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Technology Framework of the Intelligent Command and Control System

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Abstract. With the rapid application and development of artificial intelligence technology in the civilian field, the research on intelligent combat and command systems in the military field is also intensifying. In order to improve the cognition and decision-making ability of international command and control system, this paper elaborates the overall technical framework of the system, and brings forth intelligent solutions and development suggestions in situation cognition, planning, decision making, and action control.

1. Introduction

It is internationally agreed that the future war will be based on the informatization and networking system. With the development of artificial intelligence (AI) technology, the military field will focus on the development of intelligent equipment technology, and strive for battlefield informatization advantages on cognition, decision-making, and action [1]. Intelligence is defined as extension of human behaviors by machine simulation, including calculation, perception, cognition, prediction, thinking, and decision-making [2]. Moreover, intelligent command and control system (ICCS) assists commanders with AI in solving commanding problems of calculation, perception, understanding, and cognition.

The ICCS of each country is its military core equipment, which is based on the network center and has certain information advantages. However, it is difficult to transform the explosive growth of battlefield information to the cognition and decision-making advantages of commanders. Traditional methods fail to adapt to the complexity and nonlinear characteristics of commanding the battlefield [3]. The emergence of new combat styles, such as unmanned combat and cyber warfare, poses severe requirements on the capabilities of cognition and decision-making. Future wars require accurate situation understanding and intelligent planning and decisions, which is a difficult problem and relies on breakthroughs in cognitive technologies.

2. Research Status of ICCS

The foreign military is very concerned about the research of intelligent technology in combat and command systems. The Defense Advanced Research Projects Agency (DARPA) of the US military has carried out research on combat intelligence as a disruptive technology. In 2007, it launched the dark-green plan [4], which can predict enemy actions, automatically launch different combat plans, and guide commanders to make quick and correct decisions, based on parallel simulation technology and real-time battlefield situation. The plan was suspended in 2011 due to the lack of breakthroughs in cognitive



intelligence technology at that time. It is unknown whether the research has been carried out in the near future. The dark-green plan, as an exploration of the US military in the intelligence of combat and command system, is worthy of learning for the understanding of the battlefield situation and the search strategy for decision-making.

In 2015, the US military proposed a third offset strategic plan to use AI technology to improve the decision-making effectiveness of commanders. In the field of intelligent sensing, DARPA has launched research projects, such as insight, XDATA, deep learning, deep text search filtering, distributed battlefield management, and human-machine collaboration, to develop deep understanding, feature extraction and association mining technologies on the analysis of texts, images, voices, videos. In the field of cognitive intelligence, it has launched research projects such as Mind's Eye, trace, distributed battlefield management, human-machine collaboration, X-plan, and cognitive electronic warfare. Using intelligent algorithms for situation awareness, reasoning, and efficient independent decision-making in different combat scenarios, the agile advantage in the observation, orientation, decision, and action (OODA) is obtained.

In 2016, the United States (US) Army launched the commander virtual staff program, and the US Army launched the commander virtual staff program. The US military command system was further developed toward intelligence, using AI technologies to provide intelligent human-machine interaction to achieve situation awareness, recommendations for forecasting, automatic plan generation, and knowledge-based electronic warfare programs [6]. At the same time, the US Air Force and the University of Cincinnati jointly developed the intelligent system Alpha AI [7], using genetic fuzzy algorithms to defeat the experienced US Air Force colonel in simulated air combat, which indicates that AI has made a breakthrough in the ICCS. In 2016, to ensure the leading position of the US, the US military released three white papers on the military development strategy of artificial intelligence, and set up projects to improve capabilities of manned and unmanned control, including independent negotiation formation, big dog, and hummingbird. In short, the US military has applied intelligent technologies to the field of ICCS, and some technologies have made breakthrough and passed actual tests, which reaches the world's leading technology level [7].

In addition, Germany, France, Russia, and Israel have also achieved many results in intelligent information perception and processing, intelligent and autonomous unmanned combat platforms [8]. The ambition of intelligent militarization demonstrated by all countries will surely set off a global military intelligent technology competition.

Domestic civil AI technology has made great progress in image recognition, speech recognition, and natural language processing. In the aspect of real-time strategy (RTS) games, a certain number of game confrontation samples have been accumulated, and a good technical ecology has been formed. In the field of ICCS, with the exposure of the US military AI plan, and the advent of AlphaGo, especially the rapid development of a new generation of artificial intelligence technology represented by deep learning and reinforcement learning, domestic literature has carried out military AI technology research [2, 8].

3. Overall Architecture of ICCS

3.1. Functional System Architecture

The international ICCS architecture will transform from informatization and network center to intelligence and knowledge center, which uses AI to assist commanders in solving problems in computing, perception, understanding, and cognition. Significant changes will occur from both the integrated architecture between systems and the technical architecture within the system. Integration between systems can bring about the sharing of informatization, intelligence and knowledge. The system intelligently applies functions such as situation, command, control, and protection, to enhance the cognitive and decision-making advantages of combat and command system. The functional system architecture is proposed in this paper, as shown in Fig. 1.

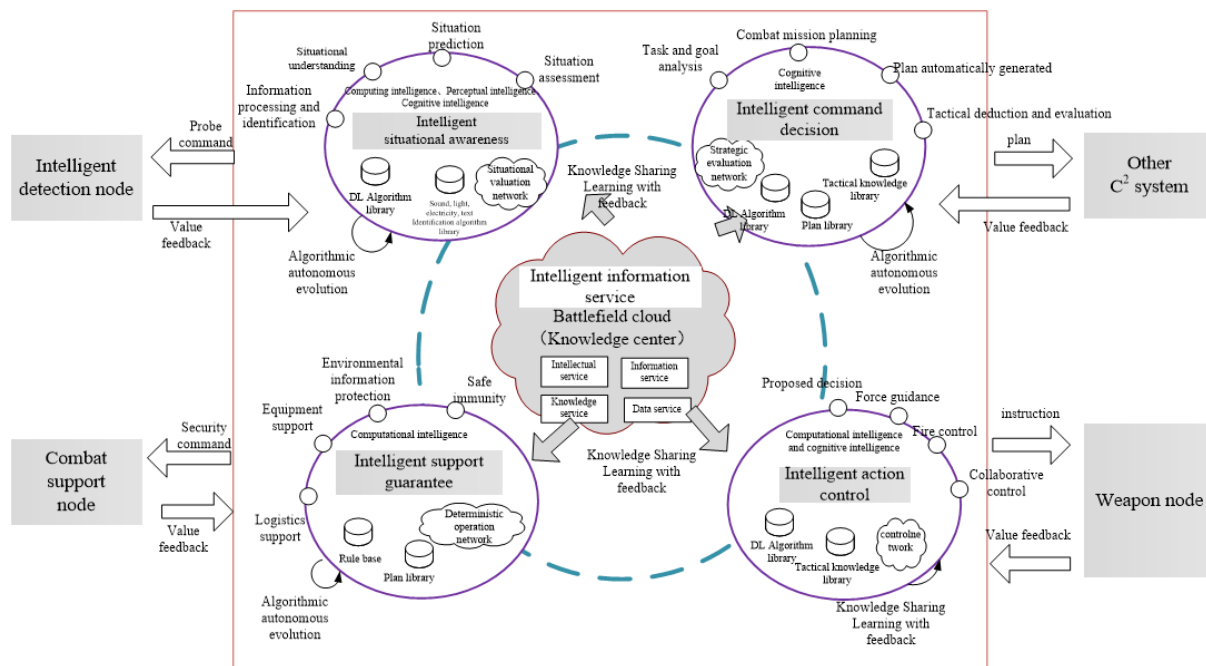


Figure 1. Intelligent command information system architecture concept diagram

The ICCS is equipped with intelligent training and learning capabilities in the functional elements such as situation awareness, command decision, action control, support guarantee, and information service to meet the needs of intelligent algorithm for machine learning and data accumulation. The system uses the AI algorithm for self-learning and self-evolution, and provides the commander with the intelligent ability to understand, predict, and make decisions.

Artificial intelligence can be divided into computational intelligence, perceptual intelligence, and cognitive intelligence. Intelligent situation awareness covers computational intelligence, perceptual intelligence and cognitive intelligence, which is responsible for target recognition and battlefield intelligence information processing. It understands and predicts the situation, and can enhance information superiority. Intelligent command and decision-making, which is based on cognitive intelligence, solves combat planning problems, and provides commanders with intelligent reasoning, optimal combat and action plans. The intelligent decision-making at the tactical level is relatively easy to break through. The decision-making at the operational level involves complex command art problems and is difficult to break through. Intelligent mobile control is based on computing intelligence and cognitive intelligence, which can complete task action monitoring and temporary tactical control, and provide action optimization strategies for knowledge reasoning, such as command, guidance, firepower coordination, unmanned platform and cluster intelligent control. Intelligent comprehensive security, based on computational intelligence, is responsible for optimization of battlefield resources under prior knowledge and rules. In addition, intelligent training and learning is a special feature of the intelligent system. It combines accusation with simulation training, training personnel and algorithms in peacetime and deducing parallel programs in wartime.

ICCSs are based on cloud-end architecture. Intelligent knowledge is integrated and shared with information integration. Each system deploys intelligent algorithms and knowledge rules in the cloud center, and finally forms a knowledge sharing center, providing plug-and-play knowledge services for battlefield detection and heterogeneous nodes such as command and weapons. The ICCS acquires existing intelligent knowledge from the knowledge center, and combines the acquired battlefield data for secondary learning and training to improve algorithmic capabilities. A battlefield knowledge network is formed between each ICCS and the battlefield cloud.

The ICCS has a self-evolving feedback learning mechanism. First, the nodes can learn independently and optimize the intelligent algorithm. Second, the system uses the battlefield cloud to share intelligent algorithms and knowledge, and collaboratively complete the learning evolution of each node. Third, the corresponding command execution effects are collected, after the operational plans and plans are issued to other command systems and tactical nodes. These feedback results are beneficial to the learning evolution of intelligent algorithms in related fields.

3.2. Technical Architecture

The technical architecture is the technical framework for system design, development, integration and testing. The technical architecture of the ICCS is shown in Fig. 2. Based on the traditional computing environment of the system, the intelligent computing environment is built and the AI is integrated, whose software and hardware meet the intelligent computing requirements of the system. The intelligent computing environment is an open computing environment, which adopts a service-oriented approach to system integration, providing intelligent services for related situation, decision-making, and control services. At the same time, it provides intelligent human-machine interaction means for commanders to improve the system performance.

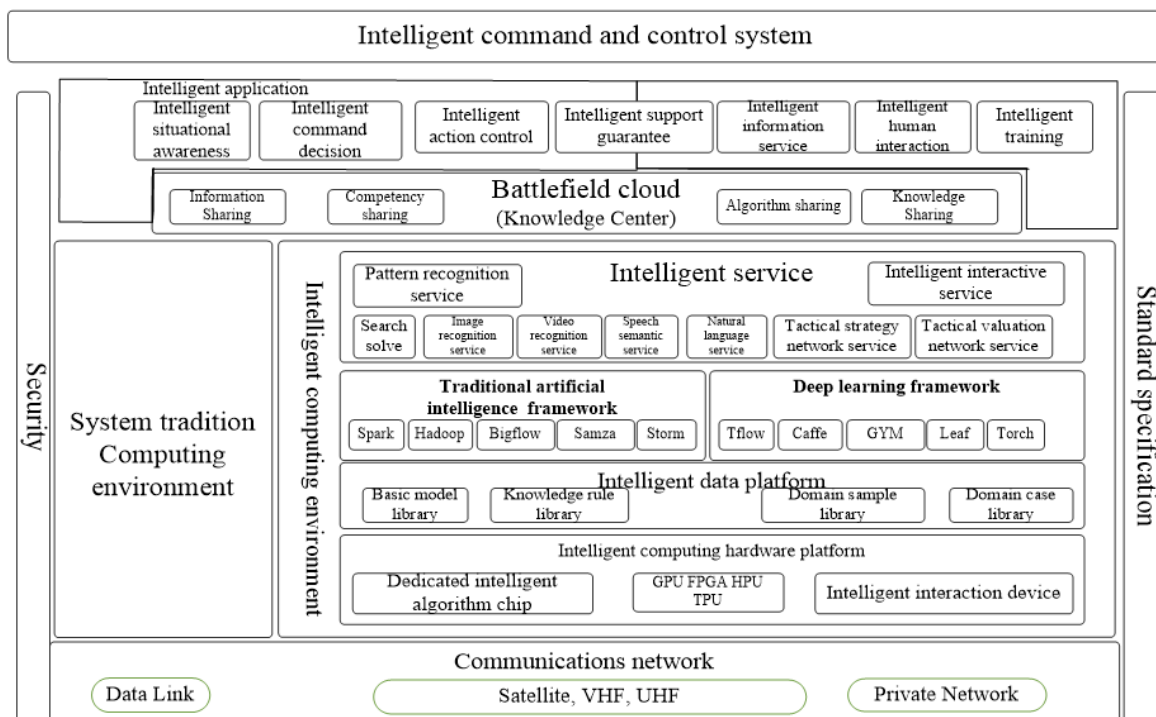


Figure 2. Intelligent command information system technology architecture concept diagram.

The intelligent computing environment consists of six layer structures.

(1) The intelligent computing hardware platform layer. It includes AI computing hardware devices, such as graphics processing unit (GPU), field-programmable gate array (FPGA), and tensor processing unit (TPU), to adapt to the computing power required for deep learning. Some algorithms use brain-like chips of neuron processing mechanisms or solidified intelligent computing chips, such as embedded image recognition chip.

(2) Intelligent data management platform layer. This platform carries out management of intelligent data, samples, basic model libraries, knowledge rule bases, and typical cases.

(3) Deep learning framework layer. The development environment integrates deep learning and reinforcement learning. The framework is flexible and scalable, and provides an efficient and intelligent algorithm library for feature learning and extraction, and reinforcement learning.

(4) Traditional AI computing framework layer. This layer is for AI and distributed computing support for search solving, knowledge reasoning, big data mining, and parallel processing.

(5) Intelligent service layer. Based on the AI computing framework, the application-oriented general intelligent algorithm service library covers the basic general algorithm library of computational intelligence, perceptual intelligence, cognitive intelligence and other aspects, and provides an intelligent solution service interface for application development.

(6) Intelligent application layer. This layer consists of many functional elements, including intelligent functional situation recognition, planning decision-making, action control and information services, human-machine interaction, and learning and training, which is the core problem to be solved.

The above intelligent computing environment is combined with the intelligent application layer to realize the development, operation and deployment of the ICCS, to provide information knowledge sharing and synchronization between the systems with the service-oriented capability of the battlefield cloud. The system learns in actual combats, and improves the ability of various situation awareness, command, and decision-making. The ICCS will jointly build an intelligent battlefield command information system, and change the command and control mode from the physical and information domain to the cognitive domain.

4. Technical Analysis of ICCS

The intelligent system technology mainly solves the intelligent problem of various functional elements of the system, and transforms the information advantage into the cognitive and decision-making advantage. For the intelligent technology of the system, the literature has some analysis [2, 8]. Based on the literature for the intelligent technology and the international understanding of the system, the application of intelligent technology is analyzed, as shown in Fig. 3.

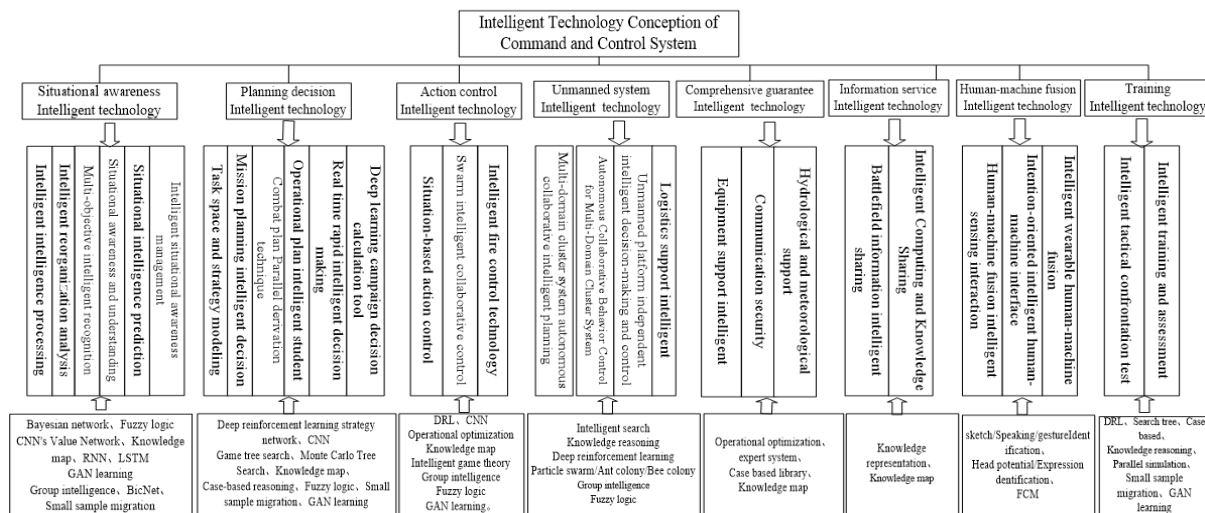


Figure 3. The technology analysis and AI method of Intelligent command information system.

4.1. Intelligent Technology of Situation Awareness

It mainly solves battlefield cognition problems, including intelligence processing, intelligence reorganization analysis, target intelligent recognition, situation cognitive understanding, and situation prediction. Here, intelligence processing belongs to the category of computational intelligence, and target intelligent recognition belongs to perceptual intelligence, situational cognitive understanding and situation prediction is in the category of cognitive intelligence.

For intelligence processing technology, the optimal filtering fusion algorithm based on optimal control and knowledge rules is used to integrate the battlefield target state. The deep learning method can be applied to the target maneuver mode and relevance discrimination to improve the reliability of the fusion.

With intelligence reorganization analysis technology, commanders can be liberated from massive information and focus on command and decision, by using big data, deep learning, fuzzy logic, knowledge maps and other technologies for information intelligent association matching, text semantic intelligence analysis, lyric search and extraction.

For multi-objective intelligent recognition technology, the feature extraction and automatic recognition of optical, infrared, electromagnetic and acoustic targets acquired on the battlefield are carried out. The deep learning method is used to construct a multi-layer convolutional neural network (CNN), and the sample feature parameters are used to complete the target classification.

For intelligent situation awareness and resource management technology, real-time resource planning and coordinated deployment of various sensors and detection platforms on the battlefield to optimize detection tasks and maximize information advantages. The method is mainly based on linear operation, supplemented by swarm intelligence algorithm.

For situation awareness and understanding techniques, the dynamic relationship, behavior intentions, and trends between combat entities can be estimated, including tactical group identification and capability analysis, intention analysis, and timing of engagement. The traditional template-based situation cognitive reasoning techniques, Bayesian network methods, and fuzzy inference methods are difficult to accurately describe situational trends. The mechanism of AlphaGo valuation network technology can be used to simulate the thinking process of commanders' battlefield situation cognition. CNN has powerful feature expression and fitting ability, which is beneficial to analyze the space of each combat entity in the battlefield situation, distribution, and correlation feature extraction fitting. To get the understanding results, a mapping from situational image to situational understanding results can be established with CNN [9]. In addition, small samples of Bayesian learning methods, migration learning methods, recurrent neural network (RNN), long short-term memory (LSTM) and other intelligent algorithms can also be applied in situational understanding.

For situational intelligence prediction technology, to estimate and derive the enemy combat behavior, a situation prediction network can be constructed with the integration of AlphaGo strategy network and parallel deduction technologies.

4.2. Intelligent Technology for Planning and Decision-making

Modeling techniques for combat mission space and strategy. Using the complex network modeling and Bayesian network modeling technology, the state and action strategy of the combat mission space are modeled and described.

Intelligent decision-making technology for mission planning. Using deep reinforcement learning combined with fuzzy reasoning, group intelligence, and knowledge reasoning algorithms, the combat units are planned for force compilation, task assignment, firepower distribution, group coordination, and action path.

Parallel deduction technology for combat plans. Referring to the dark-green system parallel simulation technology, the Monte Carlo search tree, and the game test method are used to preview and evaluate the action flow.

Intelligent generation technology for operational plan. Relevant operational plans and command sequences are generated automatically with natural language understanding, voice command recognition, and sketch recognition technologies.

Real-time intelligent decision-making technology. Based on the battle plan, the reinforcement learning algorithm is applied to generate the temporary plan with the current situation.

A battle decision calculation tool based on deep learning. Provide computational tools for the analysis of campaign tasks for high-level decision-making.

4.3. Intelligent Technology of Action Control

Situation-based temporary action control technology. Parallel simulation and reinforcement learning methods are used to predict the situation, determine the deviation of combat operations, and adjust the action [4].

Group intelligent collaborative control technology. Based on the ant colony and bee colony control algorithm, the tactical strategy control is constructed with reference to the AlphaGo deep reinforcement learning method

Intelligent precision firepower control technology. The speed and accuracy of threat target recognition and firepower distribution can be improved through intelligent algorithms.

4.4. Command Technology for Combat Integrated Support

Deterministic methods such as operational optimization, expert systems, case libraries, and knowledge maps can be utilized for the command, dispatch and coordination of logistics support resources such as logistics, equipment and communications.

4.5. Intelligent Control Technology for Autonomous Collaboration of Manned and Unmanned Systems

Intelligent planning technology for autonomous coordination of multi-domain cluster systems. The particle swarm, ant colony, bee colony, RNN and other swarm intelligence algorithms are used to coordinate the task planning and motion trajectory of the manned and unmanned system.

Behavior control technology for autonomous coordination of multi-domain cluster systems. The group intelligence algorithm is used to conduct mission command, guidance, conflict detection, and collision avoidance of unmanned platforms.

Independent intelligent decision-making and control technology for unmanned platforms. The fuzzy logic technology is used to control the tactical tasks of unmanned platforms.

4.6. Intelligent Information Service Technology

Based on the subscription services, battlefield information intelligent sharing technology uses fuzzy reasoning and semantic association technologies to analyze user information needs and preferences, and pushes information actively.

Based on knowledge modeling, intelligent computing and knowledge technologies share intelligent algorithms between systems and knowledge centers with service technology.

4.7. Intelligent Human-machine Interaction Technology

Intelligent sensing and interaction technology with human-machine fusion. Using deep learning methods, multi-channel human-machine interaction means are provided including sketch, speaking, gesture, head pose, expression, eye movement, and brain electricity [5].

Intention-oriented intelligent human-machine interface technology. Human-machine interaction interfaces are provided on demand with the interaction reasoning method based on fuzzy c-means (FCM).

With intelligent wearable human-machine fusion technology, an interactive mode between a single soldier and a wearable device is provided.

4.8. Intelligent Technology for Training and Assessment

Intelligent combat game test technology. Based on the modeling of combat knowledge, intelligent red and blue confrontation training is carried out with game theory and decision tree technology.

Intelligent training and evaluation techniques. Based on the collected data samples and deep reinforcement learning techniques, tactical effectiveness are evaluated with the constructed intelligent decision-making algorithms.

5. Problems and proposals in ICCS

Although AI can enhance the cognitive and decision-making ability of the system, there are still many problems before it can be applied to the ICCS field.

5.1. Battlefield information is incomplete and state space modelling is difficult

Battlefield situation is difficult to distinguish between true and false, and the tactical strategies of both sides are completely unknown, which leads to the complete uncertainty of the battlefield and makes it impossible to establish an accurate model of battlefield situation, mission, and resources for the state space.

5.2. Difficulties in Strategy Space Expression of Intelligent Decision-Making

Due to the lack of consistent understanding of operation rules and knowledge, it is difficult to develop standard methods for operation rules and expressions. It is more difficult to express a higher-level decision-making strategy.

5.3. Lack of Training Samples

It is difficult to acquire battlefield tactical sample data, which is not conducive to the solution of intelligent algorithms [10].

5.4. Computational Power Needs to Be Strengthened

Intelligent algorithms for ICCS need a proprietary intelligent computing hardware platform to construct a huge amount of state space, and input multi-layer neural network for feedback learning and reasoning, need. For instance, AlphoGo uses more than 1200 central processing units (CPUs) and more than 170 GPUs. The calculation ability required by intelligent algorithms needs to be strong.

5.5. Proposals for ICCS

Strengthen the knowledge engineering construction in the field of ICCS. Accumulate military rules, tactical knowledge, actual combat data, and carry out knowledge modeling.

Establish a confrontational game test platform. By conducting flag-based deduction, man-machine confrontation, red-blue confrontation, accumulate training samples, and establish an accurate strategy network and value valuation network [11].

The international focus is on the application of deep learning in the situation, the application of deep reinforcement learning in planning decision-making, and the actual demonstration and verification of intelligent algorithms [12].

Research from easy to difficult in stages. In the first stage, AI techniques such as image, voice, gesture, and face recognition are applied to intelligence processing and analysis. In the second stage, deep learning and reinforcement learning techniques are applied to situational awareness and command decision making. The application of intelligent technology is a long-term process.

6. Conclusion

This paper proposes the architectural vision and key technical framework of ICCS, helps to arouse wider reference and debate, and provides a method for its development. From the open literature, there are not many verified projects in the field of international ICCS, and the application of intelligent technologies needs long-term research. Once the intelligent technology lags behind, it will be the backwardness of the "intelligence" of the battlefield, which results in an expanding gap in equipment technologies. Therefore, the application of intelligent technologies in ICCS is extremely urgent for various countries.

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