

Principles And Applications of Artificial Intelligence (AI) Algorithms: A Review of The Literature

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Abstract. Artificial intelligence technologies, represented by machine learning and knowledge graphs, have gained rapid popularity in the last century, and their research has been involved in a wide range of applications such as license plate recognition, face recognition, speech recognition, intelligent assistants, recommendation systems, and autonomous driving. With the increase of data, computing power, maturity of learning algorithms, and richness of application scenarios, people have started to pay attention to this "new" and widely successful research field in academia and industry, and its development history, working principles, and practical applications have attracted much attention and created a new round of AI enthusiasm. The main content of this paper includes the analysis of classical AI algorithms, the reduction of neural networks, decision trees, and biological evolutionary algorithms from the perspective of algorithm principles, and the description and overview of their practical applications and problem-solving processes in various fields and technologies, summarizes and prospects the future development of AI in the context of its development history and existing research results so that readers can better understand the future trends of AI.

Keywords: Artificial Intelligence, Computer Engineering, Intelligent Algorithms, ChatGPT, Applied Engineering, AlphaGo.

1. Introduction

In the context of the digital era driven by big data, research on artificial intelligence emerged like a wave in the 1950s in large numbers. With the advancement of time and the rapid development of technology, the desire to make computers simulate human intelligence processes was gradually realized, allowing computers to become capable of reasoning, learning, and decision-making like humans [1]. AI research has far-reaching scientific implications. By simulating human intelligence processes, AI research can better explore the relationship between intelligence and philosophical issues such as consciousness and the self. Artificial intelligence research can also promote the intersection of several disciplines, such as computer science, mathematics, and statistics, to bring more technological advances to humanity [2-3].

Artificial intelligence is an interdisciplinary discipline that focuses on how to build intelligent agents that can reason, make decisions, learn, and interact with natural language like humans. The components of artificial intelligence are very rich and diverse, and the superficial components include artificial neural network algorithms, biological evolutionary algorithms, machine learning algorithms, and the most popular deep learning algorithms. The diversity of these algorithms has allowed the development of the AI field to move solidly forward, from AlphaGo's victory over the human professional Go champion in 2016 to the continuous testing of driverless cars by Google-led companies and the successful development of the Xiaomi CyberOne full-size bionic robot in 2022, which demonstrates the significant breakthrough of AI algorithms in the field of automation. With the continuous development of technology, the application areas and research content of AI will continue to expand and deepen.

From the perspective of algorithms, AI is a technology that uses computers to simulate human intelligence thinking process. For example the principle of the technology of machine learning is to let the computer discover and adjust the parameters of the model by learning data patterns, that is, to train and test the model a lot based on pre-processing and extracting completed features, and its pattern is similar to the way humans solve real-life problems , and trained and tested completed

models can be applied to multiple important fields such as image recognition, speech recognition, and natural language processing.. Unlike mechanical learning, the core of deep learning lies in deep learning model design, that is, the model structure of neural networks, which needs to select the appropriate network structure and parameters according to the characteristics of the problem. The selection of a convolutional kernel can make the process of data processing such as extracting features more efficient, but it also means that each step needs to be carefully processed and adjusted in order to get an efficient and accurate deep learning model. Migration learning is a machine learning method whose basic principle is to use knowledge and models already learned to help solve new problems, adding migration application domains to improve the generalization and performance of the model. For example, migrating language and image models to machine translation, medical imaging, and other classification tasks can improve the accuracy and reliability of the models. Reinforcement learning is also part of the machine learning approach, distinguished from supervised and unsupervised learning, and does not rely on labeled datasets. It enables intelligence to gradually learn the action strategy that yields the greatest reward in a given environment through the interaction of intelligence with the environment. Experience is gained by interacting with the impact of actions on the environment, and the action strategy is gradually optimized in response to errors. Such a reward and punishment learning mechanism can find optimal solutions to most problems given environmental factors, and it can be used to full advantage in games such as Go, Minesweeper, and other games in the field of strategy optimization, as well as in medical and financial fields where models can be used to predict outcomes.

In summary, artificial intelligence involves different fields and applications such as machine learning, deep learning, computer vision, image recognition, and natural language learning. In this paper, we address the development and working principles of classical AI algorithms such as Artificial Neural Networks (ANN), Feedforward Neural Networks (FNN), BP Neural Networks, Convolutional Neural Networks (CNN), and so on. Convolutional Neural Networks (CNN), Recursive Neural Networks (RNN), Decision Trees, and Bio-evolutionary algorithms are reviewed in the field of artificial intelligence. The structure and principles of the above AI algorithms and their diverse architectures are analyzed from the perspectives of algorithms and biological evolution, followed by the practical applications of AI algorithms in various fields and technologies, then the current problems of AI are presented, and finally, some prospects for the future development of AI are offered.

2. The basic mathematical principles of artificial intelligence algorithms

2.1. Machine learning

Machine learning is a branch of artificial intelligence where the ultimate goal is to develop intelligent computer programs that can learn and continuously improve on their own. It is the analysis and learning of data so that computer systems can automatically learn and improve based on experience and data to perform tasks such as recognition classification, clustering, and so on, at an efficient computer computational rate. Machine learning focuses on the realism of the data and the amount of training data, and looks at the optimization process, usually using methods from multiple fields such as statistics and computer science to design and develop high-quality and accurate algorithms that can discover patterns and laws from the data and use these patterns and laws to make predictions and decisions [4].

The components of machine learning can be outlined in their entirety in the following parts: First, there is the collection of data. This process has a lower limit on the sample size, and attention needs to be paid to the presence of bias in the data collection process. Then the steps performed are pre-processing, filling or replacing gaps and abnormal data, deleting, followed by extracting features, and searching for features through a unified approach to all data, an example used in the picture field is the convolutional kernel of a convolutional neural network for the appearance of special lines after computation. Then comes the design of models, training models are the core of machine learning

algorithms, including various types of models, such as decision trees, neural networks, support vector machines, etc. Training a model means using existing data for learning, and improving the accuracy and generalization ability of the model by continuously adjusting the model parameters. The next step is to evaluate the model and optimize the tuning parameters. The recall, F1 values, etc. are fine-tuned to update the accuracy while avoiding underfitting and overfitting. The final step is to apply the model to the data in the desired application scenario, analyze the data features, and finally interpret the results in a supportive way.

Before the 1960s, the origins and exploratory phase of machine learning focused mainly on methods based on logic and symbolic reasoning, but also on basic mathematical principles such as logistic regression algorithms and decision tree algorithms. The most typical and well-understood algorithm is the K-means algorithm, which uses distance calculation to select the center of mass to minimize the distance from the center of mass to the nearest K points and adjusts the center of mass to better classify the data points into two categories to extract features, As shown in **Fig.1**.

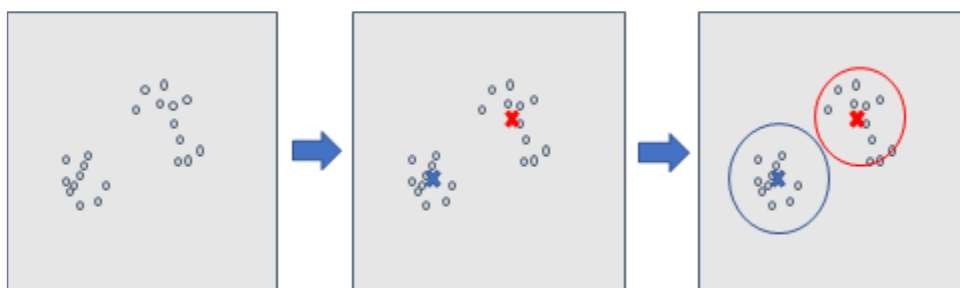


Figure 1. K-means algorithm structure

The 1970s to 1980s: This phase is the transition of machine learning from theory to practice, mainly focusing on statistical-based learning methods, such as linear regression and least squares. Among them, the knowledge of linear regression algorithms became the classical development base algorithm in the context of the later diversification of function restrictions and treatments. It is used to predict the relationship between a continuous output variable such as study time and one or more input variables such as test scores. Mathematically, linear regression can be expressed as:

$$y = w_0 + w_1x_1 + w_2x_2 + \dots + w_n * x_n \quad (1)$$

In the equation, y is the dependent variable, x_1, x_2, \dots, x_n are the independent variables, w_1, w_2, \dots, w_n are the weights or coefficients, and w_0 represents the intercept. People continuously solve the optimal weights and intercepts by adjusting the weights to ensure that the line fits the data sufficiently to predict the trend by minimizing the squared error between the predicted value and the true value. The gradient descent algorithm is a common optimization algorithm that can also be used to make the distance error of the model gradually decrease after adjusting the weights and intercepts, as shown in **Fig.2**.

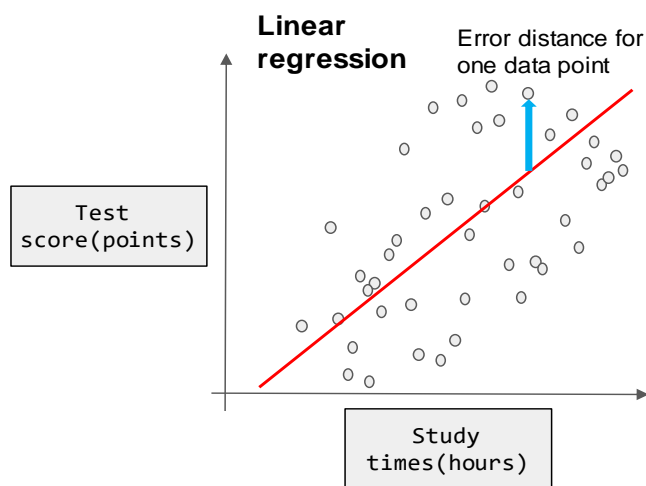


Figure 2. Linear Regression Algorithm

1990 to 2010: This phase belongs to the modern era when machine learning emerged from the traditional to the modern transformation. Not only did biometric algorithms such as ant colony algorithms, genetic algorithms, and artificial immune system algorithms (AIS) that simulate biometric features emerge and develop, but also modern machine learning methods such as neural networks and support vector machines (SVM) were introduced intensively. The ant colony algorithm is a typical example of a biogenetic algorithm, which forms the basis of a biogenetic algorithm by simulating the backward propagation process of a colony of ants searching for food by "trial and error" with the advantage of large numbers. Because it is possible that there are situations where the answer is limited to a local optimum, therefore, in the ant colony algorithm, some parameters need to be set, such as the volatility of the pheromone, the weighting factor of the pheromone, and the weight of the pheromone concentration and distance factors in the heuristic function. From the 2010s to the present, this phase is the most rapid transition phase of machine learning from application to popularity.

The last decade has seen breakthroughs in the development of artificial intelligence, with the most prominent algorithms including deep learning and reinforcement learning. This development has also led to the emergence of various algorithms and application areas of this AI, such as migration learning and reinforcement learning. OpenAI's ChatGPT model has made important progress in the field of natural language processing, achieving an intelligent answering machine with a huge database of payroll, using the Transformer model inspired by neuroscience in deep learning about the brain's neurology, and being able to use a huge database to simulate and learn a model for real conducting text generation and dialogue scenarios. In addition, Baidu's Xiaodu intelligent robot start to realize a variety of artificial intelligence technology applications such as voice recognition and image recognition. Now, in 2023, with the improvement of numerical computing power and computer hardware performance in recent years, and the widespread use of computer-aided engineering (CAE) software such as MATLAB or Python tools. The continuous development and innovation of these technologies have promoted the development of AI in various fields, making AI applications more intelligent, automated, and digital, and foreshadowing a broader and more challenging future for AI [2].

2.2. Deep learning

With large-scale development. The inspiration since the twenties evolved a more complex and comprehensive machine learning approach: the machine learning approach of Deep Learning (Deep Learning), which is centered on building multi-layer neural network models, trained and optimized by back-propagation algorithms to simulate artificial neural networks of human brain neural networks. Compared with traditional machine learning algorithms, deep learning has great advantages in data processing and feature extraction. While traditional machine learning algorithms usually require

manual feature design and selection, deep learning can automatically learn and extract features from data through multilayer neural networks, thus reducing the workload and error of feature engineering [5-6].

Deep learning models where the most typical and critical neural network structure usually contains an input layer, multiple hidden layers, and an output layer, where the hidden layer has a high number of neurons to automatically learn and extract features from the data. For example, in the classical artificial neural network algorithm BP neural network, the algorithm can usually be divided into three layers: 1, input layer 2, hidden layer 3, and output layer. The input layer receives external inputs, each of which corresponds to an input neuron; each hidden layer consists of multiple neurons that can perform feature extraction and transformation on the inputs; and the output layer performs tasks such as classification and regression based on the output of the hidden layer. Each neuron usually consists of three parts: input weight, bias term, and activation function. The input weight indicates the weight of the input received by the neuron on the result; the bias term indicates the underlying output value of the neuron; and the activation function indicates how the output of the neuron is processed and passed to the next layer of neurons. When training feedforward neural networks, optimization is usually performed using the backpropagation algorithm, which means that the weights and bias terms of the network are adjusted by the gradient descent method to make the prediction results of the network as close as possible to the actual results [7]. The backpropagation algorithm can effectively use the multilayer structure of the chain rule to calculate the gradient of the loss function on the weights and bias terms of each layer shown in **Fig.3**, so that the parameters can be updated to obtain near-optimal parameters.

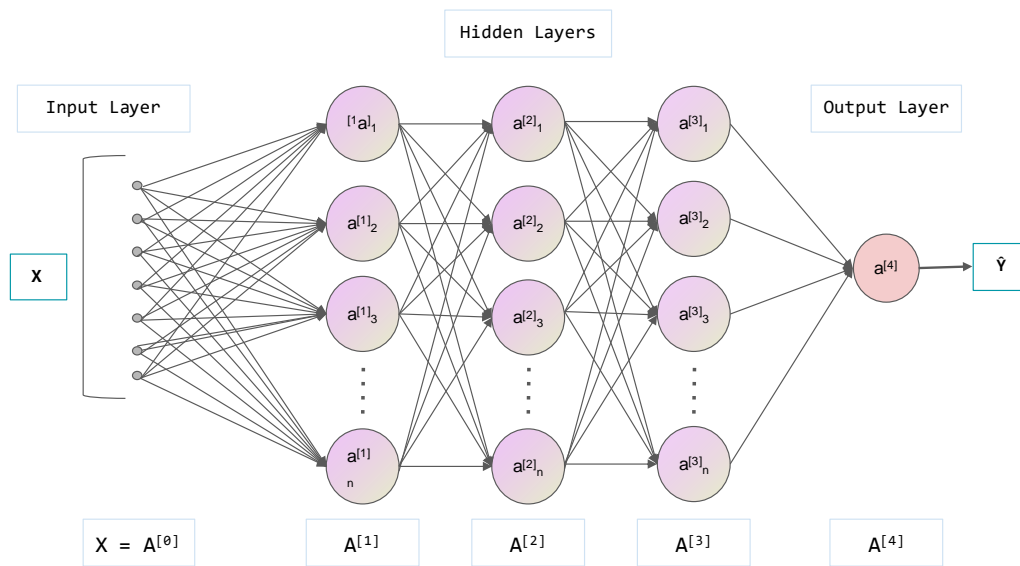


Figure 3. Deep Learning Structure

Compared with FNN, the deep learning model of CNN convolutional neural network has the following structure: input layer - pooling layer - convolutional layer - output layer, with the convolutional layer and the pooling layer added to the feedforward, and the concept of convolutional kernel introduced. The convolution layer can extract the local features from the original image [8]. The convolution operation can be seen as a filter sliding over the image, and each filter can extract a certain class of features in the image, such as edges, textures, colors, etc. The pooling layer, on the other hand, down samples the output of the convolution layer to reduce the size of the feature map and enhance its invariance to position and scale as shown in **Fig.4**.

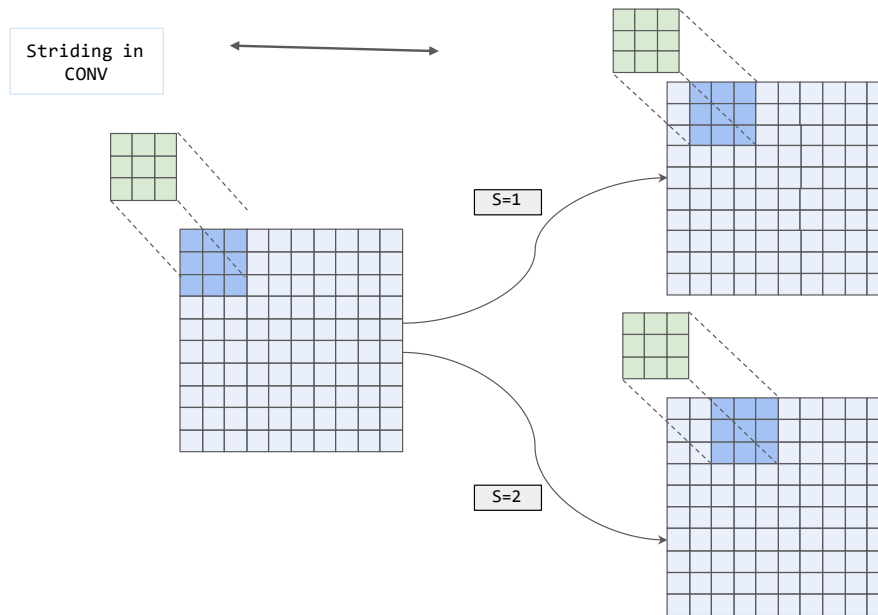


Figure 4. Convolutional Neural Network Structure

A more complex model right Deep Neural Network (DNN) is a model for machine learning and deep learning that can learn advanced representations in data by multilayer nonlinear transformations. The multi-layer tessellation function adjustment and data iteration can be understood as multiple processes in a realistic airport environment. Long Short-Term Memory (LSTM) is a variant of Recurrent Neural Network (RNN) that optimizes the problem with the memory pattern of the human brain and is used to solve the long-term dependency problem that exists in traditional RNN. With a three-layer structure of forgetting gates, input gates, and output gates, it can effectively control the flow of information and maintain long-term memory avoiding the anomalous situation of memory unit disappearance. GRU has the same characteristics as LSTM in controlling the risk of attrition, controlling memory units, and storage of long sequence data, and its characteristics are more efficient in many cases because of simplicity while maintaining long-term memory [4].

Overall, Deep learning algorithms are better suited to handle large-scale, high dimensional, and complex data, and can automatically extract useful features from the data, and perform classification and prediction.

2.3. Transfer learning

Transfer learning is a machine learning technique that migrates the knowledge and parameters of an already trained model (called the source model) to a new task (called the target task) for training and prediction. The core idea of transfer learning is that the training process of a new task can be accelerated and the prediction accuracy of the model can be improved by using the existing knowledge and experience with appropriate adjustments and fine-tuning. A real-life example could be that people learning English can learn French more easily because existing knowledge and experience in language learning can be transferred to other domains to improve efficiency, and so can computers. Unlike mechanical learning and its offshoot deep learning, this algorithmic approach can be applied to data from one or more target domains, thus simply cross-domain to obtain more profile-efficient performance and results [9].

2.4. Reinforcement learning

Reinforcement learning is a branch of machine learning whose counterparts in the same class of machine learning methods are supervised learning and unsupervised learning. Reinforcement learning is mainly used to train an intelligent body to learn how to make the best decisions in the environment. In reinforcement learning, the intelligence learns by interacting with the environment, it observes the feedback from the environment by taking different actions and adjusts its strategy

based on this feedback to achieve the goal of maximizing the reward. The core of the algorithm is to learn an optimal policy, i.e., a set of decision rules that allow the intelligence to maximize the desired reward in different environments. The core concepts in reinforcement learning include state, action, reward, and value function. The state is the current situation of the environment in which the intelligence is placed; the action is the decision taken by the intelligence in the current state; the reward is the feedback signal obtained by the intelligence in the current state; and the value function is the long-term reward that the intelligence can obtain by taking an action in the current state, which can self-tune into a mutually optimal state, outcome, over time and in the direction of its reward instructions.

Reinforcement learning has unique characteristics, although it is a branch of machine learning that differs most from neural networks or classification methods in that it does not have training data sets and labels but rather learns the best strategies by interacting with the environment, and it is primarily used to train an intelligence to learn how to make the best decisions in the environment. Typically, reinforcement learning uses a stochastic strategy. Stochastic strategies have several advantages: 1) by introducing a certain amount of randomness, the environment can be better explored, thus accelerating learning; 2) the actions of stochastic strategies are diverse, which is important when multiple intelligences are playing. Intelligence with deterministic strategies always make the same actions for the same environment and can predict their strategies, potentially reducing their likelihood of success and making the strategies impossible to implement, so introducing randomness is necessary under certain conditions [10].

3. The applications of Artificial Intelligence

With the continuous development and innovation of AI technology, its application areas are also expanding and deepening. Currently, AI is widely used in various fields, including healthcare, finance, education, transportation, manufacturing, etc. For example, in the industrial applications of the digital twin of CAE intelligent efficiency work assistance, driverless car topics, language processing level AI is also used in database retrieval side highlighted in the popular the the ChatGPT search engine. The AlphaGo AI Go has also made breakthroughs in the field of decision processing, which can help humans make more accurate and effective decisions. These and many more applications and the wide range of fields involved demonstrate the great potential and expanding promise of AI technology for solving real-world problems.

3.1. ChatGPT search engine

The ChatGPT is one of the most famous artificial intelligence technologies in the field of artificial intelligence applications today. Based on the evolution of AI technology, it employs a technique called Natural Language Processing (NLP), which uses machine learning and deep learning algorithms to train computer systems to understand and generate natural language text. one of the most advanced natural language processing models available. The performance of the ChatGPT in generating natural language text has been gradually improved and enhanced by continuous training and tuning after referring to and using the deep neural network model derived from large-scale corpus data and training. So now the ChatGPT is of great help to human beings, it can help people process and understand a large amount of natural language text, such as articles, news, social media posts, etc., faster and more accurately, and it can make get help for the information access and understanding needs of industries such as finance, medical, legal, news media, and even ordinary people. The future may see more intelligent and humanized dialogue systems and assistants, which will have a positive impact on human life [11-12].

3.2. Driverless cars

If the ChatGPT is the only one in the field of natural language processing among the various fields of artificial intelligence, driverless is the comprehensive and integrated use of various intelligent

technologies of artificial intelligence in the automotive field. Driverless is an important application area, its development is inseparable from the technical support of many fields, including computer vision, deep learning, algorithm-based decision-making, planning, etc., which can enhance the interaction and efficiency between human and artificial intelligence. Computer vision technology is the branch of artificial intelligence that helps driverless cars accurately perceive obstacles, other vehicles, pedestrians, road signs, and signals in the surrounding environment to avoid collisions and other safety issues. By making intelligent decisions through deep learning technologies and machine learning algorithms, driverless cars can learn and predict road conditions, traffic flow, and the behavior of other vehicles to make optimal driving decisions and path planning, which can also improve driving efficiency and safety. Language recognition technology can convert language into a form that computers can understand and respond to, which can increase the interaction between driverless cars and users and increase the user experience. Thus, it seems that the development of artificial intelligence makes several fields benefit driverless cars and human beings, in the context of improving life, becoming more and more safe and convenient is the goal to which the development of artificial intelligence has been committed [12].

3.3. AlphaGo: Artificial Intelligence Go

The AlphaGo, a Go artificial intelligence program developed by DeepMind, successfully defeated South Korean Go master Lee Sedol in March 2016, becoming a major milestone in the field of artificial intelligence. the emergence of AlphaGo back in 2016 was phenomenal, and the success of Go, the top game in the decision-making category, has drawn much attention to AI's potential for a wide range of concerns. And one of the key technologies supporting this is the category of artificial intelligence. Most notably deep learning technology, AlphaGo uses deep neural networks for training and decision-making to further improve itself and its capabilities by learning and analyzing thousands of Go games. At the same time, AlphaGo also employs reinforcement learning techniques to constantly improve itself by playing against itself. the emergence of AlphaGo has caused a sensational effect not only in the field of Go but also in the field of artificial intelligence, which has been widely discussed and explored. the success of AlphaGo shows that artificial intelligence has the potential to make major breakthroughs in the field of complex tasks, and opens up new opportunities for artificial intelligence in The success of AlphaGo shows that AI has the potential to make significant breakthroughs in complex tasks, and provides strong support and inspiration for the application of AI in games, natural language processing, visual recognition, robotics, and other fields, and illuminates the future of AI [13-14].

4. Conclusion and Prospect

This paper examines and retraces the background of the development of the field of artificial intelligence, restoring the development process step by step while elaborating and dissecting the understanding of the origin of algorithms on the timeline in the form of mathematical principles. By summarizing and elaborating the process in a summarizing language that can be digitally understood, the reader is given an expansive and feasible view of the prospects and potential of the development of the field of artificial intelligence, and finally a modern perspective on the future directions and applications of the technology in this field.

At present, there are many shortcomings and problems in the practical application of AI technology, such as the increase of data in human society brings security and data privacy issues, future development also needs to adapt the device to many computing needs, etc., and these problems need to be solved to provide security for its sustainable development. The future of artificial intelligence will also be expanded in more areas to achieve substantial help. For example, the auto industry's hot self-driving technology can bring traffic to a whole new level to achieve the ideal state of risk-free and high efficiency, the current development trend of artificial intelligence in health care and finance means that people's health and capital protection, the development of robotics and the demand for

chip manufacturing can also gradually pull the future of automation and intelligence closer. Continued research into the feasibility and effectiveness of AI technology in various fields will extend the field into a future of infinite possibilities.

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