PING-PONG PLAYING ROBOT

UVU MECHANICAL ENGINEERING
UTAH VALLEY UNIVERSITY

CAPSTONE – FINAL REVIEW
SPRING 2022

Group Members: Patrick Butler
Daniel Hernandez
David Evans
Noah Parker
Derek Wright

Coach: Dr. Matt Jensen

PRESENTATION OVERVIEW

- Problem Definition
- Concept Generation and Selection
- Modeling, Testing and Analysis
- Final Design
- Questions/Feedback

gamesrader+. 2010. Retrieved from https://www.gamesradar.com/wii-ping-pong-controller-is-coolest-most-useless-wii-controller-ever/

PROJECT GOALS

- Follow the engineering design process
- Work in a project management setting
- Build an interactive, game-playing robot
- Represent the Engineering Program

"The Enterprisers Project" Retrieved from https://enterprisersproject.com/article/2019/5/rpa-robotic-process-automation-how-explain

PROBLEM DEFINITION

- Robot Capabilities:
  - Interactively Play Ping-Pong
  - Meet all safety standards
- Completion Within Timeframe
  - September 2021 – April 2022
- Stay Within Budget
  - $5,625.00

Collabforge. 2014. The Einstein Problem Definition Process. Retrieved from https://collabforge.com/the-einstein-problem-definition-process/

EXPLANATION AND EVIDENCE FOR DESIGN NEEDS

The Design and Needs were defined by

- Interviewing Players
  - Novice
  - Intermediate
- Independent Research
  - Peer Evaluated Journals
  - Documented Projects
  - Brain Storming

Inside the games. 2019. Retrieved from https://www.insidethegames.biz/articles/1078357/different-colour-rubbers-to-be-permitted-in-table-tennis-after-tokyo-2020

CUSTOMER NEEDS

No.	Customer Needs
1	Autonomously play Ping-Pong
2	Easy to transport
3	Easily operable
4	Variable difficulty settings
5	Minimal assembly required
6	Reasonably priced

UGN. Identify a Customer's Needs for Better Sales. Retrieved from https://ugn.com/customers-needs-better-sales/

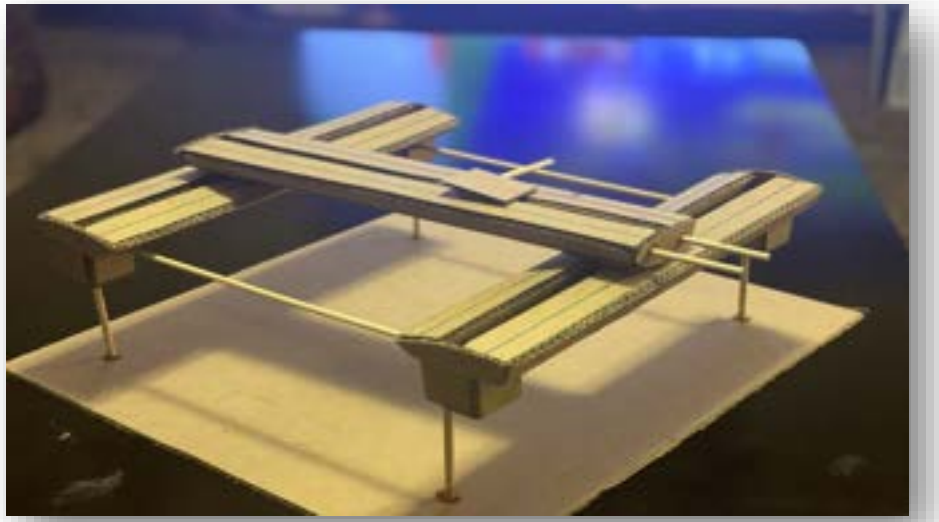
DESIGN REQUIREMENTS

- Design requirements were developed for:
  - Standard Ping-Pong Table
  - Maximum Ball Speed of 40 ft/s

TIGER PONG. Room Size. Retrieved from https://tigerpingpong.com/room_size

Metrics for Playing Mechanism	Value	Units
Maximum paddle travel speed	10	ft/s
Paddle range of motion (radius)	3	ft
Possible ball return vertical angles	± 45	deg.
Possible ball return horizontal angles	± 30	deg.
Paddle position accuracy at location of ball	1.5	in
Paddle reaches ball position late	< 10	%
Ball return angle accuracy (vertical and horizontal)	2	deg.
Rate of successfully returned serves	80	%

DESIGN REQUIREMENTS CONTINUED



Cardboard Prototype

Metrics for Vision System/Processing	Value	Units
Calculated ball position accuracy	1.5	in
Frequency of locating the ball's current position	60	Hz
Frequency of Ball Position Calculation	120	Hz
Works with common background setting	1	bin
Likelihood of equipment damage per game	0.5	%
Electrical Power Consumption	<1800	W
Enjoyable ping-pong game	1	subj.
Robot endurance (continuous game-play)	>1	Hr.
Robot meets OSHA/ANSI Guidelines for Robotic Safety	1	bin
Portability (packed size without table)	<6	ft^3

APPLICABLE CODES AND STANDARDS

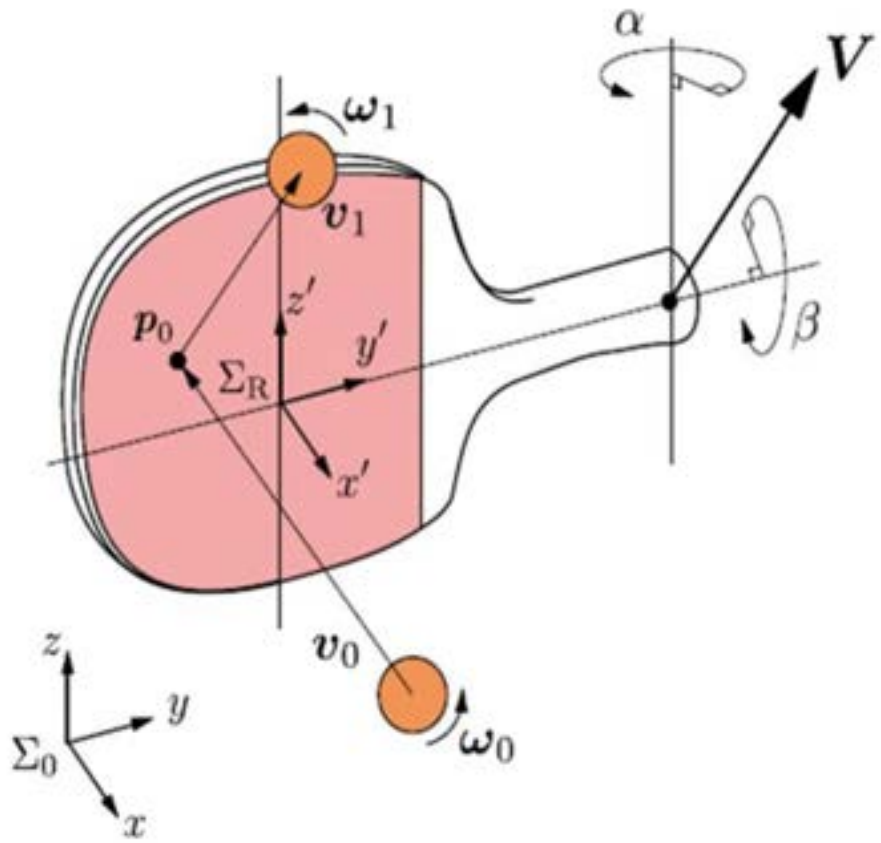
- The control of hazardous energy (OSHA, 1910.147)
- Any Machines that create a hazard must have safeguards (OSHA, 1910.212)
- Use of limiting devices (ISO 10218-1:2011)

Emergency Stop Switch. Retrieved from https://www.pepperl-fuchs.com/global/en/classid_2395.htm

Limit Switch. Retrieved from https://wecount.com/product/down-limit-switch/

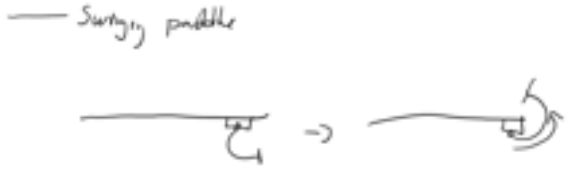
CONCEPT GENERATION FACTORS

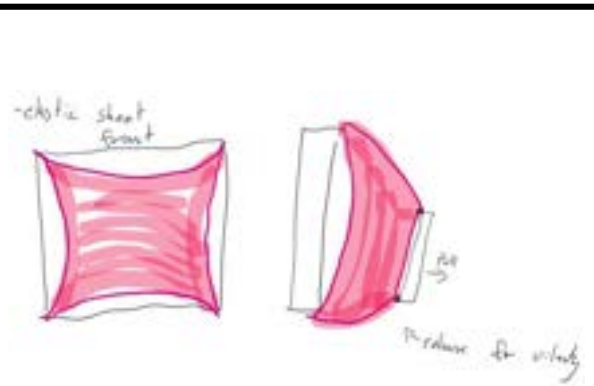
- Hit Velocity
- Ease of Transportation
- Cost
- Range of Motion
- Play-Time Endurance
- Accuracy of Ball Placement

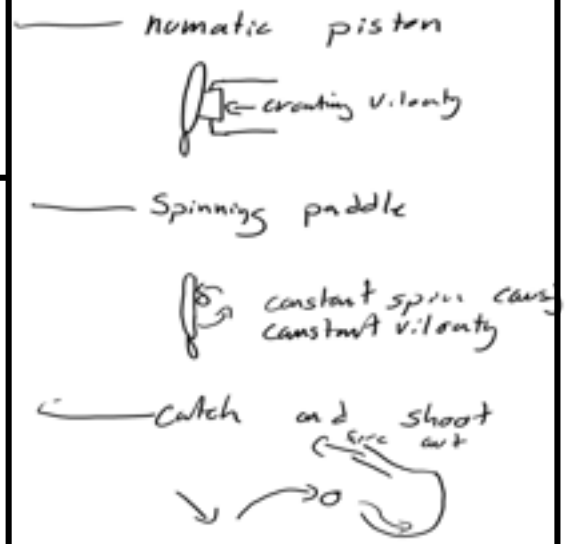


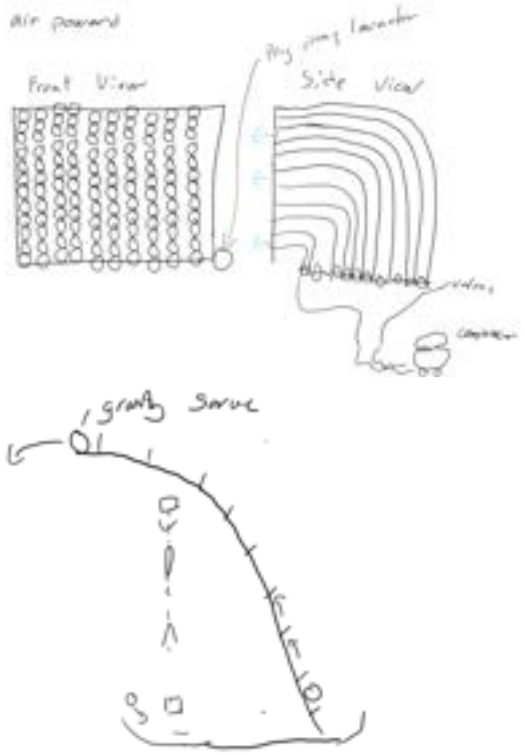
Conceptual image of racket motion planning for return shots - Omron Robotics

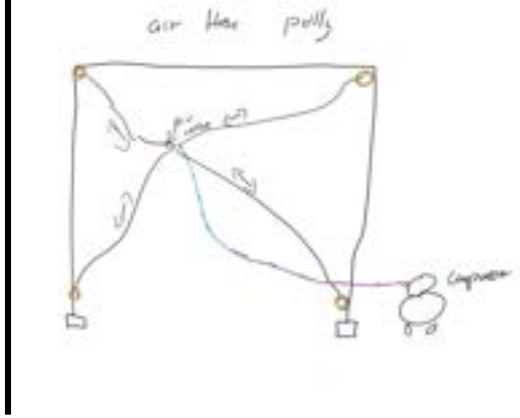
CONCEPT GENERATION

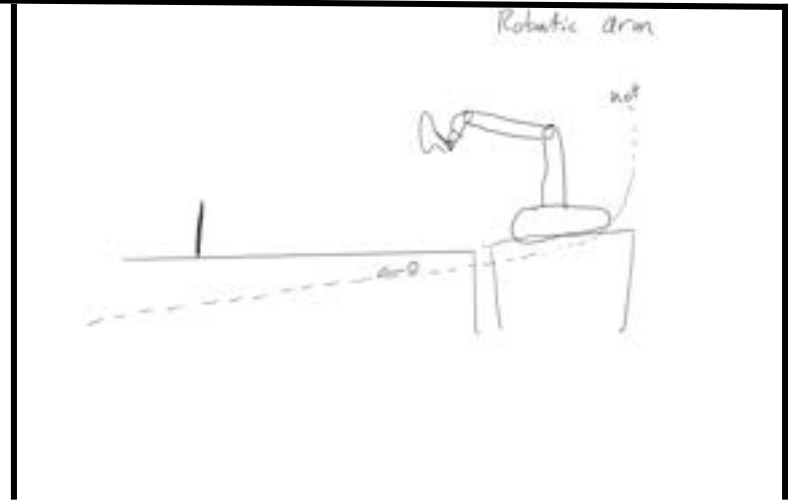


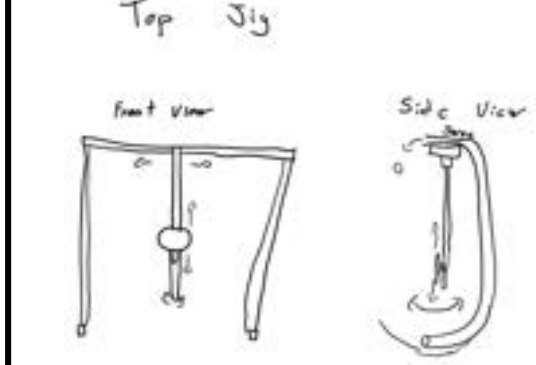












CONCEPT SCORING MATRIX

Criteria	Weights (%)	Gantry System	Robot Arm	4-Paddle Arm
Hit Velocity	10	3	5	4
Ease of Setup/Transportation	5	3	5	4
Cost/Part Quality	10	4	2	5
Range of Motion (Volume)	23	5	3	2
Paddle Velocity/Location	25	4	5	3
Accuracy of Return Ball in Play	17	4	5	2
Stability/Moments Created	10	4	3	5
Weighted Total		4.08	4.04	3.4
Complexity to Break Tie		3	1	-

VISUAL CONCEPT GENERATION

- Xbox 360 Kinect
- Single Camera
- Two Synchronized Cameras

Xbox 360 Kinect - Microsoft

ELP 3D Stereo Camera - ELP

DimaxCS High speed camera - Pco.

BALL DETECTION SELECTION MATRIX

Criteria	Weights (%)	1 Camera	2 Cameras, Synched Internally	2 Cameras, Synched Externally
Accuracy	30	3	5	4
Complexity	15	5	5	1
Cost	10	5	4	2
Portability	10	3	5	5
Durability	5	3	5	5
Weighted Total		2.6	3.4	2.15

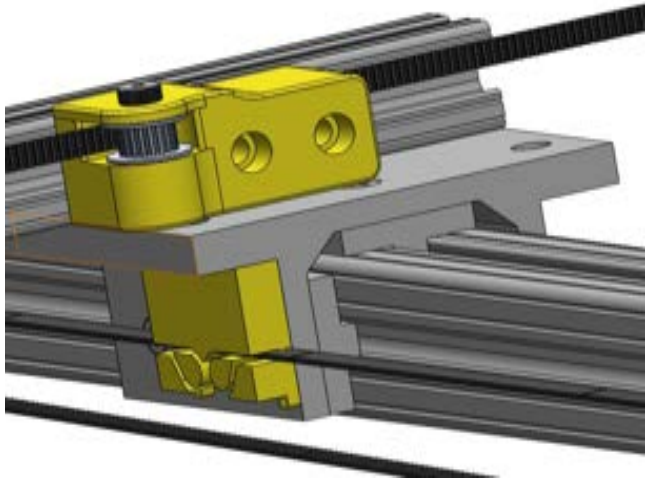
MODELING & PROTOTYPING

AutoCAD

- Ping-Pong Table Frame
- Motor Mounting and Hardware
- Design Belt Assembly for 3D printing

3D Printing - Testing/creating custom hardware

Ping-Pong Table Frame



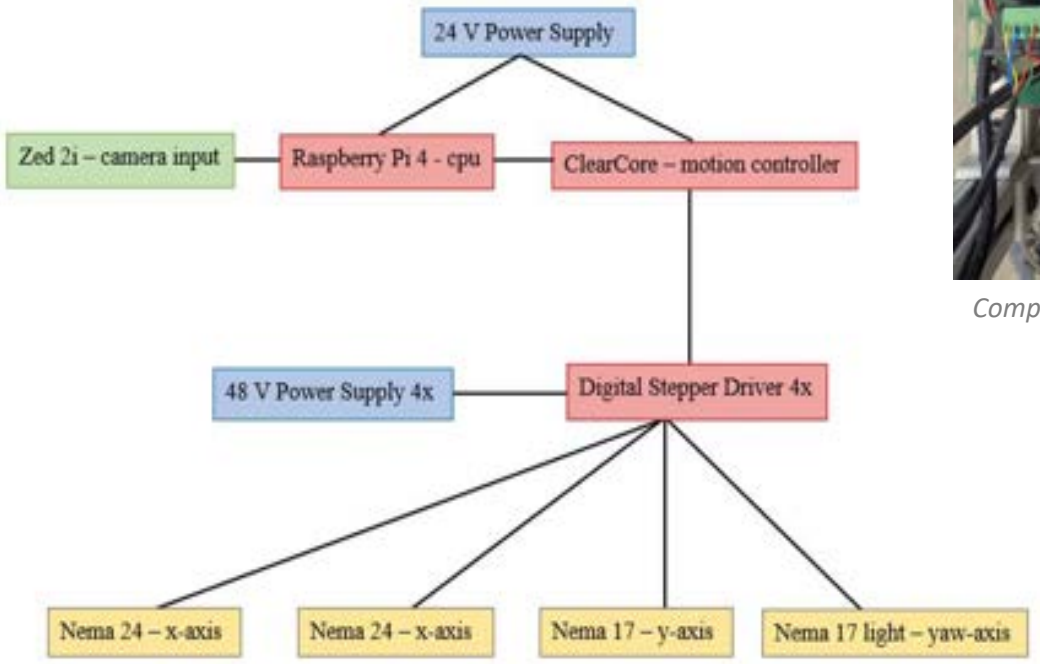
Belt Assembly Design

Belt Assembly 3D Printed

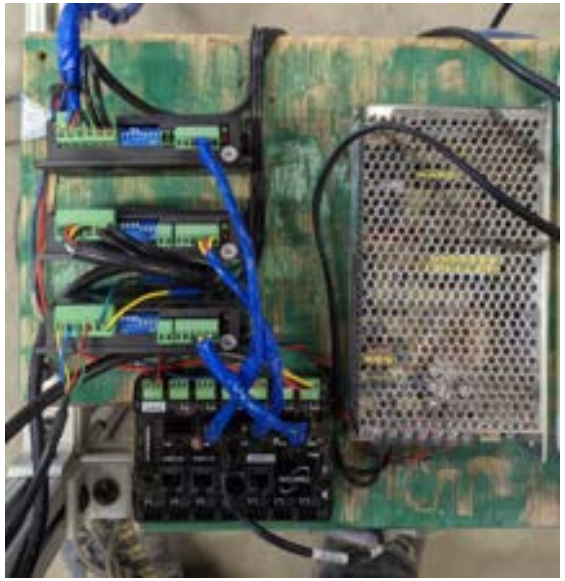
Motor Mounting

ELECTRICAL DESIGN

- Motion Controller
  - Teknic ClearCore
- Stepper Motors
  - NEMA 17 and NEMA 24
- Stepper Drivers
  - StepperOnline DM542T
- Power Supplies
- Camera Data Processing



Simplified Wiring diagram



Completed Electrical Component Board

SOFTWARE DESIGN

Motion Control

- Arduino IDE
  - ClearCore Wrapper

Arduino IDE and Teknic ClearCore Logos

Video Processing

- Python
  - OpenCV
  - PyZED
  - Serial

OpenCV and Python logos

FINAL DESIGN/PROTOTYPE

- Gantry System with 2 Degrees of Freedom
- ZED 2i STEREOVISION Camera
- Successfully returns serves
- Can achieve a volley of 3

ZED 2i stereovision camera by STEREOLABS

Final Prototype

FINAL DESIGN IN ACTION

Questions