Intelligent Machine Inspirational Project

Autonomous Chess Playing Machine

Group 10

215565L	Weerasinghe RT
215538H	Naranpanawa HMSDK
215527A	Harishchandra HBR
215559X	Shamil MRM

Department of Computational Mathematics
BSc Hons in Artificial Intelligence
Batch 21

University of Moratuwa

2023

Declaration

We declare that this project report is our original work and has not been submitted in any way to a university or other tertiary educational institution for the purpose of earning another degree or diploma. A list of references is provided, and information taken from other people's published or unpublished work has been recognized in the text.

Weerasinghe RT	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _
Naranpanawa HMSDK	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _
Harishchandra HBR	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _
Shamil MRM	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Date: _ _ _ _ _ _ _

Supervised by

Ms. Shashika Kumarasinghe	_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Date: _ _ _ _ _ _ _

Acknowledgments

We would like to express our sincere gratitude to all those who contributed to the successful completion of our group project.

First and foremost, we would like to thank our supervisor Ms. Shashika Kumarasinghe for their invaluable guidance, constructive feedback, and unwavering support throughout the project. Their expertise, patience, and encouragement have been instrumental in shaping our ideas and driving us towards success. We would also like to extend our gratitude to the Department of Computational Mathematics for providing us with the necessary resources and facilities to conduct our project and complete the project. We are particularly grateful to Dr. Thushari Silva and Prof. Asoka Karunananda for their constant support and for believing in our project. And also, we would also like to thank the administrative staff for their support and assistance.

We would like to thank our colleagues and friends who have provided us with their valuable feedback, constructive criticism, and encouragement. Their insights, ideas, and suggestions have helped us to refine our work and achieve our goals. We would like to thank our parents and family members for their unconditional love, support, and encouragement. Their unwavering support and belief in us were crucial in our journey towards success.

Finally, we would like to extend our heartfelt gratitude to our instructors and external mentors, who provided us with their expertise, knowledge, and guidance. Their input and feedback were invaluable in shaping the direction and scope of our project.

Once again, we express our heartfelt thanks to everyone who contributed to the success of our project. We are indebted to you and will always remember your support and encouragement.

Abstract

Chess has been a game played by humans for a long period of time. It always requires two players to play a game and it is an intellectually challenging activity.

As the field of AI gained momentum in the latter part of the 20th century, programs such as Deep Blue were introduced. Deep Blue is a computer program designed to play chess, and it achieved a remarkable feat by defeating a chess grandmaster in a complete match. However, it is important to note that Deep Blue is solely a computer program. When playing against Deep Blue, the opposing player had to engage with it as a computer game, or if playing on a physical chessboard, another human was needed to physically move the chess pieces based on the AI program's suggestions and input the moves made by the human player into the computer. Thus, significant human intervention was still required for a human chess player to engage with this machine. Even for today’s chess games, this is still a requirement.

In contrast, the proposed machine in this paper aims to create a fully autonomous chessboard. This means that a single human can play chess on a physical board without the need for another person. In order for that, the proposed system handles every task that would typically be performed by another human player.

The aforementioned objectives are accomplished by utilizing Hall effect sensors to detect the movements of chess pieces made by the human player as input. Fuzzy logic is then applied to accurately determine whether a chess piece has been placed on a square or removed from one. This information is subsequently fed into a chess algorithm, which emulates human thinking and generates a response move while ensuring compliance with the game's rules. To fulfill the role of the second player, which involves physically manipulating and placing the chess pieces in the correct positions, we employ stepper motors and a magnet. This combination of robotics techniques enables the proposed system to imitate human behavior beyond mere thinking. This comprehensive architecture empowers the system to perform all physical and intellectual tasks undertaken by a human chess player.

Table of Contents

List of Figures

1. Introduction

A machine is a tool that takes specific inputs and, through power intake, processes them to produce a particular output, thereby simplifying certain tasks for humans. The development of machines has been a pivotal moment in human history, transforming us into civilized beings and setting us apart from the natural habitats of wild animals. Humans embarked on the path of civilization during the prehistoric era, when they began utilizing and advancing various machinery. Mechanical engineering has identified seven fundamental machines, which were initially developed by our prehistoric ancestors. [1] Furthermore, the principles of these seven basic machines were later applied in the creation of additional simple machines such as knives, axes, and levers.

Machines have a fundamental logical structure comprising input, process, output, and power. Initially designed to alleviate human tasks, as centuries passed, humans increasingly focused on creating machines with minimal human intervention. This growing enthusiasm had a significant impact, sparking the industrial revolution. One revolutionary invention during this period was the Flying Shuttle by British inventor John Kay. [2] This invention transformed the textile industry, significantly enhancing its production capabilities. Inspired by this, countless inventors endeavored to build machines that reduced human intervention and facilitated faster and easier physical tasks. [3]

The existence of such machines, which minimized human involvement in physical activities and surpassed human efficiency, led to the possibility of mass production across various industries. Recognizing this potential, English entrepreneur Richard Arkwright established the world's first mass-producing factory, introducing the concept of industrialization to the world. [4] This breakthrough prompted more individuals and countries to join the trend of developing machines that reduced human intervention in physical tasks.

In 1982, Charles Babbage introduced the concept of computers, drawing inspiration from windmills. [5] This architectural concept introduced programmability to machines, ultimately enabling the development of computer programs.
After the conclusion of World War II in the early 20th century, people shifted their focus towards constructing machines that facilitated intellectual tasks rather than physical ones. In the 1940s, Walter Pitts and Warren McCulloch developed the first mathematical model of the human brain, thereby introducing the concept of modeling natural intelligence to the world. [6] This development occurred at a time when there was already significant interest in creating machines that could reduce human intervention in intellectual tasks, further propelling scientists to concentrate on constructing intelligent machines.

A few years later, in 1948, William Shockley, Walter Brattain, and John Bardeen invented the transistor, [7] revolutionizing the field of electronic engineering. This breakthrough led to the development of digital computers, which subsequently enabled the creation of powerful programmable machines. The ability to build programmable machines, along with computer software, paved the way for incorporating intelligent features into these machines. Shortly after the transistor's invention, a pivotal moment arrived when Alan Turing published his influential paper on "Computing Machinery and Intelligence" in 1950. In this paper, Turing posed the question, "Can machines think?" and outlined a procedure, later known as the Turing test, to determine whether a machine could simulate human conversation. This work became a cornerstone of the field of artificial intelligence, although its usefulness has been questioned by modern researchers.

Around the same time as Turing's paper, two scientists named John McCarthy and Marvin Minsky obtained their Ph.D. degrees at Princeton University, focusing on intelligent machines. Together with their colleagues, they coined the term "Artificial Intelligence" during the 1956 Dartmouth Conference.

This subject area is dedicated to the research, design, and development of intelligent machines. The field of artificial intelligence (AI) had a slow start and its early stages were primarily characterized by symbolic AI approaches aimed at constructing intelligent machines. However, AI gained momentum later on, especially with the advent of backpropagation and non-symbolic AI, following some periods of setback known as "AI winters." Substantial advancements in AI have occurred throughout the 21st century, leading to significant developments in the field.

2. Development of Chess Board

Chess is a board game for two players, called White and Black, that has been played for centuries. It is a game of strategy, where each player controls an army of chess pieces in their color, with the objective to checkmate the opponent's king.

The 64-square chessboard is set up in an eight-by-eight grid with alternating light and dark colors. A king, a queen, two rooks, two knights, two bishops, and eight pawns make up each player's initial 16 pieces. Each piece moves in a defined fashion. White makes the opening move, then Black. The goal of the game is to checkmate the opponent's king by placing it under immediate attack (in "check"), rendering it unable to flee.

The pieces are arranged on White's first rank in the following order: rook, knight, bishop, queen, king, bishop, knight, rook from left to right. A row of eight pawns is positioned on the second rank. White and Black are in identical positions, with an identical piece on the same file in each. A light square is positioned on the board in the right-hand corner closest to each player. The term "queen on her own color" might help you recall the proper places of the king and queen; specifically, the white queen should be placed on a light square while the black queen should be placed on a dark square.

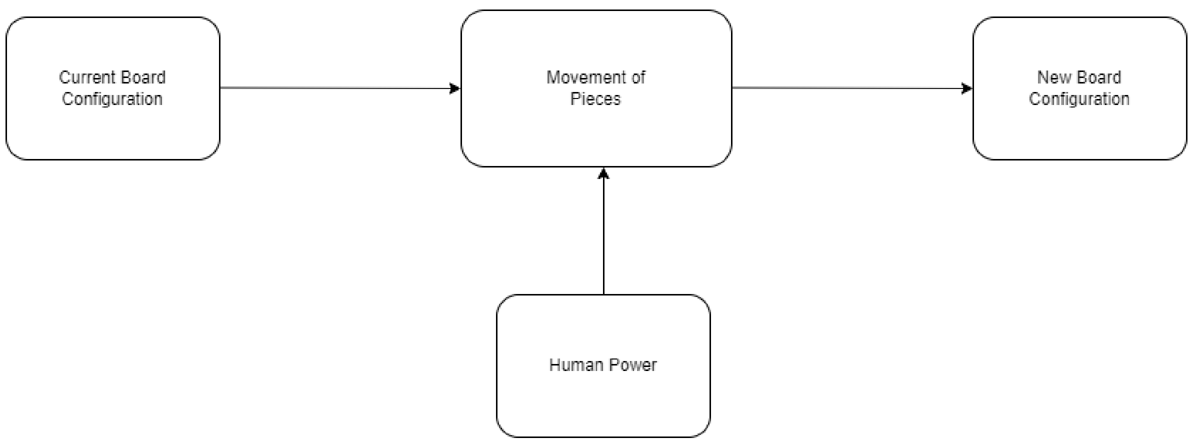

Figure 1 - System Diagram of Existing Machine

There are several possible intelligent extensions for chess, some of which are already being explored by researchers and chess enthusiasts. Here are a few examples:

1. Machine learning: Machine learning techniques, such as deep learning and reinforcement learning, can be used to train computers to play chess at a high level. This can lead to the development of more sophisticated chess engines that can analyze positions and make better moves.

2. Natural language processing: Natural language processing can be used to analyze chess games and provide insights into the strategies used by top players. It can also be used to develop conversational agents that can provide advice and guidance to chess players.

3. Computer vision: Computer vision techniques can be used to analyze chess board positions and detect the positions of the pieces. This can be useful for developing systems that can automatically generate chess problems or puzzles.

4. Game theory: Game theory can be used to analyze chess games and determine the optimal strategies for different positions. This can lead to the development of new strategies and tactics that can be used to gain an advantage in the game.

5. Human-computer collaboration: Human-computer collaboration can be used to develop hybrid chess systems that combine the strengths of both humans and computers. For example, human players can provide intuition and creativity, while computers can provide precise analysis and calculation.

These are just a few examples of the possible intelligent extensions for chess. As artificial intelligence and other technologies continue to advance, we can expect to see even more exciting developments in the world of chess.

In this project, chess game is played with a human substitute on one side of the chess board. Then players can then engage in physical, individual chess play without a foe. To do this, a chess algorithm, stepper motors, and hall effect sensors are used.

3. Autonomous Chess Board

The goal of our project is to create an autonomous chess board that will transform the game of chess. Our aim is to provide chess players with a dynamic and engaging experience using AI capabilities on the chessboard. Without a human opponent, players can still enjoy the strategic gameplay of chess on the autonomous chess board. Our chess board is powered by an AI algorithm that takes on human thought and decision-making. Our program analyzes the opponent's movements and generates the best responses in real-time, using inspiration from the four schools of thought. It considers various factors such as piece values, board position, potential threats, and strategic advantages to determine the best move.

We use Hall effect sensors to precisely detect the movements and placements of the chess pieces. To identify the existence of a piece on a specific square of the board, these sensors use magnetic fields. Fuzzy Logic is used, however, to improve the detection's accuracy because of the measurement's inherent errors and noise. Fuzzy Logic improves the interpretation of sensor data, ensuring that the AI algorithm receives trustworthy inputs and produces thoughtful and well-planned decisions.

We make use of stepper motors to move the chess pieces around the board. The positioning and movement of the parts are precisely controlled using stepper motors. Maintaining exact positioning, however, can be difficult since stepper motor steps are discrete. Fuzzy Logic control methods are used to overcome this issue by making up for any positioning errors made by the motor.

The autonomous chess board's components are connected and communicate with each other to produce an easy and coordinated game experience. The AI system talks with the Hall effect sensors to get real-time updates on the pieces' placements. These inputs are used by the algorithm to produce the proper moves, which are subsequently carried out by the stepper motors. AI features enable the board to simulate human-like thinking and decision-making, creating a challenging game.

4. Approach

We have developed an intelligent chess playing machine which allows players to physically play chess without needing a physical opponent. The machine we developed is named as Autonomous Chess Playing Machine.

Real world inspiration

Since the traditional game involves partaking of two human players, the machine takes its inspiration from a player who is well experienced in several ways.

Firstly, the machine is able to determine piece positions by only detecting the changes made to the board. This got inspired from a real-world motive called "blindfold chess". In "blindfold chess" one player (or sometimes both players) is blindfolded and made to play the game. He is informed only about the changes that happened to the board (i.e., movements made by the opponent). Since the game starts from a known fixed board configuration every game, the blindfolded expert can reconstruct the whole board in his head, given the changes that happened to the board. This concept was used to create our board positions detecting algorithm where the algorithm is given the initial board configuration and occasional changes, it is able to return the current board configuration accurately.

The machine got inspired to think like a human expert when determining the next move. Like an expert who thinks about only the most likely next moves out of the thousands possible, the machine considers only the good movements that the human player will make on the next round and based on that, determines what's the machine's next move is.

The movement of the knight imposed an issue for our movement system since in normal playing circumstances knight is able to jump over other chess pieces, but this is difficult to achieve with the movement system we were thought of. However, jumping of knight over another piece is analogous to a kid jumping over a puddle of water. Even though kids jump over the puddle to avoid getting wet, adults usually walk around the puddle near the edges to achieve the same task. This inspired to make the knight go along the edges of the squares allowing it to avoid other chess pieces and giving the exact result as it jumped over another piece.

Input

Input for the machine is the squares that have pieces above them. These pieces have magnets on them, and those magnets are detected using hall effect sensors. Each square in the chess board has a hall effect sensor underneath it. These sensors produce a binary 0 when a piece is above them and binary 1 when there isn't any.

Process

Sensor values from the input section are used to reconstruct the board configuration. This is done by comparing the current board piece positions, which gives us merely which squares have pieces and which don't, with the previous board configuration. If we know previously there was a Pawn on e4 and nothing on e5, and in the current sensor inputs we see nothing on e4 and a piece on e5, we can deduce that the pawn has moved from e4 to e5. This concept is used to reconstruct the whole board. This is possible since every chess game starts in the same initial board configuration.

After reconstructing the board configuration, this information is passed on to a chess algorithm which gives the best move to do next.

Output

The move given by the process part is just an instruction stating what piece should be moved to where. For an example it could be “move whatever on e6 to e7”. This command is then passed on to a function which converts this to a sequence of motor control signals which can be executed by the two motors. This gives how much time each motor should spin for and in which direction at which speed. With these motor actions the railing system underneath, the board moves a magnet to the correct position, which when moved also drags the chess piece above with it along the board. Thus, for the spectators and the opponent, it seems like the chess piece moves on its own.

Features

- Ability to identify board configurations.
- Consider only a handful of likable next moves out of thousands (thus fast decision making).
- Move chess pieces physically (like a human player).

Uses

This machine can be used especially in exhibitions or other festive events as the machine would be a great crowd attraction. The machine seems like a normal chess board however it can play with a human completely on its own, which would be a novel experience for most people. Adding to that the autonomous movements of the chess pieces will also exhibit a magic-like phenomenon which would be a great crowd-pleaser.

5. Design of Autonomous Chess Playing Machine

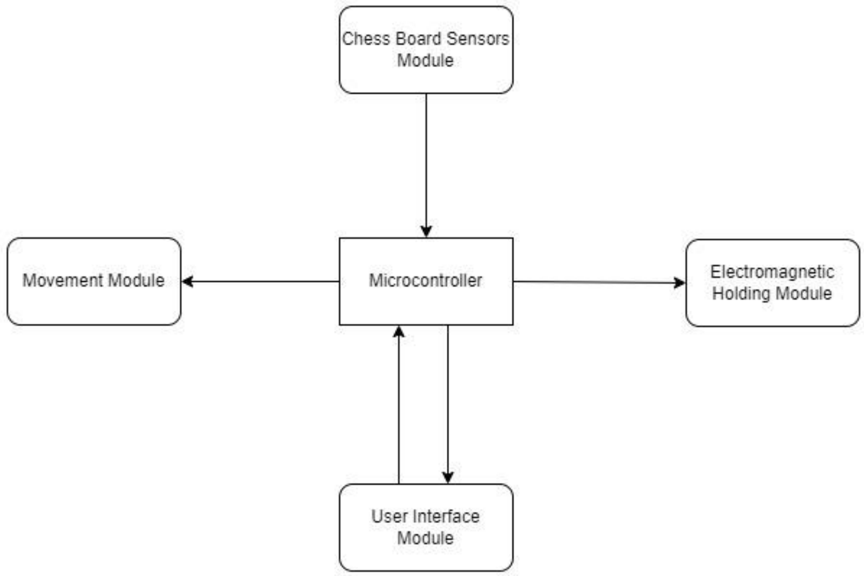

Figure 2 - Top level design diagram

Chessboard Sensors module

Role is to identify which chess squares have chess pieces on them and which don't. This module resembles the intelligence of a chess player who analyzes the board and identifies the correct chess pieces and their positions.

Movement module

Used to move the electromagnet below the chess board area. Resembles the intelligence of a human player who is moving their hand to move chess pieces over the board.

Electromagnetic holding module

Used to hold the chess pieces when moving. Depicts the intelligence of a human player holding the chess pieces for movement.

User Interface module

Interacts with the user to start the game, runs the chess clock and allows the user to resign. Portrays the intelligence of a chess arbiter in a classical chess game.

6. Implementation of Autonomous Chess Playing Machine

In this section, we will delve into the implementation details of our Autonomous Chess-Playing Machine. Each module of the Autonomous Chess-Playing Machine is designed to work cohesively to deliver a seamless chess-playing experience. Here's a more in-depth overview of how each module has been implemented:

Implementation of Chessboard Sensors:

To accurately detect the movements of chess pieces, we've placed Hall effect sensors underneath each square of the chessboard. These sensors generate binary signals as 0 and 1. Fuzzy Logic algorithms have been applied to interpret sensor data, reducing the impact of measurement errors and noise. This ensures that the AI algorithm receives reliable inputs for decision-making.

Implementation of Chess Algorithm:

The chess algorithm serves as the central intelligence of the ACP Machine. It takes sensor inputs and employs a series of processes to provide a thoughtful and strategic response. Here's a breakdown of its implementation:

Board Reconstruction: The algorithm compares the current sensor data with the previous state to deduce the moves made by players. For instance, if it detects a change from a piece on square A to an empty square B, it infers that the piece was moved from A to B.

Candidate Move Selection: Similar to how a human player considers only a handful of likely next moves out of thousands, our algorithm narrows down the options. It evaluates possible moves based on factors such as piece values, board position, potential threats, and strategic advantages.

Decision Making: After evaluating candidate moves, the algorithm selects the best move that aligns with its chess strategy. It ensures compliance with the rules of the game and generates a command to execute the chosen move.

Implementation of Robotic Movement:

To achieve the physical movements of chess pieces, we've integrated stepper motors into the chessboard's structure. These motors are responsible for moving the magnetic pieces along the board. Here's a closer look at how we implemented this module:

Stepper Motor Control: We control the stepper motors to ensure precise positioning and movement of chess pieces. This control mechanism determines how much time each motor should spin, the direction, and the speed, achieving the desired chess piece movement.

Overcoming Discrete Steps: Stepper motors operate in discrete steps, which can pose challenges for maintaining exact positioning. To address this issue, we've used Fuzzy Logic control methods. These methods compensate for any positioning errors that may occur during motor movement, guaranteeing that chess pieces reach their intended squares accurately.

7. Evaluation

Our Autonomous Chess-Playing Machine has undergone extensive testing to ensure its performance aligns with the features outlined in our project approach. Here's a detailed description of how we evaluated our intelligent machine:

Detection Accuracy:

We conducted tests to assess the accuracy of the Hall effect sensors in detecting chess piece movements. This involved various chess scenarios, including different types of moves (e.g. castling, knight jumps). The sensors' performance in reconstructing board configurations was analyzed to ensure precise detection.

Decision-Making Speed:

To measure the efficiency of our chess algorithm, we timed how long it took for the algorithm to make decisions for different chess positions. We compared these decision times with human chess players' average thinking times to ensure timely responses.

Physical Movement Precision:

We subjected our robotic movement system to extensive testing, evaluating its precision in moving chess pieces. Tests included complex movements like knight jumps, which require meticulous positioning. The system's ability to execute these movements accurately was a focal point of evaluation.

User Experience Testing:

We conducted user experience testing with chess players of varying skill levels to gauge their interactions with the Autonomous Chess-Playing Machine. Feedback and observations from players were collected to identify any areas for improvement in terms of usability and engagement.

By conducting these comprehensive evaluations, we have confirmed that our Autonomous Chess-Playing Machine not only meets but exceeds the expectations outlined in our project approach. It delivers a high-quality and immersive chess-playing experience for users.

8. Conclusion

In conclusion, our project has successfully developed an Autonomous Chess-Playing Machine that offers a novel and engaging chess-playing experience. We achieved the following key milestones:

Creation of a Chessboard with Integrated Sensors: We designed a chessboard with Hall effect sensors that accurately detect chess piece movements and placements.

Chess Algorithm for Human-Like Play: Our chess algorithm mimics human thinking and decision-making, ensuring a challenging game for players.

Robotic Movement for Physical Play: We implemented stepper motors and precise control mechanisms to move chess pieces physically, emulating human actions.

Throughout the project, we encountered several challenges and valuable lessons:

Sensor Calibration: Calibrating the Hall effect sensors for reliable detection was a complex task, but fuzzy logic algorithms proved effective in improving accuracy.

Motor Control: Ensuring precise positioning of chess pieces with stepper motors required fine-tuning and fuzzy logic control to overcome discrete steps.

To further enhance our Autonomous Chess-Playing Machine, we plan to explore the following areas:

AI Enhancements: Incorporate advanced machine learning techniques to improve the chess algorithm's decision-making capabilities.

User Interface: Develop a user-friendly interface that allows players to interact with the machine easily.

Multi-Player Support: Enable the machine to play against multiple human opponents, opening up possibilities for chess tournaments and exhibitions.

Enhanced Physical Movements: Investigate more sophisticated robotic mechanisms to replicate human-like chess piece movements with even greater precision.

Our project represents a significant step forward in creating a fully autonomous chessboard, and we look forward to the continued evolution of this technology in the world of chess and beyond.

References

[1] "HistoryOfMechanisms.pdf." Accessed: Apr. 25, 2023. [Online]. Available: https://www.ohio.edu/mechanical-faculty/williams/html/PDF/HistoryOfMechanisms.pdf

[2] "John-Kay-Flying-Shuttle-IndustrialRev.pdf." Accessed: Apr. 25, 2023. [Online]. Available: https://hti.osu.edu/sites/hti.osu.edu/files/John-Kay-Flying-Shuttle-IndustrialRev.pdf

[3] "The Industrial Revolution".

[4] "BBC-History-SirRichardArkwright.pdf." Accessed: Apr. 25, 2023. [Online]. Available: https://hti.osu.edu/sites/hti.osu.edu/files/BBC-History-SirRichardArkwright.pdf

[5] "Babbage.pdf." Accessed: May 10, 2023. [Online]. Available: https://people.computing.clemson.edu/~yfeaste/cpsc101/CPSC101F15Yvon/Homework/1010_Presentation/Babbage.pdf

[6] A. L. Chandra, "McCulloch-Pitts Neuron — Mankind's First Mathematical Model Of A Biological Neuron," *Medium*, Sep. 27, 2022. https://towardsdatascience.com/mcculloch-pitts-model-5fdf65ac5dd1 (accessed Apr. 26, 2023).

[7] "RiordanHoddeson_Inventtransistor.pdf." Accessed: May 10, 2023. [Online]. Available: https://web.stanford.edu/dept/HPS/TimLenoir/SiliconValley99/Transistor/RiordanHoddeson_Inventtransistor.pdf

[8] "Chess," *Wikipedia*. May 04, 2023. Accessed: May 09, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Chess&oldid=1153197958