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Tic-Tac-Toe Reinvented: Teaching Artificial Intelligence Concepts with TensorFlow-Based Game Development

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ABSTRACT : *In the era of rapid technological development, artificial intelligence (AI) has emerged as a primary focus in various fields, including education. This article highlights the importance of introducing AI concepts to beginners through a practical and interactive approach. The primary focus is developing a tic-tac-toe game based on artificial intelligence using TensorFlow. In developing this tic-tac-toe game, the engine was programmed to be the opponent to humans. AI in this game aims to enhance gaming intelligence, making the game more complex and engaging. Dataset was a crucial component in our game development to boost its intelligence. We designed the application to allow students to create and enhance various datasets, making the tic-tac-toe game smarter. The results of this application development show great potential in teaching fundamental concepts of artificial intelligence, including dataset development, training processes, and testing.*
KEYWORDS *AI education, dataset creation, tic-tac-toe game*

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I. INTRODUCTION

Learning the basics of artificial intelligence (AI) is very important for secondary-level students to face future challenges, including developing technological skills, solving problems, increasing digital literacy, understanding social impacts, increasing career opportunities, increasing creativity, and facing global challenges [1][2]. Learning AI can increase interest in Science, Technology, Engineering, and Mathematics or STEM [3] [4]. One way to teach the basics of artificial intelligence is to use AI-based games because they can increase motivation, provide challenges, and increase interest. [5].

Problems with learning the basics of AI for school students in Indonesia, in general, are that there is no appropriate learning material, limited access to technology, lack of teacher training, little practical application, wrong perceptions about AI, and lack of provision of practical skills [6][7]. The solutions include creating an appropriate curriculum, training teachers, increasing supporting learning resources, and using an interactive AI learning approach focusing on problem-solving. Another way that is more instant and easier to realize is by using applications or software in the form of games that are interactive, interesting, and challenging. In this research, we develop web-based software for tic-tac-toe games for AI learning.

1.1 The Tic-tac-toe games

Tic-tac-toe is a simple board game for two players using the symbols "X" and "O." The game board is square and divided into nine parts in a 3x3 formation. In this application, we create a number code for each part. The first three rows contain code 1,2,3, the second row contains code 4,5,6, and the third row contains codes 7,8 and 9. Both players have the same goal. The objective remains identical for both players: to become the first to strategically position three symbols consecutively in a row, whether horizontally, vertically, or diagonally. Integrating AI algorithms to mimic player intelligence enhances the game's adaptability to varying player strategies and skill levels, enriching the gaming experience. Researchers and enthusiasts often explore various AI approaches in replicating the player intelligence model within tic-tac-toe, making it an intriguing subject for study. Consequently, educators frequently use the tic-tac-toe game as a practical example or introductory project for teaching artificial intelligence concepts.

1.2 The AI approach

By utilizing artificial intelligence, such as TensorFlow, software developers can create AI that can make a computer replace one of the players' roles. Bauta intelligence in tic-tac-toe has varying levels of intelligence, from very simple (easy to beat) to very complex (challenging to beat and can even win).

The role of two players in a tic-tac-toe game is crucial to creating a game experience between humans and computers. The first player acts as a human opponent; his task is to beat the computer. In essence, human opponents compete against artificial intelligence systems that continue to improve their capabilities. Meanwhile, the second player, part of the artificial intelligence system, is called the AI player. Its job is to respond to attacks by continuously improving the software's intelligence. The interactive approach occurs in competition between a human opponent trying to win the game and an AI player trying to make the machine a formidable opponent.

II. AI-BASED LEARNING AND GAMING

The connection between the tic-tac-toe games that apply artificial intelligence and learning lies in how students understand basic concepts such as search, strategy, and decision-making, especially how machine learning works. In developing this software, we emphasize creating online learning facilities so that students understand the principles of artificial intelligence through the tic-tac-toe game.

2.1 Basic Concept

Many researchers use the tic-tac-toe game as a case study or initial project in learning artificial intelligence, including implementation in LabVIEW [8], soft computing techniques [9], using the minimax algorithm [10], decision trees algorithm [11] , and ANN Classifier [12]. In contrast to conventional tic-tac-toe game development approaches, our aim is to develop an online application that serves as a platform for exploring the principles of artificial intelligence within the context of the game. Employing TensorFlow, we engineered a tic-tac-toe system featuring a spectrum of intelligence levels, spanning from easy to challenging difficulty settings. This game is designed for both solo and multiplayer gameplay, as the primary objective is to develop a tic-tac-toe system that can be trained to enhance its intelligence through improving the quality of training data.

2.2 The Classification Approach

We use a game pattern classification approach to create machine intelligence in this development. Classification is a branch of artificial intelligence with the working principle of grouping data into categories or classes using specified features or attributes. AI data classification involves training AI systems to categorize data into predefined classes or labels. By learning patterns from historical data, AI classification sorts through large amounts of data, creating order. The goal is to make predictions about categories or labels from new data based on experience gained from previously provided training data. The classification process is often carried out using machine learning techniques, where a model or algorithm is trained using a dataset that has been labeled.

In a tic-tac-toe game, classification can predict the best move based on the game's current state. We developed an AI system capable of making optimal decisions for the tic-tac-toe game. The model uses data derived from various game states and optimal decisions. Classification is suitable to be applied in the game of tic-tac-toe because of its relatively simple nature. Some reasons why a classification is a suitable approach for tic-tac-toe are as follows:

1. We use a game pattern classification approach to create machine 1. The tic-tac-toe game has a clearly defined structure: a 3x3 game board. Each step the player takes will result in a new state in the game. Thus, tic-tac-toe is an excellent example of a classification problem because each game state can be classified into the appropriate category.
2. In tic-tac-toe game, there is a limited number of moves that each player can take, as well as a limited number of game board configurations. Given that there is only a limited number of possible game board configurations, we can use a classification algorithm to predict the optimal move based on the game's current state.
3. Each state in the tic-tac-toe game can be interpreted as a feature vector representing the game board at a certain point. We can train a model to predict optimal moves based on these feature vectors by utilizing classification techniques.

Thus, the use of classification in the game of tic-tac-toe allows us to solve problems efficiently, enabling the modelling of artificial intelligence that understands the game's rules and can make optimal decisions based on the game's current state.

III. THE SOFTWARE DESIGN

TensorFlow is a framework that is often used in the development of artificial intelligence (AI). This flexible framework can be used for various artificial intelligence applications. Web-based application developers can use TensorFlow on the back end to build and train models and on the front end to run models on the client side. Web-based applications fundamentally use the JavaScript programming language to control the behavior, interactions, and dynamics of websites on the client side. Therefore, this research uses an elementary JavaScript library to build a web-based tic-tac-toe game and apply artificial intelligence for learning purposes.

3.1. P5 and ML5 JavaScript library

The P5.js JavaScript library allows developers to create interactive applications on the web with easy-to-understand syntax. P5.js provides various functions for creating geometric shapes, manipulating images, setting colours and visual effects, and handling user input such as mouse and keyboard.

The ML5.js JavaScript library allows web developers to access and apply Machine Learning (ML) techniques in their web applications. This library facilitates using pre-trained ML models or creating your own ML models interactively on the client side using the JavaScript programming language. The ML5.js library makes it very easy to add ML functions to our websites or web applications without in-depth knowledge of Machine Learning. On the backend, ML5.js uses TensorFlow.js.

We use P5.js to create creative visualizations, animations, and interactions on the web and ML5.js to access machine learning. Combining the two makes it easier for us to create web applications that are interactive, interesting, and practical for learning basic concepts of artificial intelligence.

3.2. The dataset

Datasets in TensorFlow are data collections for training, validating, or testing Machine Learning models. In the tic-tac-toe game, we change the game pattern into a dataset as a representation of the current condition (current position) as input and decision-making by computer using AI (next decision) as output. Figure 1 shows the table of dataset structure for training. Understanding how to construct a table serves as the cornerstone of mastering the usage of this application. Students engage in critical thinking as they contemplate ways to manipulate game pattern data and discern the optimal numbers for the computer to select.

The relationship between the current position and the subsequent decision position is the basis for creating data sets, as shown in Table 1. This concept is the core of learning for AI players. In practice, a student can be the first player (human opponent) and the second player (AI player) because their function is to learn basic AI concepts.

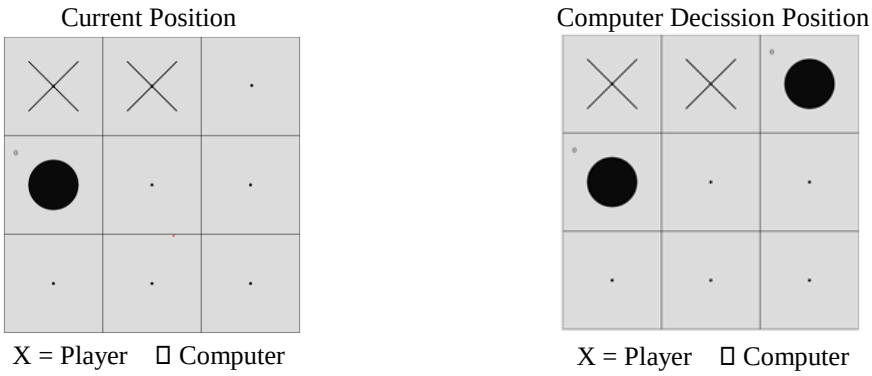

Fig.1. The AI core concept as data set generating

The first player has a maximum number of steps of five, and the second player (computer) has a maximum of four steps. So, there are a total of nine steps. If each box uses a number code, there are nine combinations. These nine combinations form a game pattern and become the input dataset, and the next step becomes the output data set (label). The input game pattern (X1 – X9) consists of:

1. Blank or no input yet using the number symbol 0
2. The first player position uses the number 1 symbol
3. The second player position uses the number 2 symbol

Tabel 1. Data set structure for training

X1	X2	X3	X4	X5	X6	X7	X8	X9	Label
1	0	0	0	0	0	0	0	0	2
1	2	0	1	0	0	0	0	0	7
1	2	1	1	2	1	2	0	0	8
2	1	1	0	2	1	0	0	0	9
0	0	1	0	0	0	0	0	0	2
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
0	2	1	0	0	1	0	0	0	9
0	2	1	0	1	1	0	0	2	7

X1-X9: input Label: output

3.3 The Algorithm

Figure 2 shows the block diagram of the tic-tac-toe game software. The working principle uses the following sequence:

1. Players choose a number on the game board. In this game, the player always chooses before the computer responds. Conditions like this are not fair in the actual game, but we chose this method because this game aims to teach the basic concepts of artificial intelligence.
2. The computer recognizes the final pattern or condition after the player chooses. This pattern becomes testing data for the software.
3. The computer looks for testing data in the input data set. If found, the software will store it in an array.
4. If the array is empty, the software will enter testing data into machine learning to determine the computer's choice of numbers. If the array is not empty, then the software will randomly choose one of the numbers in the array as the computer's chosen number.
5. After making a choice, the software will check whether a winning position exists. If there are none, then the player will choose another number. If there is a winning position, the software will display the winner.

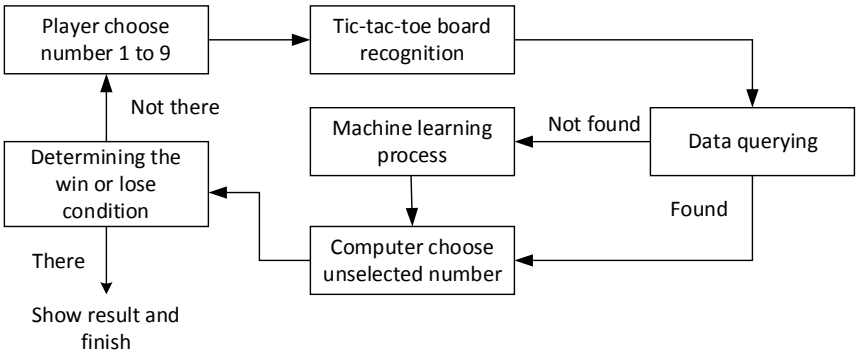

Fig.2. The tic-tac-toe software block diagram

This system's novelty lies in data querying, namely determining steps for the computer based on a single, definite pattern. The application will use artificial intelligence if the input pattern does not exist in the data set. This method is beneficial for increasing the computer's accuracy in determining the next step.

IV. RESULT AND DISCUSSION

Game software that teaches students to create input data for artificial intelligence must have a simple user interface, contain interactive elements, have a guide, and be customizable. The application should also provide feedback on decisions made, integrate elements of educational games, and stimulate student engagement. The teacher's ability to monitor needs to be considered in the design. Learning applications must continue to support various school devices and the curriculum. In addition, relevant supporting materials and

documentation must be included, such as instructions for using the application and learning content. Thus, this application effectively facilitates student learning by creating training data for AI model training. We designed this application to be indirectly exciting and able to provide additional insight for teachers.

This game requires a minimum of one player. As mentioned previously, the goal of this application is to understand the intelligence approach used and make the application smarter so that it becomes more difficult to lose or win more often. We designed a web-based application to form a lesson, as shown in Figure 3. The learning steps are as follows:

1. Understand the concept of tic-tac-toe game intelligence,
2. Understand the concept of creating data sets for training, namely, using the current game position to determine the computer's moves.
3. Arrange training data based on the current game position as input (X1-X9) and computer steps as output (label). The training data includes a combination of input numbers 0, 1, and 2 for input. Label data uses a combination of numbers 1 to 9. Training data is in file form using CSV format.
4. Upload CSV to the system
5. Carry out machine training
6. Testing the application.

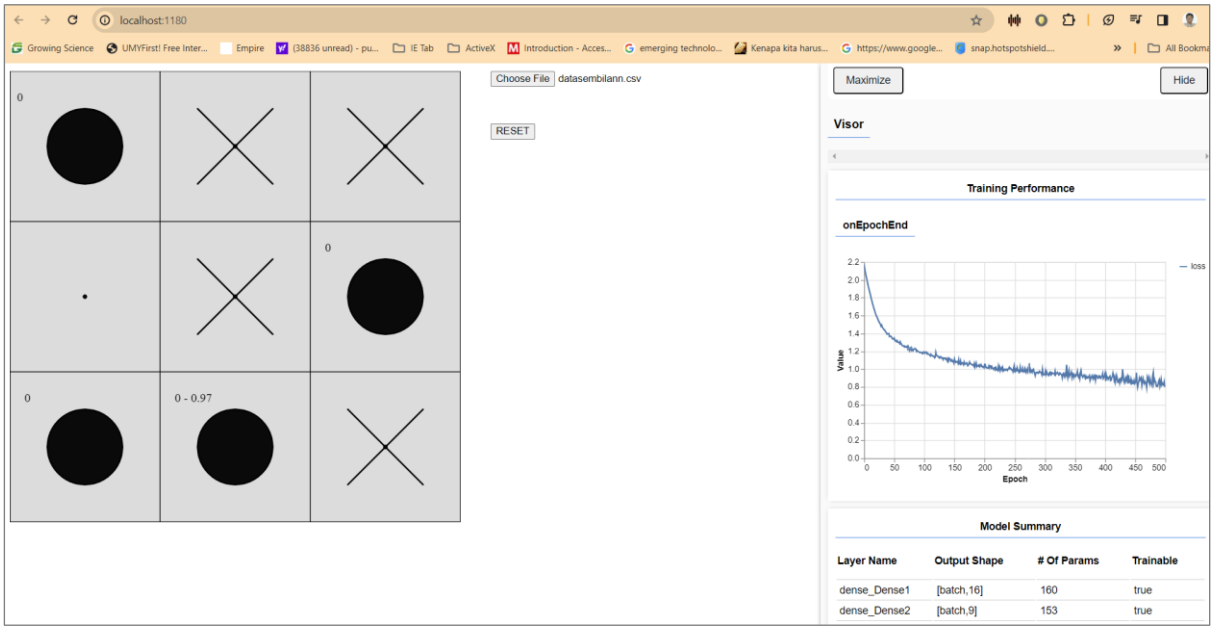

Fig.3. Tampilan aplikasi pembelajaran AI berbasis game tic-tac-toe

We achieved the development of this web-based application by utilizing a combination of HTML and JavaScript libraries, namely P5.js and ML5.js. Other JavaScript functions are reading CSV files, responding to player steps, displaying settings, checking win conditions, model training, and testing. We integrated the system into the Learning Management System as a SCORM module in the experiment.

By grasping each condition, players can make better decisions during gameplay, while developers can utilize this information to refine and enhance the overall gaming experience. Within this game, multiple game conditions are present:

1. The initial condition has no game trigger
2. Game start conditions (the first player chooses one of the numbers)
3. Advanced game conditions (first player chooses the second, third, and fourth numbers). The application will use an intelligence model at each step to select the first to fourth numbers.
4. The game condition stops because one of them is the winner.

To clarify, if the first player cannot win the game, they are considered to have lost, as there is no draw condition. Various winning patterns exist, such as the combination of numbers 1, 2, and 3. In JavaScript code, conditions like this encompass the winning criteria, as depicted in Table 2. The system will examine these combinations throughout the game to ascertain the victor.

Our research thoroughly evaluated this system through a tic-tac-toe game experiment. We aimed to demonstrate the creation of interactive and enjoyable input data, facilitating direct practical experiences, and delivering immediate feedback, all while ensuring relevance within an educational setting. Our findings suggest that game-based learning, exemplified by this approach, offers numerous advantages over potential drawbacks. [13].

Table 2. Winning Positions and Number Combinations in the Game

Position	Number Combination
Horizontally	1,2,3
	4,5,6
	7,8,9
Vertically	1,4,7
	2,5,8
	3,6,9
Diagonally	1,5,9
	3,5,7

Twenty-nine students attempted this game, and we assessed its comfort level using the System Usability Score (SUS). [14]. As a result, the application obtained an SUS score of 70 or was in the comfort category for students. The pre and post-tests show that students' understanding of the basic concepts of artificial intelligence has also increased. The pre-test and post-test consist of 15 questions on artificial intelligence concepts, including the meaning of intelligence, data sets, training variables, and system testing. As a result, the average pre-test score was 30, increasing to 78 in the post-test. In summary, this game allows the repetition of tasks, stimulates creativity, and demonstrates the concept of data sets in artificial intelligence in real-world situations.

V. CONCLUSION

The aim of creating this online tic-tac-toe game application is to build a learning tool to understand the principles of artificial intelligence. The essence of learning is how players can increase machine intelligence by increasing the variety of datasets for training. In creating a dataset, players must understand current patterns to determine steps to win the game. Players must also understand how to create datasets by creating game patterns to determine the proper computer steps. The higher the dataset's quality, the smarter the application will be. The more often you try, the more players will understand how the principles of artificial intelligence work. A representative, balanced, and diverse dataset will produce better tic-tac-toe intelligence in determining the next step to win.

We succeeded in creating an online learning application using HTML and the P5.js and ML5.js JavaScript libraries. We also successfully integrated the application into the LMS. From the test results, the Tic-tac-toe software is proven to function well, is comfortable for students, and increases knowledge of basic concepts of artificial intelligence.

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