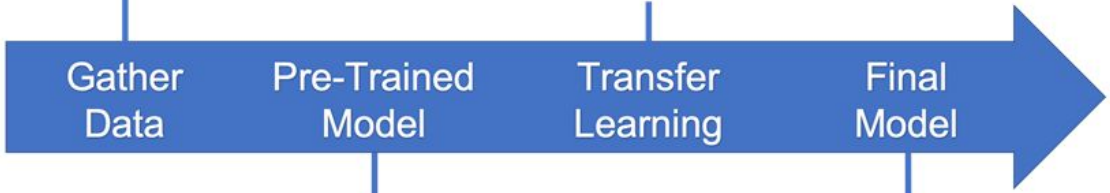
Launching



System Design - Training Pipeline

Gather data to train the model
- Took 400 pictures of squirrels and then downloaded an extra 200 images from the internet.
- Annotated the images with bounding boxes around the squirrels and converted the box data to a csv file.

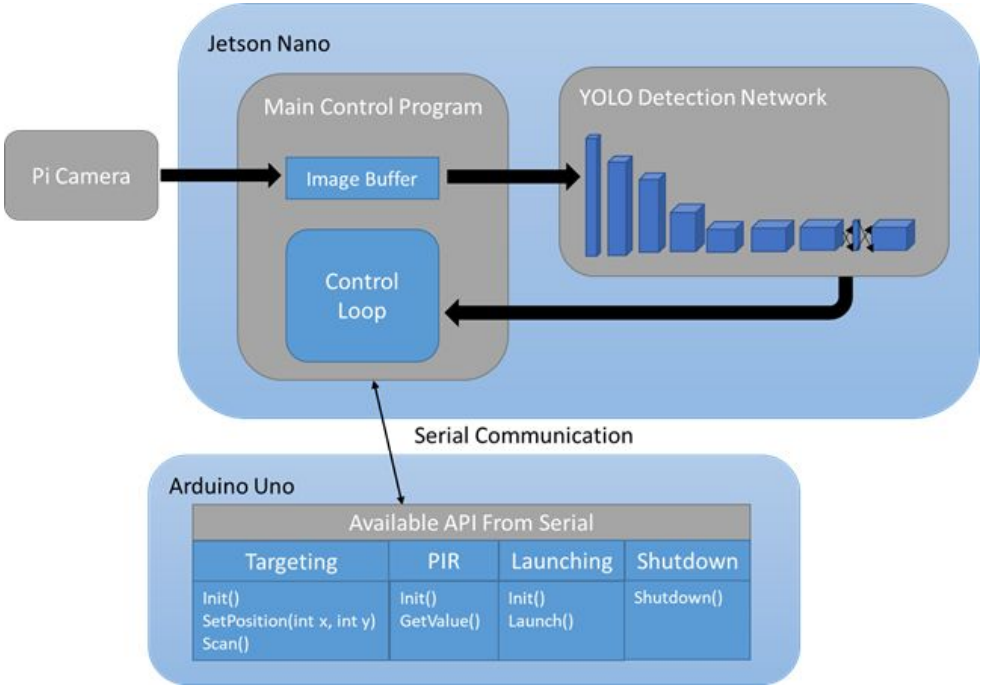
Use the pretrained model to train our own custom model
- The pretrained model is already very capable of useful detections, such as lines and shapes.
- Remove the final layers from the pretrained network that are used for classifying irrelevant objects.
- Transfer the remaining network to our custom model.



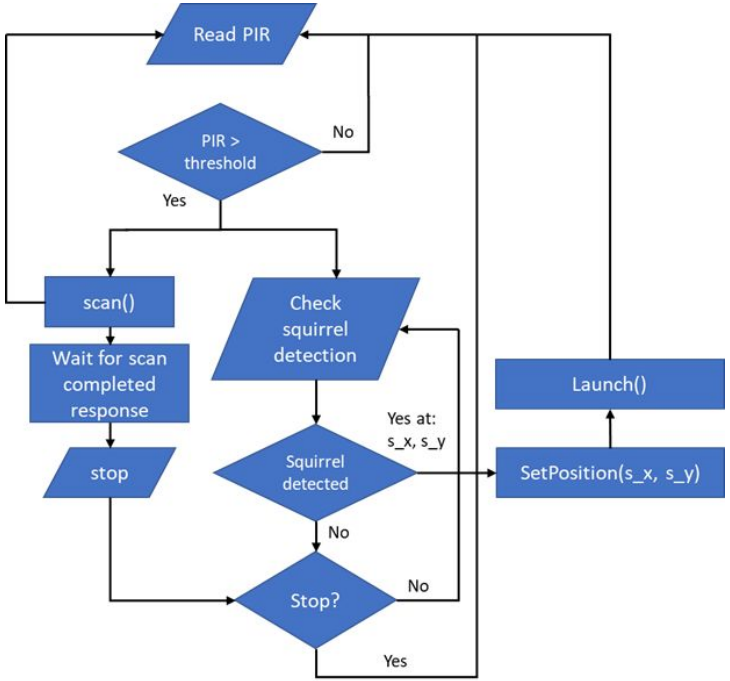
Find a pre-trained model similar to our goal
- Used "Tiny-Yolo", a small, pretrained model that can detect a few objects like people, cats, and dogs.

Finish training the model
- Train our transferred network on the 600 annotated squirrel images.
- The final model and its weights are saved and ready to be used for detection.

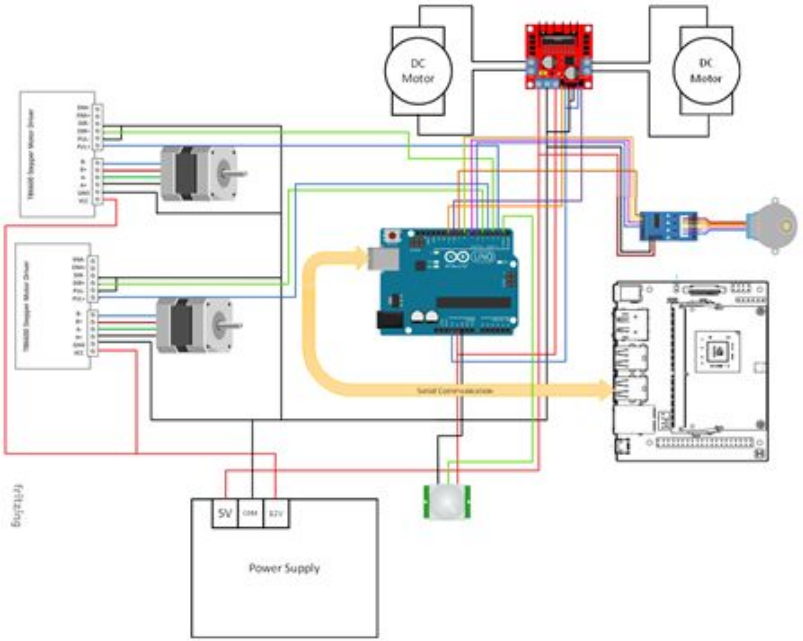
Project Sketches - Architecture



Project Sketches - Control Flow

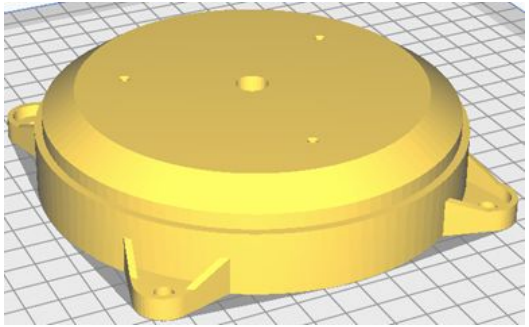


Project Sketches - Schematic

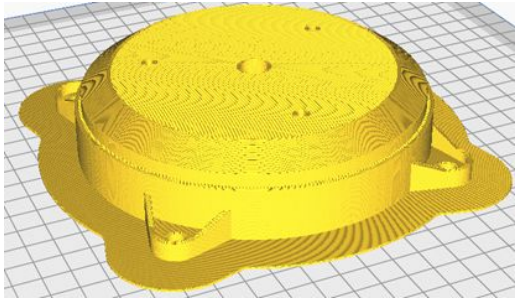


3D Printing - Targeting and Launching

- # of parts: 27
- Total print time of successful prints: 167 hours
- Average print time of only successful prints: 6.3 hours
- Est. amount of plastic used: 1.4kg



Model

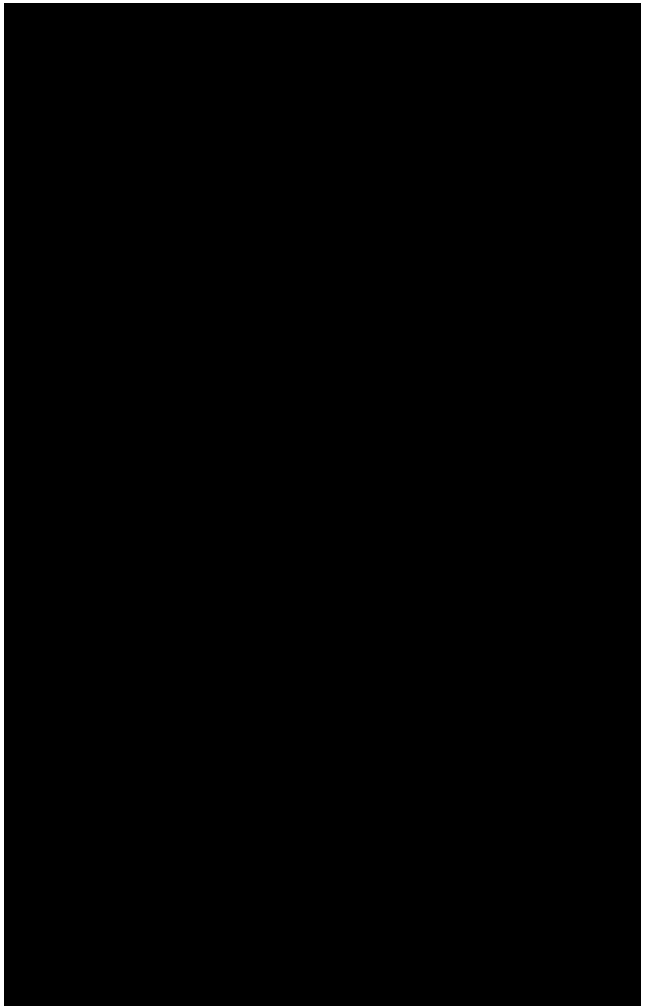


Sliced model with raft

Prototypes - Demo

Squirrel Detection

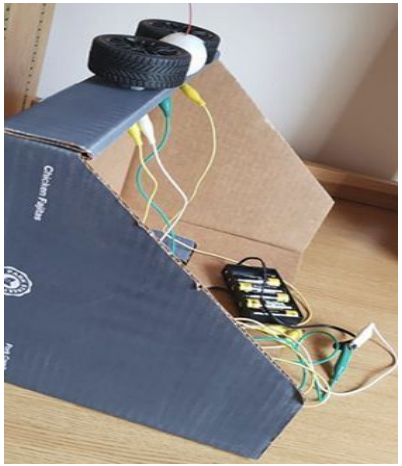
The squirrel detection takes around .2 seconds per image or video frame. Capable of detecting them at just about every angle, even on backgrounds that they blend in with.

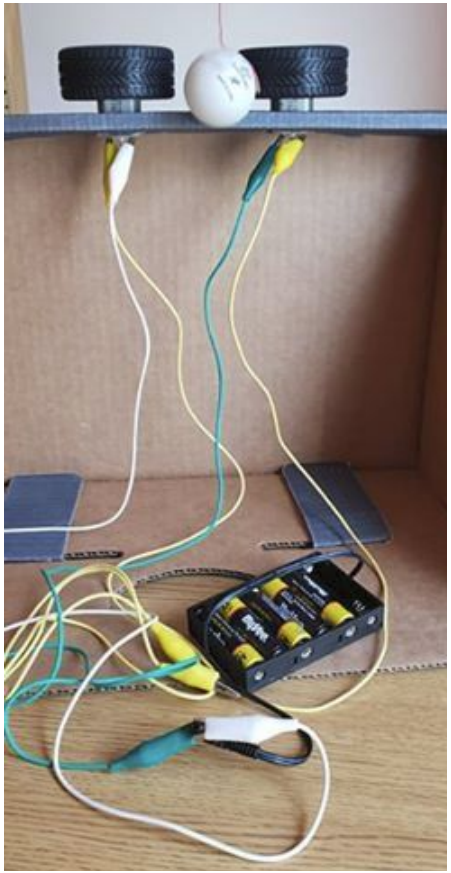


Prototypes

Fly-wheel prototype built to test drag on ball with fishing line attached.

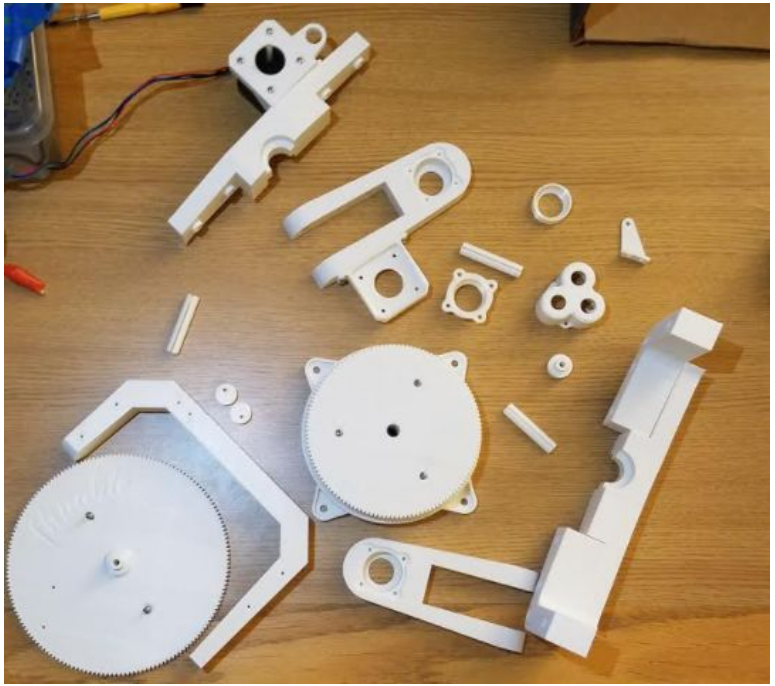
Showed a near comparable distance between with and without fishing line.





Printing Issues

3-D Printed Parts



Testing

Testing Strategy

Because of the shortened semester and the minimal amount of programming needed for this project we did not deem it necessary to go beyond manual testing.

Unit - Verify functionality of a single feature

Integration - Verify functionality of multiple features integrated together

Acceptance - Verify systems ability to satisfy the customer

Systems - Verify systems meet the stated functional / non-functional requirements

Note: because this was a short term project we saw no need for regression testing

Testing Breakdown				
Unit	Acceptance	Integration	Systems	Total Tests
20	8	8	4	40
50%	20%	20%	10%	100%

Functional Test Results - Passing

Targeting System - Can be controlled manually by using the serial API

Launching System - Can be triggered manually by the serial API

Vision -Our squirrel detection algorithm runs on live video at 5 Fps, and can provide coordinates to the location of the squirrel

Power - The stepper motors receive sufficient power

	Subsystem				
Test ID	Targeting	Launching	Reeling	Vision	Power
S1					
S2					
S3					
S4					
S5					
S6					
H1					
H2					
H3					
H4					

Functional Test Results - Failing

Targeting System - The remaining tests cover integration with the vision system

Launching System - The remaining tests cover integration with the vision system

Reeling System - We were unable to complete the reeling system resulting in all tests failing.

Vision - We did not complete the integration of the PIR motion detection.

Power - Our power supply was insufficient to power the flywheel motors.

	Subsystem				
Test ID	Targeting	Launching	Reeling	Vision	Power
S1					
S2					
S3					
S4					
S5					
S6					
H1					
H2					
H3					
H4					

Squirrel Detection Test Results

Recall - Percentage of total squirrels detected - 11/17 squirrels detected = a recall of 64.7%
Precision - Percentage of correct positive results - 11/13 = precision of 84.6%
Intersection over Union - Percent overlap between the hand drawn bounding box and the computer generated bounding box - 65%

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	image	xmin	ymin	xmax	ymax	Detected xmin	Detected ymin	Detected xmax	Detected ymax	confidence	Detection Result	Intersection	Union	IoU
2	milan-gurung-nSoe5nE8Pq8-unsplash.jpg	none	none	none	none	718	1217	2718	4368	0.34378365	False Positive	N/a	N/a	N/a
3	felipe-bustillo-S-5_g_tvBGA-unsplash.jpg	none	none	none	none	none	none	none	none		True Negative	N/a	N/a	N/a
4	alex-7pTsJgiVlMg-unsplash.jpg	none	none	none	none	1123	1834	2853	4543	0.43954605	False Positive	N/a	N/a	N/a
5	cristina-schek-oJieg2n8duk-unsplash.jpg	4054	1881	5329	2922	3977	1804	5399	3137	0.6576522	True Positive	1326914	1895526	0.70
6	deepak-h-nath-iHOvGljFpSg-unsplash.jpg	1210	2314	2490	4452	none	none	none	none		False Negative	N/a	N/a	N/a
7	hillie-chan-kKsbR_BGwIE-unsplash.jpg	1926	1316	2526	1997	1797	1365	2643	2160	0.67516077	True Positive	379313	702191	0.54
8	melvin-thambi-5BILwkk6w6I-unsplash.jpg	2044	635	3617	2249	none	none	none	none		False Negative	N/a	N/a	N/a
9	joakim-honkasalo-3Xdff7Amc8k-unsplash.jpg	1345	888	2429	1991	none	none	none	none		False Negative	N/a	N/a	N/a
10	mathew-schwartz-mRitYzw9_-I-unsplash.jpg	1055	314	3031	2344	919	0	3560	2531	0.44462132	True Positive	4011634	6684371	0.60
11	ilnur-kalimullin-D3fLgDc9uOQ-unsplash.jpg	1938	1147	3978	3183	1924	1122	4712	3069	0.72002935	True Positive	3920785	5661449	0.69
12	kulli-kittus-qyt0cPByJjs-unsplash.jpg	1350	686	2583	1956	none	none	none	none		False Negative	N/a	N/a	N/a
13	caleb-martin-Tk71SYS8UBY-unsplash.jpg	2231	805	4696	2801	2251	1124	4777	2578	0.89104784	True Positive	3555285	5035935	0.71
14	IMG_0502.jpg	1950	1932	2188	2258	1776	1823	2338	2277	0.77029121	True Positive	77481	255148	0.30
15	IMG_0515.jpg	363	1492	1705	2033	468	1517	1805	1992	0.69712096	True Positive	587640	773754	0.76
16	IMG_0716.jpg	930	1677	1883	2435	953	1559	1872	2522	0.66349566	True Positive	696324	910465	0.76
17	IMG_0743.jpg	2527	2097	2854	2341	2506	2081	2871	2323	0.65300775	True Positive	74066	94356	0.78
18	IMG_0743.jpg	363	2092	474	2300	none	none	none	none		False Negative	N/a	N/a	N/a
19	IMG_0789.jpg	1076	1652	1968	2021	965	1594	1838	2044	0.67657566	True Positive	281057	440687	0.64
20	IMG_0800.jpg	1009	2114	1408	2573	986	2148	1457	2631	0.54308152	True Positive	169485	241027	0.70
21	IMG_0748.jpg	1347	1195	1528	1851	none	none	none	none		False Negative	N/a	N/a	N/a
22														
23	PRECISION	0.84615385												
24	RECALL	0.64705882												
25	Average IoU	0.65												

Non-Functional Testing Results

- Our non-functional tests for the squirrel detection algorithm passed
- We did not complete our other non-functional tests as they were mainly dependent on full system integration.

Conclusion

Conclusion

There is still a long way to go before the product is ready to be released.

- Reeling System
- Weather Protection
- Completion of other core components