Study on Artillery Intelligent Engineering Concept and Overall Architecture

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ABSTRACT

To solve the problems of confusing concepts and uncertain technologies in the development of intelligent artillery, this paper proposes to study intelligent artillery from the perspective of intelligent engineering concept. First, the concept of intelligent artillery engineering is explained, and the scientific ideas and methods of intelligent artillery research are defined. Second, through the analysis of the characteristics of including artificial intelligence in artillery weapons, five typical forms of intelligent artillery are preliminarily envisaged. Then five levels of intelligence are proposed for AI-enabled artillery weapons. Based on this, the typical characteristics of intelligent artillery are summarized, and the focus of the development of intelligent artillery is described. Finally, the overall architecture of intelligent artillery is analysed, the heuristic system composition and its correlation at the core of the algorithm are clarified, the instantiated overall architecture diagram of intelligent artillery is established, the centralized and distributed implementation modes of intelligent artillery are proposed, and the conceptual image of intelligent artillery is presented.

Keywords: Artificial intelligence; Intelligent artillery; Intelligent engineering; Overall architecture; Fire strike

INTRODUCTION

Artillery is the backbone in conventional weapons and equipment, undertaking critical firepower output tasks in modern military operations. The sophistication of artillery weapons represents the modernization level of a country's military forces and is a key development direction of the weapon industry in many countries. As military intelligence and equipment intelligence are accelerating in a comprehensive way, the concept, enabling mechanism and related theories of artillery intelligence are the basis to support the construction of the artillery intelligent engineering system.

Although some world military powers started the research on artillery intelligence much earlier, they mainly focuses on component intelligence or application intelligence, and a comprehensive study on artillery systematises is yet to be done. The concept of intelligent artillery remains unclear and its definition is under discussion. At present, the concept description is mainly about its intelligent characteristics in the process of application. For example, the intelligent artillery weapon system applies artificial intelligence (AI) technology to the operational links such as artillery weapon task understanding, target detection, combat command, action control, so that artillery weapons have the capabilities of autonomous perception, autonomous judgment, independent decision-making, autonomous action and autonomous coordination, and realize

complete autonomy in the whole operation process from detection, tracking, striking and damaging targets [1]. The basic functions of the unmanned intelligent artillery system are:

- Automatic positioning
- Automatic perception-automatic analysis
- Automatic identification
- Autonomous judgment
- Intelligent decision-making
- Autonomous disposal
- Automatically reporting evaluation
- Automatic reset

In the autonomous disposal link, the function of human authorized intervention needs to be added to deal with the complex battlefield environment and make the weapon more accurately strike the target [2]. The above concept basically describes the application of artificial intelligence technology in artillery weapons in a more comprehensively way, but improvement is only made in terms of the unmanned and intelligent functions of some existing artillery weapons, and cannot accurately clarify the key points and direction of using AI technology to drive the reform of artillery weapons,

which also restricts the rapid integration of AI into artillery weapons to realize innovative development.

LITERATURE REVIEW

Concept of intelligent artillery engineering

Intelligent artillery is still under exploration and development, and its basic concept has evolved gradually in this process. However, as an overall technical direction leading the reform and development of artillery equipment in the future, its technical field and objectives must be clearly defined so as to guide the systematic development of intelligent artillery. Therefore, it is proposed to study it from the perspective of intelligent engineering. Intelligent engineering is based on intelligent science to develop intelligent application systems by using intelligent technology and intelligent system tools, and combing the specific needs of national economy and national defense construction, so as to realize intellectualization on the basis of informatization driving industrialization [3]. Intelligent artillery engineering, namely the combination of intelligent engineering and artillery, is based on intelligent science to study the intelligent artillery weapon systems by using intelligent technology, intelligent system tools and combining the needs of military equipment development, so as to realize intelligence on the basis of artillery mechanization and informatization. Its conceptual framework is shown in Figure 1.

In the concept, intelligent science focuses on the essence of intelligence, and provides a theoretical basis for the construction of intelligent systems through the frontier interdisciplinary research in brain science, cognitive science, artificial intelligence and other disciplines; intelligent technology, under the guidance of intelligence theories, is employed to study the implementation method of intelligence, and provides a technical basis for the development of intelligent systems through technical integration of pattern recognition, machine learning and neural network; intelligent system tools are guided by intelligent technology, aim to study the realization of intelligence, and provide development tools for the development of intelligent systems through the integrated

application research in chips, algorithms, databases and other tools; driven by military demand, the mechanization and information technology of equipment is taken as the basic platform support to study the specific application of intelligent technology and tools in artillery, promote the breeding of various intelligent forms of artillery weapons, and develop new artillery enabled by intelligent technology.

Based on the above analysis, the proposal of the intelligent artillery engineering concept is conducive to clarifying the ideas and methods of artillery intelligent technology research, and avoiding the narrowing of research directions due to the concretization of the concept and the convergence of equipment forms. With intelligent artillery engineering as the driver, the future form of intelligent artillery will be a complex engineering system with algorithm as the core, hardware as the basis, data as resources, links as gain and tools for expansion.

Typical forms of AI-enabled artillery

Intelligent weapons and equipment refer to the equipment with the functions of perception, analysis, reasoning, decision-making and control. As a typical intelligent weapon/equipment under vigorous development, intelligent artillery features the integration and deep fusion of artillery technology, information technology and intelligent technology. The application of AI technology in artillery engineering allows the emergence of a guidance-based enabling method with new qualitative characteristics such as autonomous learning, knowledge renewal and ability growth for artillery weapons, which completely changes the indoctrination-based enabling method of traditional equipment relying on programmed control by human. The guidance-based AI-enabling process lets artillery weapons to surpass the limit of human control ability and demonstrate more powerful capability in actual combat under the guidance of human will. According to the current development direction and trend in AI technology, combined with the characteristics of firepower of artillery weapons in combat, the intelligent artillery are developing toward the following five forms.

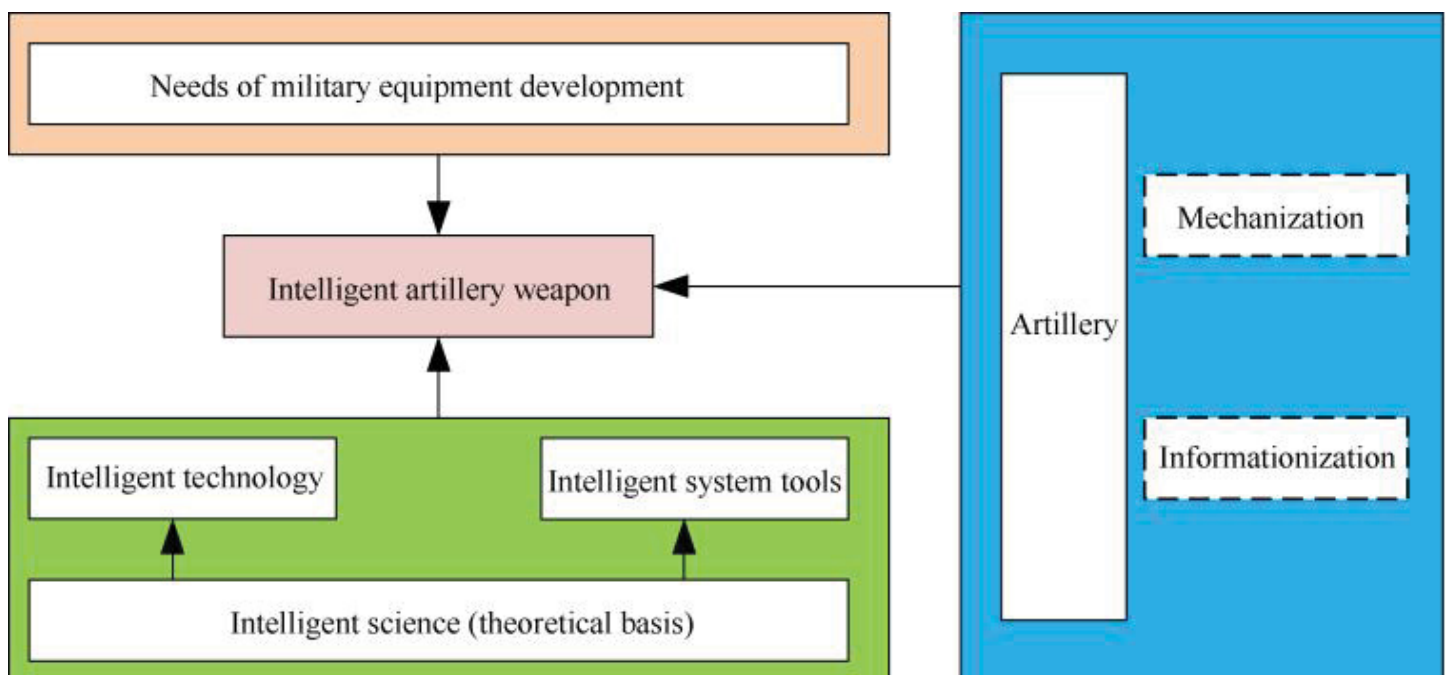**Form of independence intelligent artillery:** In this form, the

Figure 1: Conceptual framework of intelligent artillery engineering.

independence artillery equipment is the main body and has the capabilities of machine learning, knowledge updating and function upgrading based on AI technology. Its machine learning mainly depends on the cognitive norms provided by human. Under manual guidance, independent information acquisition and data mining are carried out through a single platform or system to complete the training and obtain the corresponding cognitive ability. Based on the existing cognitive ability, with less manual intervention, corresponding judgment and decision-making can be made, and the artillery can independently execute and complete the necessary tasks.

Based on the software and hardware platform of artillery weapons, developing the independence intelligent artillery focuses on strengthening the capabilities of information acquisition or learning, and using AI technology to build algorithms and models for identification, decision-making, control and management featuring more agile response, more stable state and more extensive adaptability, so as to realize the intelligent planning and decision-making, intelligent walking and deployment, intelligent loading and launching, intelligent diagnosis and repair and other operations without manual or less manual intervention. With the support of AI technology, the artillery weapon has the advantages of fast mobile combat response, strong adaptability to all-weather and all-day operations, high operational reliability in extreme environments, and sudden and fierce combined fire attack of point and surface targets.

Form of swarm intelligence artillery: Based on the independence intelligent artillery, the swarm intelligent artillery has improved capability of coordination between artillery equipment, which obtains and gains cognition through joint information of multiple equipment and has the capabilities of autonomous decision-making with more comprehensive judgment and stronger real-time performance. Data sharing can be used among multiple equipment to realize joint learning and focused training. For each independence artillery, the corresponding AI-enabling elements are determined according to the characteristics of its functional performance, deployment area and mission demand. Moreover, the equipment has the capabilities of rapid transfer and delivery of decision-making and execution, expansion and upgrading, as well as connectivity and cooperation, so as to realize AI-enabled efficiency gain.

In addition to achieving efficiency gain on the basis of independence artillery intelligence, it is more important for the swarm intelligence artillery to give play to the effect of combining multi-body weak intelligence to jointly generate strong intelligence. Its typical application is to use bionic algorithm [4]. to generate swarm enhanced AI-enabled artillery swarm. For example, the artillery swarm task collaboration based on the work division mechanism of ant colony can meet multi-task needs and realize the autonomous task execution of independence artillery through information interaction and cognitive exchange between artillery and between ammunition. The swarm artillery employs the incentive effect guided by the task trend to accumulate and aggregate the independence task results and generate a higher-level intelligent-enabling mode. This can solve the problem of poor matching between local intelligence enabling and comprehensive tasks of the independence artillery under complex system conditions, and give better play to the global effects of AI-enabled artillery in operations.

Form of system intelligent artillery: The system intelligent

artillery is to satisfy the needs of joint operations, be integrated into the battlefield combat system, build a real-time information and data interaction channel between artillery weapons and various equipment such as battlefield reconnaissance, command and control, guidance, strike, evaluation and support equipment. Under the supervision of people outside the working environment, it realizes collaborative training and knowledge co-construction between different equipment, and on the basis of the learning and evolution abilities of artillery equipment, it further integrates the cognitive and executive capabilities of the combat system. In addition, an algorithm and model base for the cognition, decision-making and execution requirements of artillery weapon adaptation system is formed based on the cloud network. In the actual combat, the artillery equipment interacts with the system cloud in real time and at high speed. On the one hand, the system cloud plans and distributes the mission objectives of each artillery unit according to the mission requirements, and assigns and updates the core algorithms and models for performing relevant tasks. On the other hand, each artillery unit continuously collects and updates battlefield information and reports it to the cloud during task execution; at the same time, it judges the task requirements according to the battlefield environment, continuously strengthens cognition during information retrieval, generates decision-making schemes and execution strategies, and retrieves reference models from the cloud when necessary to enhance the understanding of system tasks, and to realize AI-enabled artillery weapons at the campaign and tactical levels.

The development stage of system intelligent artillery will have an important impact on the essential form of artillery. As "highly generalized" and efficient interaction between the combat system and single equipment can be realized through the cognitive model, the tactical application on the battlefield is more flexible and the coordination between tasks is simpler. Therefore, two ways for artillery equipment to perform fire strike tasks will emerge. One is the assimilation of artillery equipment, i.e., the types and series of artillery equipment are extremely simplified, and the functions of independence equipment are diversified. A gun can match the corresponding functions according to the requirements of combat tasks, and perform the fire strike tasks defined by intelligent software. The other is the divergence of artillery equipment, i.e., the artillery equipment is in a modular assembly mode. According to the requirements of combat tasks, they can be autonomously matched to form the needed hardware platform. Under the battlefield combat system, the artillery can be combined in a variety of ways to perform the fire attack tasks defined by intelligent functions.

Form of co-evolution intelligent artillery: Co-evolution intelligent artillery is an organizational form of artillery with advanced intelligence. The whole artillery equipment system forms a multi-brain system of the octopus. An original ecology similar to the social organization will be built among the independence intelligent artillery, swarm intelligent artillery and system intelligent artillery. There are certain cognitive and decision-making experience exchange capabilities between equipment and between systems. Through generalized knowledge exchange, the all-time intelligent operation mode featuring multi-body mutual learning, mutual error correction and strong complementarity is achieved, which gives artillery weapons and equipment strong intelligent cognition, decision-making and execution abilities.

The co-evolution intelligent artillery allows the evolution of the traditional artillery fire attack mode based on Observation -
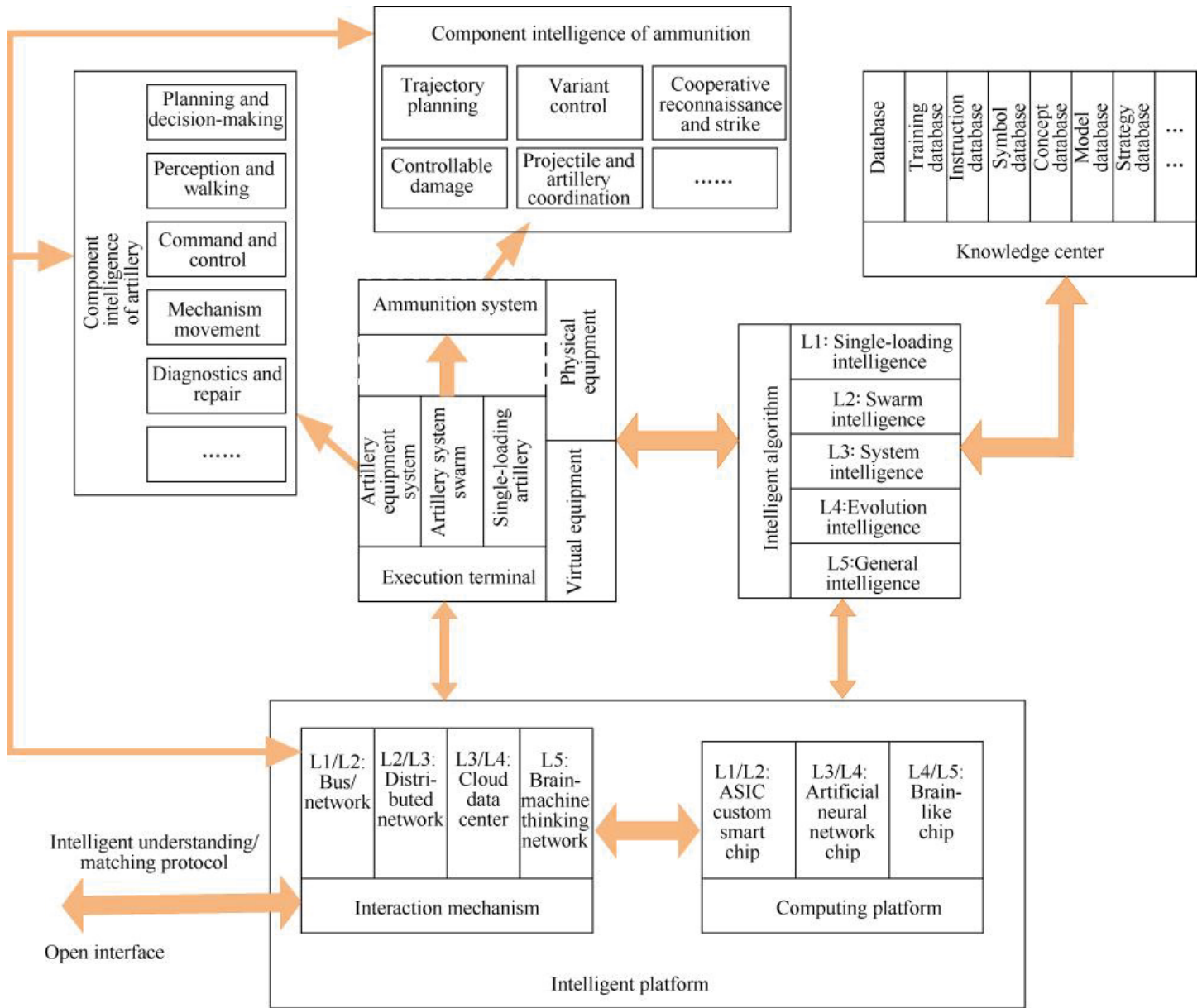
Figure 2: General architecture of intelligent artillery.

Orientation- Decision - Action (OODA cycle) into a fire attack mode based on mission prediction and action (PA mode). The reconnaissance, positioning and other links are regarded as the inherent resources of artillery weapons to simplify the cycle process, and improve the response speed and execution efficiency in high-intensity confrontation, thus achieving victory of artillery equipment with intelligence.

Form of general intelligent artillery: The general intelligent artillery is a high-level form of intelligent artillery in its development. At this stage, the artillery is combined with brain-inspired computing [5]. Which has a low ability to simulate the derivation of consciousness? With the brain-computer interface as the interactive mode, the intention of the human brain can be understood, and the ability can be increased through autonomous deduction to meet the needs of different scenarios. The most typical feature lies in the unification of the basic platforms such as intelligent chips and algorithms of general intelligent artillery, and there is no need to rely on a large number of customized software and hardware to meet the intelligent requirements of equipment. Task expectation and data resources become the decisive factors in the development direction of intelligent artillery.

The general intelligent artillery no longer emphasizes the use of the differences of functions of individual artillery units to establish confrontation advantages, but gives full play to the existing capability advantages through the integration of AI into the system in all domains. In this development stage, the core combat power of war and confrontation will be algorithm, and the core resource will be data. The performance of single equipment such as artillery, missiles and even nuclear weapons will no longer be the decisive factor in the war.

Analysis on the overall architecture of intelligent artillery

The overall architecture of mechanized and information-based artillery is a programmed system based on the hardware, and the corresponding system capabilities such as reconnaissance, command, decision-making, strike, damage and evaluation are established for the launch platform. Once the artillery platform is finalized, its basic capabilities are determined. All functions are realized in a programmed operation mode under manual instructions or direct intervention. Further performance or capability improvement can only be implemented through hardware replacement or software injection, and there is no dynamic self-growing support mechanism.

The overall architecture of intelligent artillery is a heuristic system based on the core algorithm, and the intelligent algorithm runs on the intelligent platform, which mainly performs algorithm operation and information interaction tasks. Furthermore, the intelligent algorithm and intelligent platform fall into different technical development stages supporting L1 ~ L5 intelligent artillery according to their intelligence levels. The intelligent algorithm accumulates the knowledge and experience acquired through training in the knowledge centre, and can immediately retrieve the corresponding knowledge content according to the actual application needs of artillery to guide its complex task execution. Under the control of intelligent algorithm, the execution terminal performs the specific interaction, movement, control, strike, damage, evaluation and other action processes of artillery and its ammunition. Meanwhile, it dynamically monitors, records and deduces the entity state in the form of digital twins, and integrates the twins into the system-level scene based on different time and space scales to implement task inference. This allows the artillery equipment and the ammunition fired to have the capabilities of feed forward control, parallel control and dynamic regulation, change the traditional artillery control method based on sequential program, and to deepen the understanding of enabling for better enabling. Figure 2 shows the general architecture diagram of intelligent artillery. Each main part can be used to build a centralized intelligent artillery weapon relying on a single artillery platform. Distributed intelligent artillery weapons can also be built based on different platforms and nodes in the system. The centralized and distributed modes can be freely switched and integrated, and thus high deployment freedom and expansion flexibility can be realized to an open intelligent system (Figure 2).

CONCLUSION

In the age of military intelligence, the development of artillery weapons and equipment is facing new opportunities and challenges in improving the intelligence level. This paper analysed the problems of unclear development ideas and technical directions and confusing concept of intelligent artillery, and clarified the scientific problems and key technologies to be addressed in the development of intelligent artillery from the perspective of intelligent artillery engineering. Then by analysing the trend of the integration of artillery technology, information technology and intelligent technology, this paper put forward the typical forms of artillery at five intelligent levels, which provides a preliminary insight into the big picture of intelligent artillery. Finally, the five levels of intelligent artillery was taken as the starting point, and the overall architecture of intelligent artillery was proposed, which supports the technical path of intelligent artillery engineering implementation, thus laying some foundation for the development of intelligent artillery technology.

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