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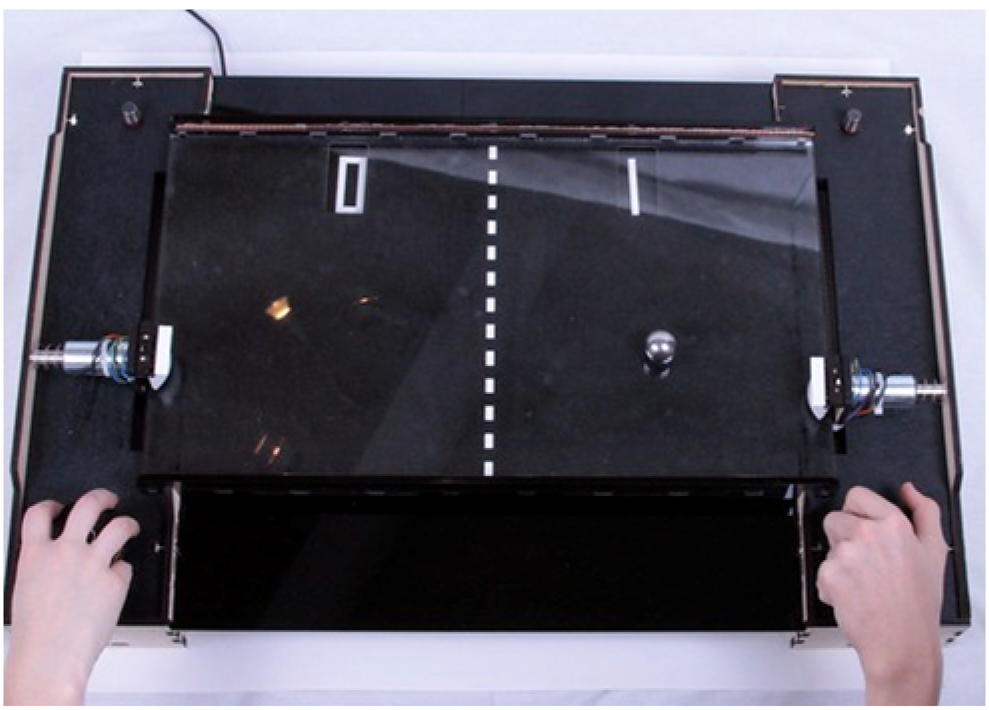
Team project proposal revision : Robopong

The core concept of our proposal is to design and construct a box that houses an electronic version of the classic Pong game. On the top of this box, the Pong game will be played, while the internal space will contain all the necessary electronics. The game involves a ball moving back and forth between two players. The primary goal is to 'hit' the ball with a paddle, preventing it from passing by. For each paddle, we can either choose to be controlled by a human part or managed automatically by a robot that tracks the ball in real time.

Detailed construction instructions for a manual version of the game can be found on the Evil Mad Scientist website at https://www.evilmadscientist.com/2010/a-playable-game-of-tabletop-pong/ . Additionally, a demonstration of the game in action is available in a video on YouTube, which can be viewed at https://www.youtube.com/watch?v=Z5mjx1iYt5g&t=67s. However, our project significantly diverges from this manual model since we plan to integrate automation into the game to control the robotic components and manage the score (details below). This addition will transform the traditional manual gameplay into an interactive and technologically advanced experience, blending classic entertainment with modern engineering.



Pong Game: A Realistic Representation of the Classic Game

Technical Overview :

Mechanical assembly: Box design, size, joints, camera mount

The play area will measure 35 cm x 50 cm and will rest on top of the game box with faces measuring 55 cm x 90 cm and a height of 10 cm. The faces of the box will be laser cut and connected via comb joints, allowing for easy removal to access internal electronics. The play area will have a slightly elevated center to prevent the ball from getting stuck in the middle during gameplay. There will be a camera mounted above the game board for computer vision purposes. On each player side, there will be a platform extending 10 cm from the game box that the slide potentiometers will be mounted upon. At the top of the game board we will have a small OLED screen that will display the score, handle the starting and ending of games, and allow users to switch between various game modes (levels of automation).

To keep a constant flow of gameplay, we will include two gutters on each “player” side *behind* each paddle. If the ball lands in the gutter, it will roll underneath the board, trigger a limit switch, and be brought back up by a tile that first lowers to pick it up. The tile will have a small divot in it to keep the ball from rolling out and present it directly in front of the paddle to be hit. The side that has been scored upon gets the small advantage of being able to “serve” the ball on the next round. As a preliminary goal, we will direct the ball to an opening at the front of the game board for a person to manually place and start the next round.

Computer vision: Software, color coordination, transforms, algorithm

The game features an option for robotic opponents To achieve this, we will employ a camera positioned atop the gaming surface taking in real time footage of gameplay. We plan to color our play area black while the ball, paddles, and calibration spots (one per corner of the play area) will each have their own unique colors. Using color detection, we will be able to detect the calibration spots, ball, and paddles. With the calibration spots, we will apply a transform to “flatten” the game board image and construct a representation of it. Our algorithm will then provide precise real-time coordinates and trajectory predictions for the ball, allowing us to make properly timed hits with the paddles. It's important to note that all computations for the computer vision algorithm will be executed locally, without reliance on internet sockets. This design choice ensures minimal latency, enhancing the gaming experience.

Motor System: Brushless motors, encoding, rails, mounts, belts

Once the trajectory is predicted, the robotic paddle is activated. Controlled with a belt system, the movement of the paddle will be driven by a brushless motor used in conjunction with the SimpleFOC library. The paddle itself will be attached to linear ball bearings that slide on 8 mm rails extending the length of each player side.

Paddle System: Connection to rail mount, size, shape, actuation vs no actuation

On the sides closest to each player, we will have a robotic paddle 3D printed into a wedge shape measuring 7 cm wide at the base. When the ball contacts the paddle, the wedge shape will ensure that the direction of the paddle's movement (parallel to the "player" side) will also partially propel the ball forward to the opposite player. The paddle will be 3D printed in two parts: a backing that remains attached to the linear ball bearings and a detachable wedge.

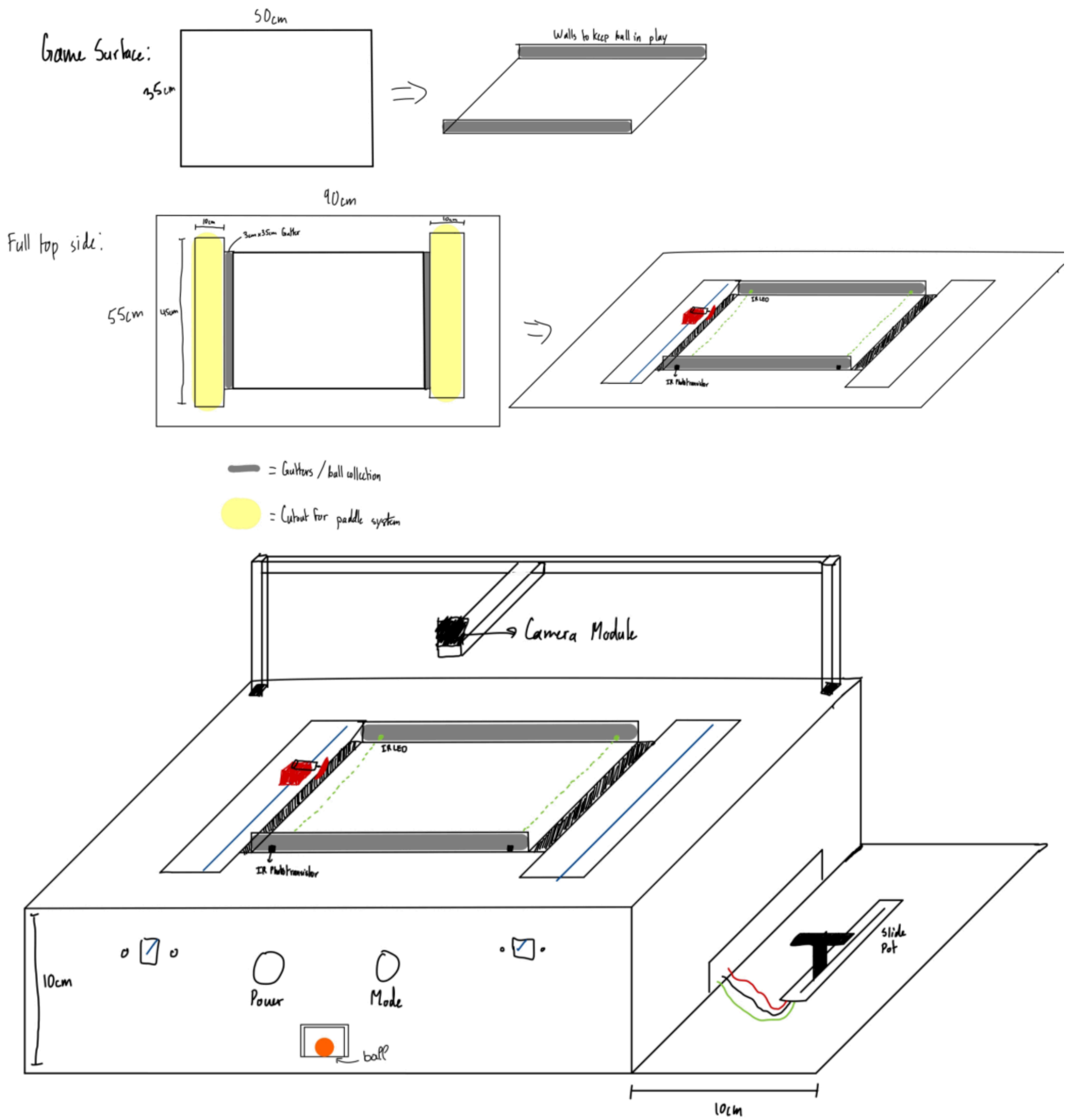
For detecting whether a goal has been scored, we have several options. Programmatically, we could use our computer vision algorithm to detect when the ball has passed a certain threshold or can no longer be detected (is in the gutter). Physically, we could also position a limit switch inside the gutter that is pressed when the ball enters, or use our photogate to infer that a goal has been scored (two gate crossings implies the ball has been hit back while one implies a goal).

Electronic components: Slide pots, microcontrollers, power system, cabled connections

We will also provide the option for manual play as well. Paddles on both sides of the board will be able to be controlled by slide potentiometers mounted outside the play area. The relative position of the slide potentiometer will be scaled to the length of a "player" side and used to determine where the motor should position the paddle on the actual game board.

Each slide potentiometer will be plugged into a corresponding Nucleo 64 board. Meanwhile, in the case of automated ball return, the two required stepper motors will be controlled via an Arduino Uno. The physical scoring detection system and screen output will also be controlled with the Arduino Uno. Our motors will be powered at 12V or 24V if we get permissions to allow a faster movement, while the two Nucleo 64 boards, Arduino Uno, and camera will be powered from a computer if we need data, otherwise we will use a step down converter to adjust the main power supply to the desired 5V voltage.

Mechanical Assembly:



User stories:

From the general public’s perspective, RoboPong is simply a fun end product to see and interact with. There is a certain charm of translating an iconic computer game into a real-world, physical game one can interact with.

From our group's perspective, one major reason we all chose to work on RoboPong was because we also felt the end result would be a fun and interesting product to play with. This project also comes with many interesting engineering problems to solve, which we thought would be challenging and fulfilling for this class.

From the perspective of the professor, a large portion of making our project function is low-latency computer vision for ball detection and position prediction for automated play. This part of our project is applicable to future projects that require computer vision for similarly fast-paced or responsive purposes.

From an IC public relations perspective, this project would make a good demo. It is instantly recognizable and associated with childhood fun and nostalgia. As mentioned earlier, there is an element of uniqueness in making a physical version of a virtual game. The demo would also be able to involve audience members, allowing them to actually play physical Pong and experience the project. In addition, the project is suitably complex both in build and software, providing a good demo of the possibilities of the IC department.

Future Opportunities ?

Looking ahead, our project presents promising prospects for future endeavors. It could lay the groundwork for a startup venture, focusing on developing robotic opponents for traditional manual games. This innovative approach would inject a contemporary edge into classic entertainment, appealing to a wide audience.

Furthermore, there's potential to commercialize our unique version of the Pong game. By offering a fully built Pong game with integrated automation features, we could cater to gaming enthusiasts and tech-savvy consumers seeking a distinctive gaming experience. This opens doors to acquiring users beyond EPFL, potentially reaching a broader market and establishing our product as a staple in modern gaming.

Risk Assessment :

Considering there are many moving parts and sensors within this build, there are a few apparent risks to be assessed. First would be with the robotic paddle actuation system. The primary areas of concern are the interaction point between the solenoid and the paddle, the stability of the solenoid-paddle system, and the time between hits. The best way to mitigate these risks is to conduct tests on various paddle prototypes prior to assembling the final system. Different paddle sizes and shapes can be 3D printed, and there can be various connective system prototypes that can be tried and tested: a hinge system, a physical connection to the solenoid, or a stationary solenoid that moves a mechanical system.

Continuing with the paddle system and its related components, the laser gate system that triggers solenoid actuation will need to be tuned. It's possible there will be some delay, so triggering actuation may not be on time. Additionally, the system must be fault tolerant, such that actuation does not occur at inopportune times. The railing systems must be tested at various speeds and the limit switches must be placed properly to avoid system damage. Some steps to complete this are to test the solenoid pusher under various operating conditions to assess reliability and consistency. Next we can implement fail-safe mechanisms to detect and address malfunctions or misfires promptly. Finally, we'll incorporate robust mechanical design principles to ensure durability and longevity of the solenoid mechanism.

The real-time computer vision system is a large risk area for us. Developing a streamlined computer vision algorithm capable of accurately tracking the ball in real-time may prove challenging, particularly considering variations in lighting conditions and ball movement speeds. To start, we can allocate sufficient time for algorithm development and testing, considering potential complexities. When testing the camera system separate from the actuators and game field, we can implement error handling mechanisms and discover any potential environmental factors. We may consider integrating machine learning techniques to enhance the algorithm's adaptability and performance.

Our system plan relies on two identical subsystems working in parallel. Controlling two systems in parallel may present some significant challenges, both when it comes to power delivery and communication. There are a variety of communication methods across the planned system, so we'll test each individually (serial, usb-usb, camera-computer, etc), then slowly integrate each component one at a time. The subsystems can be mapped online so the communication pathways can be optimized.

Ensuring seamless integration of manual and automated gameplay modes, as well as implementing features such as ball retrieval and scoring mechanisms, may pose challenges in terms of system complexity and user interaction.

We can conduct user testing and feedback sessions to iteratively refine gameplay mechanics and user interface design. Another solution is to prioritize simplicity and intuitiveness in system operation, providing clear instructions and visual cues to guide players. We'll continuously monitor user feedback and iterate on system features to enhance overall gameplay experience.

The Bill of Materials :

Name	Shop	Qte	Price (CHF)	Total price (CHF)
8mm rails	CS-358	2	x	x
Linear ball bearings	CS-358	2	0	0
17HS4401	CS-358	2	15	30
L298N (driver)	CS-358	2	5	10
Encoder	CS-358	2	x	x
28BYJ-48 + ULN2003	CS-358	2	2	4
Belt	CS-358	2*1m	x	x
Nucleo 64	CS-358	2	x	x
Arduino Uno	CS-358	1	5	5
Webcam logitech C270	https://www.conrad.ch/fr/p/webcam-hd-1280-x-720-pixel-logitech-c270-pied-de-support-support-a-pince-1426807.html	1	15,95	15,95
Slide potentiometer	https://www.reichelt.com/ch/fr/potentiom-tre-glissi-re-alps-de-grande-qualit-lin-aire-st-r-rsa0n12-lin10k-p73873.html	2	5.11	10.22
Power Supply	https://www.reichelt.com/ch/fr/bloc-d-alimentation-de-table-78-w-12-v-6-5-a-vt-3240-p215629.html	1	19,02	19,02
Power supply plug	https://www.distrelec.ch/fr/jack-de-puissance-prise-femelle-angle-droit-x6-3mm-cliff-fc681465/p/14205870	1	2.27	2.27
Step down converter	https://www.reichelt.com/ch/fr/cartes-de-d-veloppement-r-gulateur-de-tension-20-w-convertiss-debo-dcdc-20w-p233018.html	1	4,70	4,70

Limit switch	https://www.distrelec.ch/fr/microrupteur-csm405-5a-1co-25n-levier-rouleaux-simule-camdenboss-csm40540f/p/13570363	8	0.768	6.15
Set of balls	https://www.galaxus.ch/fr/s5/product/noname-jeu-de-billes-8-pcs-en-filet-ass-circuit-de-billes-14615761	1	4.90	4,9
	https://www.galaxus.ch/fr/s15/product/karlie-balles-de-caoutchouc-mousse-balles-jouets-pour-chien-12543724	1	3.05	3.05
	https://www.galaxus.ch/fr/s15/product/karlie-balle-en-caoutchouc-plein-balles-jouets-pour-chat-12543498	1	2.90	2,90
				119,20

The price below are from the 31.03.2024

Initial Design: ~1.03m^2 of 5mm MDF = 9,27chf
8mm bar