**NAME OF THE PROJECT**

Chesscake

**GROUP MEMBERS**

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**MOTIVATION**

Our aim as a group was to build up a project that could showcase the diverse and interconnected nature of Mechatronics in one compact package, simple enough to be intuitive but complex enough to be capable, after doing some research and a lot of thinking and discussions, we’ve decided that building a Chess Playing Robot would fit the criteria of what we were looking for, since it combined a lot of knowledge fields of engineering within itself, which would make it a great project to gain experience from.

Those fields being;

* Robotics with the robot’s internal component design and their mechanical and dynamic considerations,
* Electronic board design to make connections for these components to make them interact with each other.
* Implementations of control systems with embedded hardware and programming of moving parts,
* Machine Learning with the implementation of a chess engine, which would enable our system to make decisions based on player’s inputs,
* Computer Vision, with the detection of chess pieces and their locations on the chess board.

Alongside of its potential of becoming a commercial product directed towards educational institutions, various chess organizations and the general public, the project’s combination of various engineering subjects in a relatively small form factor makes it suitable for being used as an educational tool in universities and colleges for students to better comprehend intricacies of subcomponents like Sensors and Actuators, Hardware-Software interfacing, Embedded systems and Mechanical Design, just to name a few.

Finally, this project is quite generous with allowing interested students to make improvements to its design later on. Trying different form factors for the robot, experimentations with different types of microcontrollers, sensors and motors for performance improvements, and optimizations done to the program code are only some of many additions they can make to the project in the future.

**USER REQUIREMENTS**

End User:

1. The robot should accurately detect the boundaries, orientation, and position of the chessboard.
2. The robot should correctly recognize the letters and numbers on the board (mapping the board with letters and numbers).
3. The robot should accurately detect the checkered pattern on the board and map it using the recognized numbers and letters.
4. To verify the accuracy of specific moves, the robot should correctly distinguish and classify the colors of the squares that form the checkered pattern on the board.
5. It should identify the types of chess pieces and assign the appropriate moves to each piece type.
6. To ensure accurate moves and track move accuracy, the robot should differentiate the colors of the chess pieces and correctly classify them according to their colors.
7. For a seamless and smooth game experience, the robot should know the movement patterns of each piece and use them correctly.
8. The robot should be able to hold and place chess pieces independently to provide a good partnership to the user.
9. The device setup and preparation for the game should be simple and easy, allowing users to start the game quickly without dealing with technical details or complex steps.
10. It should be supportive and instructive for beginners, identifying incorrect moves, giving warnings, and suggesting possible moves.
11. The robot should be portable, enabling users to use it in different locations and take it with them on travels if necessary.
12. It should be storable, allowing users to place it in a box or cabinet when not in use to save space.
13. The robot should be easy to maintain, enabling users to quickly perform checks without needing technical expertise.
14. It should be budget-friendly, making it accessible to people from all walks of life as a hobby tool.
15. The robot should be durable against impacts and falls that may occur during daily use, providing a sense of security to the user.
16. It should be suitable for children, with an interface and control system that does not include complex structures they cannot understand.
17. The robot should offer a safe experience. It should not contain sharp edges or pointed parts that could cause injuries, and it should be designed to avoid damage to the user or surrounding objects in case of potential collisions. Proper electrical insulation should be ensured, avoiding issues like overheating and noisy operation.

Shipping and Storage Companies:

1. The product should be lightweight, making it easy for shipping and warehouse personnel to carry.
2. It should have a compact design, reducing costs in shipping and storage processes.
3. The robot should be impact-resistant, able to withstand minor collisions during transportation.
4. The packaging should facilitate easy storage and transport.

Sellers/Distributors:

1. The product should be marketable and competitive with similar products.
2. It should have a design and presentation that captures customers' interest.
3. It should offer different features that convince the customer.
4. The product should be reasonably priced and seen as an affordable option for customers.

Environmental Concerns:

1. The device should be made from recyclable or biodegradable materials.
2. It should not contain toxic substances or inhibitors that could harm ecosystems.
3. Rechargeable batteries or direct power connections should be preferred to avoid waste battery generation.
4. The product's packaging and protective equipment should be made from recyclable or biodegradable materials.
5. The product should not consume unnecessary power.
6. The device's parts should be repairable and replaceable, preventing the entire device from becoming waste due to minor regional damages.

**OBJECTIVES**

Chess Playing:

* The robot should accurately detect the boundaries, orientation, and position of the chessboard and distinguish it from surrounding objects and the surface it is on.
* It should correctly recognize the letters and numbers on the board.
* The robot should accurately detect the checkered pattern on the board and map it using the recognized numbers and letters.
* To verify the accuracy of specific moves, the robot should correctly distinguish and classify the colors of the squares that form the checkered pattern on the board.
* It should identify the types of chess pieces, classify them, and assign the appropriate moves to each piece type.
* To ensure accurate moves and track move accuracy, the robot should differentiate the colors of the chess pieces and correctly classify them according to their colors.
* For a seamless and smooth game experience, the robot should know the movement patterns of each piece and use them correctly.
* The robot should be able to hold the chess pieces independently without damaging them and place them in the appropriate positions.
* It should be supportive and instructive for beginners, identifying incorrect moves, giving warnings, and suggesting possible moves.
* The robot should grasp the pieces without damaging them and place them correctly on the target position or off the board.
* It should detect when a user makes an incorrect move and warn them.
* The robot should have the ability to develop strategies to compete with the user and offer a satisfying experience.
* It should not move too slowly.
* The robot should quickly decide on and execute its moves without making the user wait too long.
* It should keep track of the move order.
* The robot should inform the user after each move.

Ease of Use and Maintenance:

* The robot should be easy to maintain.
* The setup and preparation for the game should be simple and easy, enabling users to start playing quickly without dealing with technical details or complex steps.
* It should have easy setup procedures.
* The robot should be easy to start.
* Broken or faulty components of the device should be easily replaceable, or such services should be provided.

Portability and Storability:

* The robot should have a compact design.
* It should easily fit into its box or a similar space after use.
* The device should be easily portable by a single individual and placeable in a specified position.
* It should be easy for shipping companies to transport.
* The robot should be easy to stack and store in shops or warehouses.
* The device should be sufficiently durable to withstand impacts that may occur during transport, avoiding quick damage and breakage.

Marketability:

* The robot should have a modern and attention-grabbing design/appearance.
* It should be competitively priced.
* The device should offer unique features that make it stand out and introduce new elements.

Safe Operation:

* The device should be electrically insulated and safe.
* It should not contain sharp or pointed parts that could cause injuries.
* Its movement speed should not cause pain upon impact.
* The robot should not collide with or damage surrounding objects.
* It should be easily deactivated with a single button in case of an emergency.
* The robot should not have surfaces that can harm the skin upon contact.

Eco-Friendly Design:

* It should be made of recyclable materials.
* The device should not engage in unnecessary power consumption.
* It should not contain toxic substances or paints.
* The device should be repairable, preventing it from becoming waste due to minor malfunctions.
* It should not cause waste battery generation.

**LITERATURE AND MARKET RESEARCH**

Chess-playing robots can be used as an educational tool to help users improve their gaming skills but also enhance human-robot interaction.

In 1980 the first chess robot available for purchase was created. Named Boris Handroid. At the same time another robotic chess game was developed by Milton Bradley. There is also a chess computer called Deep Blue; a chess-playing expert system was developed. It defeated world champion Garry Kasparov in 1997 and this victory is considered a milestone in the development of artificial intelligence.

**Similar Products in the Current Market**

* **Sense Time the Sense Robot**

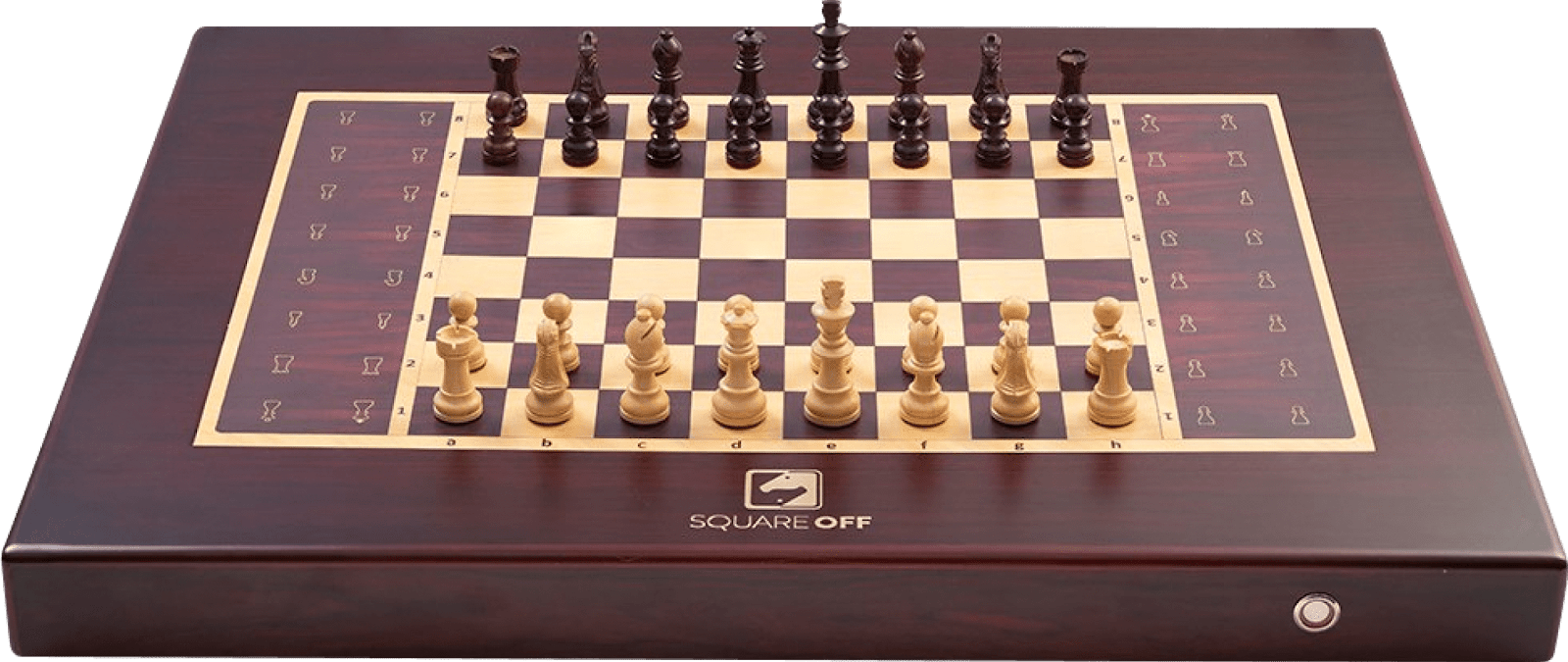
This product is designed for young learners of chess. With its extensive library of expert AI exercises, human-to-machine and online human-to-human gameplay features, and variety of tactile, visual, and auditory interactions, the Sense Robot provides a captivating and immersive gaming experience. With its wealth of features, this product is the perfect intelligent one-on-one partner for kids, helping them to grow as critical thinkers.

A robot playing chess

Description automatically generated

* **Square Off**

This is a smart chessboard that works with AI. The pieces can move by themselves. It also has a game analysis system and also can adjust the level of the game to build better strategies for the user.



* **Chess mate Project**

This is a project made by METU ROMER. They used a Franka Emika robot arm and builded up the computer vision for game tracking. Their project is capable of accurately identifying chess pieces and calculating the optimal move based on the opponent's move using the Stockfish engine.

masa, oyuncak, satranç, iç mekan içeren bir resim

Açıklama otomatik olarak oluşturuldu

**FUNCTIONAL ANALYSIS**

**Design of Chess Robot:**

General Design and Main I/O Schematic:

Power

Chess Robot

Chess Moves

Visual Data

Audio Feedback

Figure: Level-0 Design of Chess Robot

**Subsystems Of Chess Robot:**

Chess Robot

Software

Power ?V

Power Unit

Movement

Mechanical Structure

Electronics

Kinetical Energy

Feedback Signal

Visual Data

Feedback Signal

Control Unit

Figure: Level-1 Design of Chess Robot

* 1. **Mechanical Design:**

Applied Torque

Arm Movements

Mechanical Structure

Reaction Forces

Figure: Level-0 Design of Mechanical Structure

|  |  |
| --- | --- |
| **Input** | * Applied torque * Reaction Forces |
| **Output** | * Movements of the robotic arm |
| **Functionality** | * Grabbing and re-locating chess pieces * Supporting and protecting other components and subsystems |

**Subsystems:**

Mechanical System

Motion Transmission

Cable Management

Gripper/End Effector

Arm Linkages and Joints

Base and Structural Framework

Force/Torque

Motion

* 1. **Electrical design**

**Power source**

Regulated DC Voltage

Standart 220 – 230 V Houselhold Power

Power Supply

|  |  |
| --- | --- |
| **Input** | 220V-230V from a wall socket |
| **Output** | 12V DC to 24V DC voltage |
| **Functionality** | Convert AC wall outlet voltage to safe, useable DC output voltages  with enough current to drive all circuit subsystems. |

**Capacitors and Resistors**

Voltage Drop

Supplied Power

Resistors

|  |  |
| --- | --- |
| **Input** | The voltage across the resistor |
| **Output** | the voltage drop and the limited current |
| **Functionality** | * Used to control the flow of electrical current in circuit * They help regulate how much current flows to certain components, ensuring that they operate within safe limits. |

Power storage and release

Supplied Power

Capacitors

|  |  |
| --- | --- |
| **Input** | Voltage applied across their terminals (charges the capacitor) |
| **Output** | Energy released (discharges the capacitor) to stabilize voltage or supply power |
| **Functionality** | * Providing a steady output voltage * Filter out noise or fluctuations in power supply * Store energy and can supply power when needed (e.g., when motors demand a burst of current) |

* 1. **Electronic Design**

**Microcontroller**

PWM Signals

Power

Microcontroller

Vision Signals

Camera Visions

|  |  |
| --- | --- |
| **Input** | * 5V 3A Power * Camera Visions |
| **Output** | * Motor’s Movement Signals (PWM Signals) * Vision Signals |
| **Functionality** | It provides minimum 5V 3A power and enables the movement of the motors to which it is connected and the processing of the images by monitoring the camera images it obtains. |

**Motors**

6-12 V Power

Motors

Movement Signals

PWM Signals

|  |  |
| --- | --- |
| **Input** | * 6-12V Power * PWM Signals |
| **Output** | * Movement Signals |
| **Functionality** | It provides motor movement by processing the PWM signals received from the microcontroller. |

* 1. **Software Design**

**Computer Vision**

Image Data

Camera

Computer Vision

Imported Librarires

Processed Visual Data and Coordinate Systems

2D Matrix

Computer Vision Framework

|  |  |
| --- | --- |
| **Input** | * High Definition Image Data * Libraries imported from the Computer Vision Framework to be used |
| **Output** | * Processed Visual Data in the form of a 2D-Matrix |
| **Functionality** | The image data received from the camera module gets turned into a 2D matrix via the execution of the program code, which requires the necessary Computer Vision libraries to be imported in order to work. This 2D matrix is then processed to acquire quintessential info such as current chess piece locations within a constructed coordinate system. |

**Machine Learning**

Chess Strategy and Moves

Computer Viion Data

Chess Engine & ML

Warning Output

Machine Learning Framework(s)

|  |  |
| --- | --- |
| **Input** | * Chess Piece Locations Received From Computer Vision Data * Relevant ML Libraries |
| **Output** | * The Adjusted Bias Values for the Chess Piece Locations * A Warning Output In Case of an Illegal Move |
| **Functionality** | The ML algorithm powered by the relevant framework(s) gets the processed Computer Vision data that signals the chess pieces’ locations on the board. Using this data, it calculates the present bias increases and decreases for the available moves it can make and picks the best move it can make. If an illegal move is detected, it sends out an appropriate warning output. |

**Control Algorithm**

Arm Trajectory

Coordinates data

Control Algorithm

Position Data

Motor Moveents

|  |  |
| --- | --- |
| **Input** | * The Location of the Chess Piece to be Moved on the Chessboard * The Position of the Robot Arm Relative to the Chess Piece |
| **Output** | * The Path Robot Arm Needs to Take * Motor Movements |
| **Functionality** | After the new chess piece locations are determined, the Control Algorithm receives the location data of the piece to be moved in a coordinate system format, relative to its own position. Then, it activates its internal motors in a required order for the arm to grab the piece and relocate it. After the robot makes its move, it returns back to its original position. |