Materials, Sensors, Actuators Fabrication in Robotics

[ME5410]

CHESS PLAYING ROBOT WITH SAFETY FEATURES

by

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1 Introduction

Nowadays, robots are widely used in many fields, including manufacturing, healthcare, logistics, agriculture, and service industries. Robots can provide humans with automated solutions for highly repetitive, dangerous tasks requiring high precision and speed, thereby increasing efficiency, reducing errors and risks, and improving productivity and quality. The combination of robotics and artificial intelligence has a broad scope of imagination, and one of their use scenarios is a chess robot, which generally uses mechanical claws to capture chess pieces and can play chess with multiple people at the same time. In this way, people can rely on it to teach themselves chess or use it to improve the efficiency of chess player training.

While robots benefit humans in many ways, they are not perfect. As in the case of the robot injury at the Moscow Open chess tournament, robots are not always as safe and reliable as we might expect. A seven-year-old boy was playing with a chess robot called AlphaZero when the machine reached out, grabbed one of the boy's pieces, and discarded them from the board. Before the robot's arm retracted, the boy attempted another move, pushing one of his rooks into the same position as the removed piece. At this point, the robot's mechanical claw descended toward the board and grabbed the boy's finger, not the work, eventually causing his finger to fracture. The director said it had played three matches that day and had also

Figure 1: The scene of the incident

performed in many open tournaments, and that nothing as it had ever happened. Although human error or a poor understanding of how the robot works is often the cause of accidents, it was enough to set off alarm bells. We should design a safer chess robot to avoid similar accidents.

2 Mini-review

In the context of combining chess playing with robotics, many researchers have proposed the use of robotic arms as actuators. For instance, Musa Atas[2] has developed a 5-degree-of-freedom chess robotic arm system, as shown in Figure 2. It mainly consists of a central controller, a robotic arm, a game engine, and a machine learning-based image processing module. The image processing unit captures the good moves made by people and sends them to the game engine to generate reasonable outputs. Han-Pang Huang[7] designed an innovative humanoid robot arm with 12 degrees of freedom and 19 joints, as shown in Figure 3. This robot arm interacts with human chess players by articulating a 6-degree-of-freedom industrial robot arm and a five-finger robot hand.

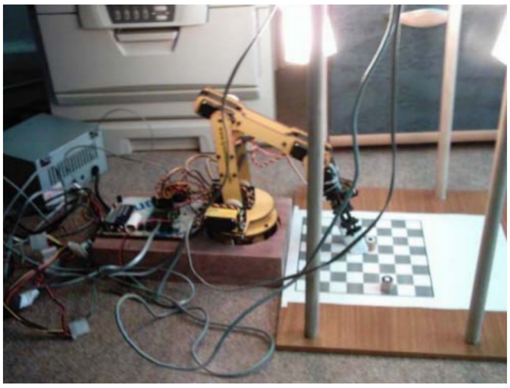

Figure 2: 5-DOF chess-playing robot

However, utilizing a robotic arm as a chess-playing robot also has its drawbacks.

2.1 Safety issues

For example, The DLR-LWR III arm[6], Schunk Lightweight Arm, and Robonaut[1] all use motors mounted directly on each joint, using harmonic drive gearheads to achieve fast motion with zero backlashes. These robotic arms have payloads ranging from 3 to 14 kg and work with large inertia, which will have severe consequences once they hit the human body. In addition, the gripper at the end of the robot arm may mistakenly grasp the human body, as we mentioned earlier.

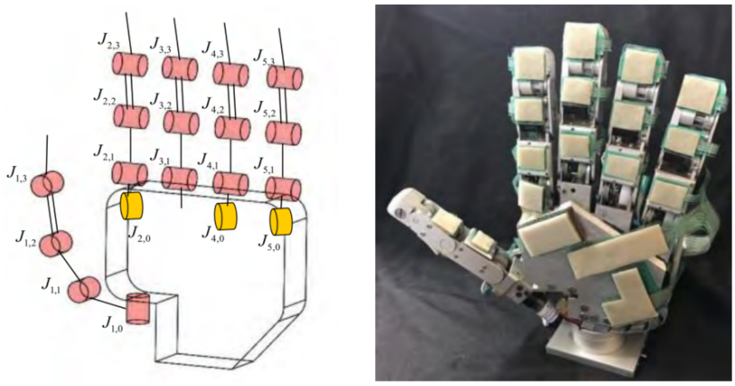

Figure 3: Five fingers robot hand and its kinematic structure

2.2 High cost

Many robotic arms are costly due to high precision actuators, and custom machining of components. In addition to the industrial robotic arms discussed earlier, some robotic arms for education or research[9] are relatively low cost. The arm on the Dynamaid robot[14] consists of a lightweight and compact Robotis Dynamixel robotic servo system. This robot has a human-scale workspace, but a lower payload (1 kg) than the previously discussed robotic arms, and its total cost is at least $3500, and that is only for the servo system. The KUKA youBot[3] is a 5-degree-of-freedom arm for robotics research . It has a relatively small working range of about 0.5 cubic meters and a payload of 0.5 kg. It has a customized compact motor and gearbox and was sold for 14,000 euros a decade ago. Although the price of such robotic arms for research has been much lower than industrial robotic arms, it is still costly to implement a chess-playing robot.

2.3 Extra workload for a matching vision recognition module

The use of robotic arms to manipulate the movement of chess pieces is closely tied to the visual recognition module, which brings about a new set of challenges. These include camera configuration and calibration [8], the use of deep learning neural networks for chess detection and tracking [15], the need for appropriate datasets to train the model, and so on. All of this implies an increase in workload and a decrease in portability when deploying the chess-playing robot.

2.4 Our solution

Despite the existence of a well-established pHRI standard [5] and the design concept of compliant control [4] being widely followed in the development of robotic arms, there is still no 100 percent guarantee that these arms will not pose a risk of harm to humans during operation. There have been cases where robotic arms have caused injury to people. Instead of taking the risk of using expensive robotic arms as chess-playing robots, it is advisable to consider alternative solutions that can prevent robots from harming people.

In order to solve the three drawbacks talked about above, our group proposes a chess-playing robot solution that is safe, simple, reliable, and cost-effective. We have opted for a combination of a Cartesian coordinate robot and electromagnet, rather than an expensive robot arm, to manipulate and move the chess pieces. Additionally, we have incorporated Hall-Effect sensors beneath the center of each square on the chessboard as binary switches for position sensing and proximity detection, thus eliminating the need for a visual recognition module. The robot uses a chess engine to follow the rules, evaluate the board, and choose its next move using an algorithm. This notion corresponds with the most recent developments in constructing mechanical games that are automated and presenting atypical interfaces for human-computer interaction.

Our system sends all piece movement instructions from the microcontroller to the Cartesian coordinate robot in real-time. With the chess engine integrated directly into the microcontroller, computation time is minimized, making gameplay more efficient.

3 Components

This section describes the key components of the proposed chess-playing robot. The system includes an embedded microcontroller for detecting chess pieces, chess pieces with built-in neodymium magnets, an acrylic board with a printed black and white chessboard image, and a Cartesian coordinate robot. The chess piece detection system is connected to a PC using a USB cable.

3.1 Microcontroller System for Chess Position Detection

The detection system for chess pieces is composed of an Arduino Nano platform, a series of 64 Hall-effect sensors, and a power supply. The fundamental principle of Hall effect sensors is illustrated in Figure 4 [11]. These sensors utilize a slender rectangular piece of p-type semiconductor material, such as gallium arsenide (GaAs), indium antimonide (InSb), or indium arsenide (InAs) [10], that conducts a constant current through it. When the magnetic field generated by the chess piece is detected by the Hall sensor, it switches 'ON' and sends a signal to the microcontroller, indicating the presence of the piece in that location. With the help of Hall-effect sensors, the system can accurately identify the state of the chessboard and the location of each chess piece throughout the game.

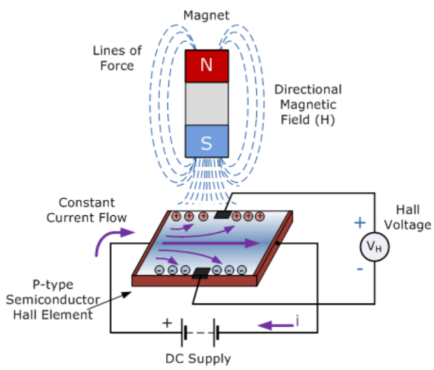

Figure 4: Hall effect sensor principles

3.2 Chess pieces and chess board

In this setting, the chess game involves a human opponent and a Chess engine, both utilizing this system. To enable magnetization, neodymium magnets are integrated into the bottom of each chess piece. Neodymium magnets, also known as NdFeB magnets[12], are a type of permanent magnet with a magnetic field that is second only to absolute zero degree holmium magnets. The neodymium magnets in the chess pieces are manufactured through a powder metallurgy process, which allow for their movement to be facilitated by another neodymium magnet controlled by devices located beneath the chessboard.

Figure 5 shows the dimensions of the chessboard used in our system. The size of each square segment is restricted by the magnetic field of each pieces. In our prototype, we include extra space surrounding the 48cm x 48cm board for storing captured chess pieces. Also, we assume this design feature ensures that the magnet only activates the sensor underneath the square of a certain chess piece occupies, and not any nearby Hall-effect switches. Additionally, all magnets are oriented with their North poles facing upwards to ensure consistent and reliable detection.

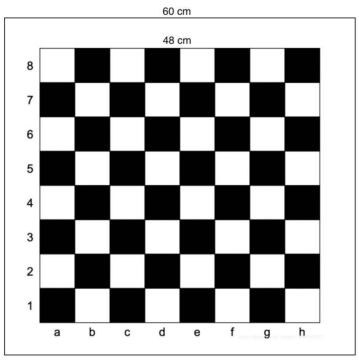

Figure 5: Chess board

3.3 Cartesian robot

Figure 6 provides a 3D model of the Cartesian coordinate robot for reference. Two linear bearings are utilized in this implementation to achieve distinct degrees of motion, which helps avoid unnecessary friction between the Cartesian coordinate systems. Additionally, two controllers are employed to allow the stepper motors to move in X and Y directions. A servo motor mounted with a neodymium magnet is above the X-axis[13], which is used to magnetize and demagnetize the chess piece, thereby controlling its movement on the chessboard. Furthermore, to ensure that the robot stays within its intended range, two limit switches are mounted on the board at both ends of each axis.

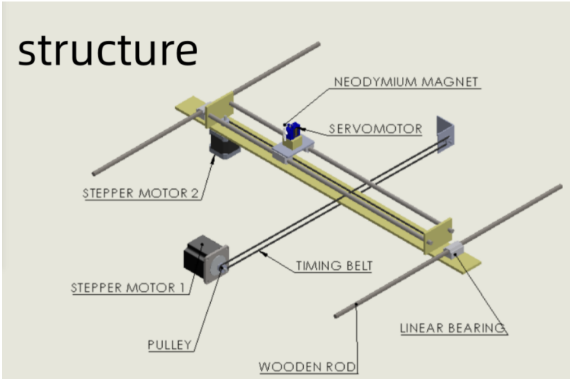

Figure 6: Cartesian robot

4 Conclusion

This paper gives an overview of the design and implementation of an autonomous digital chess board. The proposed approach combines low-cost elements with an array of Hall-effect sensors controlled by a microcontroller. The proposed method has the disadvantage of only detecting the presence of the pieces, without identifying their type or color. As a result, it is necessary to ensure that each piece is placed in the correct position before the game begins. However, this limitation is mitigated by the fact that the system is designed for use with a chess engine, which is capable of determining the correct moves based on the position of the pieces on the board. Furthermore, the use of neodymium magnets integrated into the chess pieces allows for the easy and secure movement of the pieces, while also minimizing the risk of people being accidentally hurt by the robot during play.

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