

# The Application of Artificial Intelligence Technology in UAV

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**Abstract**—From the key technology level, the application of artificial intelligence (AI) in unmanned aerial vehicle (UAV) is discussed. The basic connotation of AI technology is introduced. In the four fields which are machine learning, expert system, automatic planning and distributed artificial intelligence, the application of AI technology in UAV is discussed. The future development trend of UAV based on AI is prospected, which provides a reference for promoting the application of AI in UAV.

**Keywords**; Unmanned aerial vehicle, Machine learning, Expert system, Automatic planning, Distributed artificial intelligence

## I. INTRODUCTION

The development of artificial intelligence technology is becoming more and more rapid. Since about ten years ago, with the maturity of deep learning technology and the rapid growth of computing chips, the application of artificial intelligence in various industries is currently increasing<sup>[1-2]</sup>. The field of UAV is one of the most typical representatives of artificial intelligence applications. The core of the development of UAVs is the development of control systems. From the current development status, the problem of automatic flight control has been solved, but the problem of intelligent autonomous control has not yet been solved. Therefore, the next step in the industrialization and globalization of UAV applications must rely on the advancement of artificial intelligence technology. In the military field, UAV systems will have higher thinking and autonomous decision-making capabilities in the complex battlefield environment in the future, with the result of changing the structure of future warfare; in the civil field, such as UAV energy inspections and formation performances, which can bring huge economic benefits and has deep market potential<sup>[3]</sup>.

The intelligent strategy of UAV is vigorously promoted by the world's major powerful country. And the application of UAV with artificial intelligence technology has become a research focus at home and abroad. The U.S. Navy's aerial unmanned combat platform demonstrator X-47B successfully flew for the first time in 2011, achieved carrier takeoff and landing in 2013, and achieved autonomous aerial refueling in 2015. In human

history X-47B became the first unmanned aircraft, for it was an multifunctional military intelligent unmanned aerial vehicle with surveillance, intelligence collection and battlefield strike capabilities which was independently operated by a computer<sup>[4]</sup>. The U.S. Department of Defense established the Maven project in 2017 to speed up the integration of artificial intelligence and machine learning technology, and to quickly convert the massive data of the U.S. Department of Defense into practical intelligence<sup>[5]</sup>. The literature [1] analyzes the intelligentization of UAV systems from three levels: single-aircraft intelligent flight, multi-aircraft intelligent coordination, and task autonomous intelligentization. The literature [4] looks forward to the future development direction of intelligent unmanned aerial vehicles, and analyzes the impact of intelligent unmanned aerial vehicles on future warfare from three aspects: reshaping the air combat system, comprehensive combat effectiveness and combat victory mechanism. The literature [3] analyzes the main levels of artificial intelligence applications on UAV, and proposes specific applications of artificial intelligence in military UAV and civilian UAV.

Most of the current researches are carried out to the application of artificial intelligence in UAV from the application dimension, and there is little discussion on the application of artificial intelligence in UAV from the key technology dimension.

Starting from the basic connotation of artificial intelligence technology, the application of artificial intelligence technology in UAV is discussed by this article from the key technical levels of machine learning, expert systems, automatic planning, and distributed artificial intelligence, and then this article looks forward to the development trend of UAV based on artificial intelligence technology.

## II. OVERVIEW OF AI

Since artificial intelligence technology is born in 1956, and after more than 60 years of development, artificial intelligence technology has become more advanced and great achievements have been made in natural language processing, automatic

theorem proving, automatic programming, intelligent retrieval, intelligent scheduling, machine learning, robotics, expert systems, intelligent control, pattern recognition, vision systems, neural networks, automatic planning, multi-agent collaboration, and intelligent computing, etc.

Human behavior and intelligence can be simulated, analyzed, expanded and extended by artificial intelligence. Mechanical equipment and instrumentation are given human intelligence by artificial intelligence, which can realize automation, intelligence, and intelligent development for mechanical equipment and instrumentation. And these devices are promoted to have human perception, decision-making, and feedback capabilities by artificial intelligence [6]. The basic connotation of artificial intelligence is shown in Fig.1.

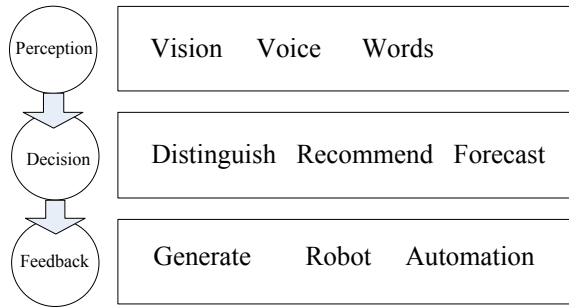


Figure 1. The basic connotation of artificial intelligence

### III. APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN UAV

The application of artificial intelligence technology in UAV is mainly discussed by this article from four aspects: machine learning, expert system, automatic planning and distributed artificial intelligence in artificial intelligence.

#### A. Application of machine learning in UAV

Machine learning is a theory and method which can improve system performance by studying the way that machines simulating human learning activities and acquiring knowledge and skills. The deep learning algorithm is a relatively efficient algorithm in machine learning. In the recent research of cloud computing and big data parallel processing, its processing power has reached a level almost comparable to humans in some recognition tasks. Deep learning algorithm is a kind of machine learning algorithm based on the further understanding of the human brain by biology. In order to obtain the optimal data feature representation, the working principle of nerve-center-brain is designed as a process of continuous iteration and abstraction in the deep learning algorithm. Starting from the original signal, the first step of this algorithm is doing low-level abstractions, and second step is gradually iterating to high-level abstractions. There are many deep learning frameworks, such as deep neural networks, convolutional neural networks and deep belief networks. The typical structure of deep belief networks is shown in Fig.2 [7].

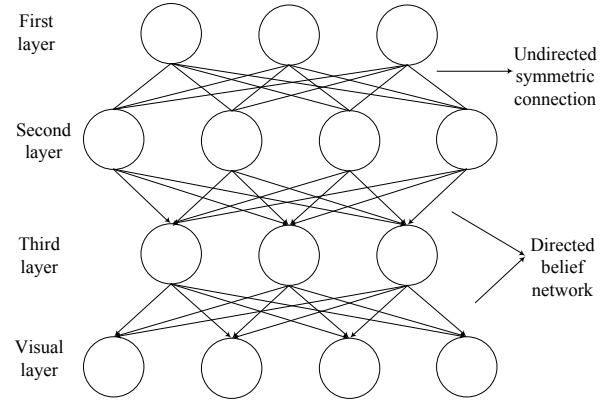


Figure 2. The typical structure of deep belief networks

Deep learning algorithms can be applied to UAV target detection [8]. Target detection is one of the key technologies to improve the perception ability of UAV. Deep learning methods based on convolutional neural networks have powerful feature learning and expression capabilities, and have become the mainstream algorithm for target detection tasks. Its network is a weight sharing structure, which is highly compatible with the input image, and can better complete the extraction and classification of image features.

#### B. Application of Expert System in UAV

Expert system is a program system with a large amount of specialized knowledge and experience. To solve complex problems that require human experts to deal with, it applies the reasoning technology in artificial intelligence, and based on the knowledge and experience provided by one or more experts in a certain field, it conducts reasoning and judgment, simulates the decision-making process of human experts. The expert system has the characteristics of enlightenment, transparency and flexibility. The difference from the general application program is that the general application program implicitly compiles the problem solving knowledge into the program, while the expert system separates the problem solving knowledge in its application domain into an entity, namely the knowledge base. The general steps of establishing an expert system are: designing the initial knowledge base; prototype development and testing; improvement and induction of the knowledge base. The structure of an expert system based on neural network is shown in Fig.3 [7].

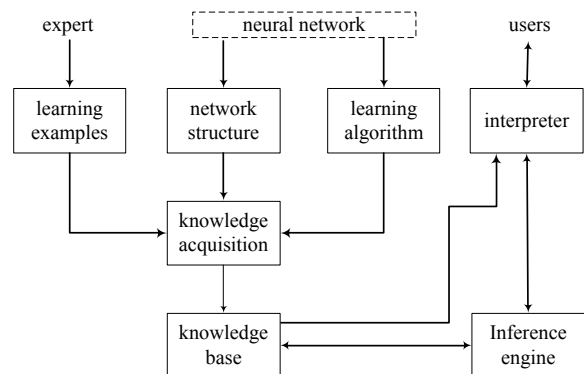


Figure 3. The structure of an expert system based on neural network

The expert system can be applied to research air combat decision-making for UAV [9]. Aiming at the mid-range decision-making problem of UAV, a 2D typical model of air combat is established, genetic algorithms and expert systems are combined to establish an evolutionary expert system tree framework and a tactical decision system.

### C. Application of automatic planning in UAV

Path planning in automatic planning means that the UAV searches for an optimal or sub-optimal path from the starting state to the target state according to a certain performance index (such as distance, time, energy, etc.). The main problems involved in path planning include: using the obtained environmental information to establish a more reasonable model, and then using a certain algorithm to find an optimal or nearly optimal collision-free path from the starting state to the target state, being able to handle uncertainties and errors in path tracking in environmental model, using all the known information to guide the flight control system of UAV to obtain relatively better behavioral decisions.

Path planning can be used in autonomous obstacle avoidance of UAV [10]. The anti-collision automatic sensing flight of UAV is of great significance for improving the efficiency of airspace and ensuring airspace safety. Path planning is the basement to realize the automatic sensing flight of anti-collision UAV. Based on Dubins algorithm, an automatic path optimization planning method for complex and multi-obstacle conditions is adopted. The maneuverability of UAV and the efficiency of mission execution are fully considered in the method, and path planning for UAV which flies autonomously is carried out.

### D. Application of Distributed Artificial Intelligence in UAV

The multi-agent system in distributed artificial intelligence studies how to coordinate intelligent behaviors among a group of autonomous mobile agents. Multi-agent coordination means that agents adjust their respective behaviors through reasonable arrangements of resources and goals, in order to achieve their or system goals as much as possible. Coordination is a dynamic behavior, which is an agent's adaptation to the environment and other agents. It is often achieved by changing the agent's own state. Multi-agent collaboration is to achieve common goals through appropriate coordination and cooperation. Countermeasures and learning are the internal mechanism of agent cooperation. Through interactive countermeasures, the agent chooses the best response action based on the opponent or joint strategy under rational constraints. The agent's action selection must be based on the understanding of the environment and other agent actions. Through the coordination of multiple UAVs, using global information, knowledge and skills, multi-UAV systems cooperate to complete complex tasks that a single UAV cannot accomplish independently. A model of multi-UAV cooperative mission planning system is shown in Fig.4 [11].

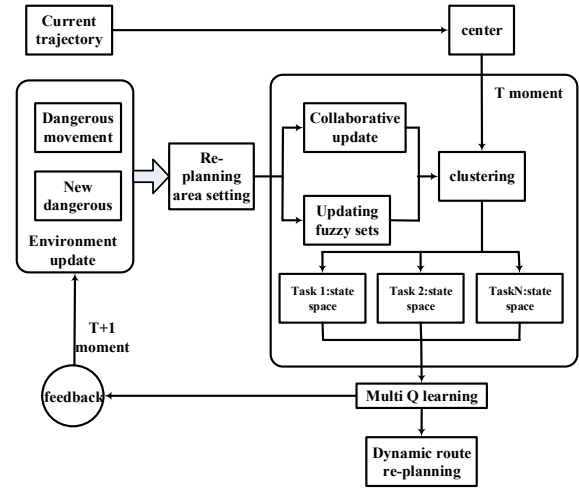


Figure 4. A model of multi-UAV cooperative mission planning system

Distributed artificial intelligence can be used in multi-UAV cooperative formation [12]. A multi-UAV formation model is established, graph theory is used to describe the communication topology of the formation. The virtual long aircraft state is estimated to guide the formation flight. Based on position, speed and heading as co-variables, a controller with a linear mixer is designed to enable each UAV to quickly follow the desired formation command and maintain the formation stability.

## IV. CONCLUSION

With the development of information technology, three major characteristics of UAV have been emerged:

- 1) The development of UAV is closely related to the new technology industry. New technologies such as big data, cloud computing, and the IoT (Internet of Things) are profoundly affecting the changes in the technology of UAV.
- 2) Information infrastructure will become an important support for main network measurement & control and flight management of UAV.
- 3) Artificial intelligence technology will become the first disruptive technology for the next development of UAV.

In addition, with the advancement of artificial intelligence technology, the continuous improvement of computer processing speed, and the development and application of cutting-edge basic technologies such as new technologies, new materials and new processes, the artificial intelligence-based UAV will be promoted to become more autonomous and miniaturized.

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