Preface

Defining future: Harbinger studies on AI in Aerospace

Artificial Intelligence (AI) is intelligence demonstrated by machines: Simulating human thinking, and eventually achieving works as the proxy of human. As AI technology proceeding, scientists have attempted to summarize it from different perspectives, and the definition of AI is far from unified. But a common sense from the basic connotation can be elaborated as "intelligent machines that can perceive, think, cognize, and act like humans, and perform tasks that typically require human intelligence".

AI technology has experienced decades of vicissitude: Sprouting in 1956 when the Dartmouth Conference marked the formal birth of the discipline of AI, with scientists led by von Neumann and Turing trying to achieve AI through symbolic programming; growing during 1960s—1980s when related techniques broke through bottlenecks and AI applications germinated; depressing at the end of the 20th century when lack of hardware capacity and defected algorithms held back AI's progress; and finally flourishing in the 21st century when information technologies, like big data, cloud computing, etc., has brought new opportunities, and low-cost techniques, like massive parallel computing, deep-learning, and brain-inspired chips, drove AI on an upward trend. Now, a new generation of AI has been deeply integrated with industries and advanced toward industrial applications. Throughout the 60 years of development, AI technology has achieved great progress, but hardly reached the full-fledged state. AI still needs careful assessment and in-depth research.

The special column "AI in Aerospace" that *Transactions of Nanjing University of Aeronautics and Astronautics* (TNUAA) presents in this issue focuses on the development of AI technologies and their various applications in both aerospace and aviation fields.

In aerospace, AI applications include: planning and scheduling of space missions; vehicle-related research, like remote sensing, communication, space-detection, intelligent structural fault diagnosis and re-organization; intelligent information processing for vehicles and related software and systems; integrated space and ground control, etc. Aerospace intelligence is to improve the "autonomy" of vehicles. The improvement mostly depends on specific, profound studies conducted on individual scenarios, and only these studies can clarify AI's efficacy in aerospace. In this regard, I would like to extend some of my views as follows.

(1) AI is a great technology, but not a panacea. Although AI has been utilized in many fields, including speech recognition, text recognition, machine translation, image understanding, etc., it has not yet reached the fundamental intelligence that the human world needs. For example, driverless cars have become relatively mature, but no one really dares to sit in one without any control of it. Some fans of AI would cite the famous fight between AlphaGo and Master Lee Sedol to defend the mighty of AI. Intriguingly, the victory of AlphaGo again verifies the power of human intelligence rather than demonstrate the power of AI: AlphaGo was accomplished through strategy networks and value networks built by deep-learning and self-gaming, and evolved by a Monte Carlo tree search algorithm. Instead of relying on a chess knowledge base, it was self-trained by combining the memorized human games and the games accumulated by self-gaming. AlphaGo's self-evolution was assisted by the huge number of games that were crystallized from generations of human masters. An AI machine defeated a human by human's wisdom, just like a human building a car and then competing with the car in running, which seems funny and ridiculous. AI's power cannot yet compete human, as Academician TAN Tieniu, an AI expert, put it: "so far, no machine translators are able to translate the sentence 'the white car is a black car'".

(2) The development of AI is a gradually perfecting process and cannot be achieved overnight. Thanks to the introduction of deep learning, AI technology has made great strides and gradually turned to practicality, which in turn has driven its rapid growth. However, AI still holds a certain gap from being good and easy to

use：No AI algorithms are universal，and specific algorithms only output better results in specific fields or application scenarios；an AI algorithm's success depends on system parameters，and its users usually do not understand the meaning of parameters and have insufficient ability to control them，which leads to unexpected results；complex algorithms require large data and resources，which limits their applications；the control authority of AI is set too high in systems with human involvement，leading to problems in human-machine collaboration

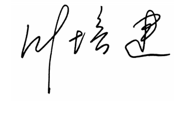
（3）Space is a special scenario with limited available resources，quite different from ground. In some cases，traditional technologies are more effective than AI. Instead of being solved by simply copying the ground solution，a space problem must be tackled from the fundamental perspective，and decisions must be made by comparing AI and traditional technologies. The effectiveness and reliability of AI depends on the learning process and the training data gleaned from past experiences. However，the limited number of spacecraft flights cannot provide enough samples for AI to learn. The predominant bottleneck of AI being applied in aerospace largely attributes to the lack of training data. Tasks in the deep space are the representative：Exploration in the deep space is more complex and eagerly needs AI's help，but the difficulty of flying into the deep space generates scare samples. Therefore，applying AI to aerospace needs to root in the practical situations，like actual mission requirements，hardware resources，software capabilities and ground synergy capabilities，and to systematically evaluate the effects，benefits and costs brought by AI. Thus，the application of AI can then be well developed.

（4）Development of AI in aerospace is a process of evolving from general to specialized and from specialized to general. It is not from scratch，and must learn from the top AI applications on the ground. But the learning process requires specialization by identifying characteristics of aerospace scenarios，finding out the commonality and generality across fields，and enacting specific hardware development measures. In this way，AI can well fit the development of aerospace technologies.

（5）Based on my own decades of aerospace practice and nearly 40 years of exposure to AI，I believe that the following directions need to be studied profoundly：1）As the ultimate goal of applying AI to aerospace，steadily improving the autonomous of spacecraft must be put as top one demand. 2）Researchers should take advantages of their respective expertise and develop application-oriented deep learning algorithms. 3）Synergistic development of spacecraft software/hardware capabilities should be emphasized to achieve optimal function. 4）A "general-special-general" route deserves an in-depth exploration for the development and application of aerospace AI. 5）Data for aerospace AI must be accumulated through international cooperation，and a ground-based support and simulation platform must be established.

These are my views on AI in aerospace sector，and I believe they echo the advantages and bottlenecks of AI in the aviation sector. Today，when AI research is in full swing，the publication of TNUAA's special column "AI in Aerospace" is of practical and provident significance. This column encompasses more than ten articles on application of AI in aircraft icing analysis，flight control，parameter prediction，target recognition，and airspace planning，etc. These high-quality papers will promote research and communication on AI technology among researchers in the aerospace field；join the efforts to enhance the depth and breadth of AI applications in aerospace；and contribute to the development of China's aerospace science and technology.

Academician of Chinese Academy of Sciences：YE Peijian



（Translator：ZHANG Bei；Editor：ZHANG Huangqun）