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Analysis of Intelligent and Unmanned Driving Modes for COMAC Aircraft

Boru Sun[1, *]

[1]Tianjin University of Technology, Tianjin, 300000, China
Corresponding author: 15831316288@163.com

Abstract:
In today's civil aviation sector, artificial intelligence (AI) has evolved into a critical arena for technological innovation and global industrial competition, reshaping how the industry operates at every level. Among the wide range of AI applications integrated across a civil aircraft's full lifecycle—from design and manufacturing to maintenance and operation—intelligent flight stands out remarkably. It not only revolutionizes traditional manual piloting modes with more precise control but also restructures future human-machine interaction paradigms in flight (shifting from pilot dominance to collaborative synergy) and reshapes air traffic management architectures to boost efficiency. This makes it the most distinctive and disruptive direction in the industry, as well as the core focus of global competition in civil aircraft intelligence.This paper elaborates on the core technologies underpinning intelligent flight, outlines a clear three-stage implementation path: "Assisted Intelligence → Enhanced Intelligence → Full Intelligence," identifies trustworthiness/airworthiness (ensuring compliance with strict aviation safety standards) and human factors (optimizing human-machine coordination) as two key foundational technologies needing breakthroughs for real-world application, and shares forward-looking insights on its development trajectory.

Keywords: Artificial Intelligence; Civil Aircraft; Intelligent Flight

1. Introduction

With the rapid development of artificial intelligence and 5G communication technologies, the autonomous driving and remote control systems for Commercial Aircraft Corporation of China (COMAC) aircraft are becoming increasingly mature, accelerating the transformation of traditional COMAC piloting modes towards automation and remote operation. This transformation not only significantly enhances the stability of air transport and reduces pilot workload but also effectively mitigates pilot shortages and lowers flight costs, injecting new vitality into the aviation industry. Under the global trend of aviation intelligence, CO-

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MAC, driven by technological innovation, proposed the technical concept of "manned supervision, unmanned driving" as early as the 13th Five-Year Plan period for design and R&D capability planning, laying the foundation for intelligent flight technology in large passenger aircraft. During the formulation period of the "14th Five-Year Plan in 2020, it further incorporated "research on autonomous flight technology for large passenger aircraft under manned supervision mode into its core technology guidelines, promoting the transition of intelligent flight from concept to practice. Its development path combines strategy and practicality: it not only relies on the accumulation of its own functional implementation capabilities to suit engineering applications but also draws on international experience by referencing the short-, medium-, and long-term plans of NASA and EASA. Furthermore, it refines the vision of intelligent flight into a three-stage path [1]. In the current fiercely competitive global aviation market, intelligent technology is key for COMAC to break through technological blockades and capture market share. Continuous R&D can enhance flight safety, optimize flight scheduling, reduce fuel and maintenance costs, and contribute to the sustainable development of the aviation industry.

COMAC's intelligent flight technology advances in three stages: The Assisted Intelligent Flight stage (2020-2025) enhances comprehensive perception through sensitive sensors, high-speed air-ground communication, and sensor fusion, relying on visual learning algorithms to achieve autonomous driving from taxiing to landing (e.g., Airbus's ATTOL project used cameras + LiDAR + radar modeling, conducting over 450 test flights), with AI providing decision support. The Enhanced Intelligent Flight stage (2025-2035) utilizes digital twins for full situational awareness and fault prediction, reduces crew costs through air-ground coordination [2], and promotes single-pilot operations supported by AR/VR [3]. The Full Intelligent Flight stage (2035-2050+) relies on an integrated space-air-ground information platform [4], uses AI + sensors for scene perception, achieves efficient decision-making through validated RPO collaborative frameworks (covering 98% of dual-pilot operations, reducing check time by 48% [5]), implements autonomous flight control and new energy technologies, ultimately achieving fully autonomous "free flight" and integrated space-air-ground coordination, providing flexible travel and precise maintenance.

Based on the background of rapidly developing communication technologies, this paper focuses on the trend of automation in COMAC aircraft, conducting research combined with existing autonomous driving and remote control technologies and systems. It provides a key review of core technologies: it outlines the composition architecture and working modes of autonomous driving systems, including perception, decision-making, and control modules, explains related technologies, analyzes the current status of Flight Management Systems (FMS) and prospects their evolution, and also focuses on the current level and future path of remote control technology.

2. Importance and Characteristics of Intelligent and Unmanned Driving Modes for COMAC Aircraft

2.1 Enhancing Flight Safety

Intelligent systems can fuse flight and weather data from multiple sensors in real-time, accurately identifying complex weather conditions and potential collision risks, and responding faster than humans. In the event of equipment failure or sudden extreme weather, preset avoidance procedures can be quickly activated, reducing risks associated with human error and significantly lowering accident rates. For example, onboard weather radar data can be used to construct an initial risk matrix, regularly updating precipitation particle distribution (dual-polarization radar distinguishes hail/raindrops). Improved A* algorithm can be used with constraints like track length, deviation, and hazard value to generate smooth detour paths [6].

2.2 Improving Operational Efficiency

Intelligent driving can optimize flight path planning, combining real-time airspeed, wind direction, and aircraft status data to optimize routes. During landing, curved approach paths can replace linear queuing, sequencing the landing order through ATC instructions, effectively improving flight punctuality and alleviating air traffic congestion. For instance, after implementing the Point Merge System at Xiamen Gaoqi Airport, arrival conflicts decreased by 30%, and on-time performance increased by 15%, mitigating "air traffic jams [7].

2.3 Reducing Operating Costs

On one hand, intelligent systems enable refined management of fuel and aviation materials, reducing resource waste. On the other hand, as technology matures, crew configuration models may be gradually optimized (e.g., single-pilot assisted systems), reducing labor costs, which is particularly significant for high-frequency, long-range flights. Using a dynamic calculation model for the cost index under remote cruise mode, considering factors like aircraft mass, cruise altitude, and ambient temperature, the flight profile is dynamically optimized with the goal of minimizing cost per unit distance. Verified by QAR data, fuel consumption is reduced by 3.7% compared to traditional cruise methods, especially suitable for long-haul flights [8].

3. Analysis of Core Technology Modules for Intelligent and Unmanned Flight in COMAC Aircraft

The realization of intelligent and unmanned driving modes in COMAC aircraft is based on the collaborative interaction of three technical modules: "Perception - Decision - Control." The perception module provides the aircraft's vision, the decision-making module acts as the "brain center," and the control module serves as the "executing hands and feet." The synergy of these three modules promotes the technological implementation from manned-assisted intelligence to fully unmanned driving.

3.1 Perception Module: Building a "Perception Network" for Full Domain Flight Situational Awareness

As the core prerequisite for intelligent flight, the primary goal of the perception module is to accurately capture real-time "aircraft self-status + external environmental information" by relying on multiple types of sensors and data fusion technologies. LiDAR scans the environment by emitting laser beams to generate high-precision 3D point cloud maps, playing a key role in obstacle detection during takeoff and landing, terrain matching during low-altitude flight, and aircraft positioning due to its centimeter-level ranging accuracy and resistance to light interference. For example, by processing point cloud data to remove distortion and combining Normal Distributions Transform with Kalman filtering, positioning accuracy of up to 97% can be achieved, especially compensating for the shortcomings of visual sensors in low-visibility scenarios like haze and heavy rain [9]. Visual sensors include infrared and visible-light cameras. The former can detect engine hot spots and aerial obstacles through thermal radiation at night or in smoky conditions, while the latter can identify runway markings, airport signs, and other aircraft outlines, together forming the core equipment for "near-field environmental perception." Collision avoidance radar monitors the distance, speed, and heading of surrounding aircraft in real-time, calculates collision risks, and provides warning data for the decision-making module. In the dual-radar combination of weather radar + collision avoidance radar equipped on COMAC aircraft, the weather radar also detects meteorological information like clouds and thunderstorms ahead via electromagnetic waves, helping to plan paths in advance to avoid extreme weather. The Inertial Measurement Unit (IMU) is the core component for perceiving aircraft attitude, acceleration, and angular velocity, forming the basis for autonomous flight attitude control. It can maintain short-term flight state awareness even when satellite signals are lost. Especially in the field of micro-small aircraft, Micro-Electro-Mechanical System (MEMS) based IMUs are widely used due to their small size, light weight, and low cost. By fusing data from multiple sensors like magnetometers on this basis and using advanced filtering algorithms, errors can be effectively estimated and compensated, achieving high-precision attitude resolution and stable control [10-12].

3.2 Decision Module: The 'Brain Center' of Intelligent Flight

The decision module is the core technology of intelligent flight. Its primary goal is to synergize real-time data from the perception module with flight mission requirements, civil aviation regulations, and safety constraints to make responses when encountering unexpected situations. Decision-making is divided into autonomous decision-making and assisted decision-making modes. Currently, COMAC flights primarily use "assisted decision-making, with a gradual evolution towards fully autonomous decision-making in the future.

3.2.1 Core decision vehicle: flight management computer

The independently developed Flight Management Computer (FMC) equipped on COMAC aircraft is the core part of the decision module. This technology provides key support for flight safety and efficient mission execution through three core functions. The first is mission planning and path optimization. This function integrates multi-dimensional information such as origin, destination, real-time weather conditions, preset route planning, and fuel consumption to automatically generate optimal flight paths including flight speed, cruise altitude, and turning points, and can dynamically adjust in real-time based on changes during flight. The second is flight status monitoring and risk prediction. By dynamically comparing perception module data with safety thresholds, it immediately triggers risk warnings when abnormal conditions are detected and provides preliminary response plans for different scenarios. For example, it may suggest returning or diverting in high-risk landing scenarios [13]. For sudden anomalies during flight, it can adjust thrust, check specific systems, or change flight altitude and track based on the actual situation, assisting pilots and controllers in making quick decisions. The third is multi-task collaborative decision-making. For special mission aircraft like cargo

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drones or delivery aircraft, it can plan appropriate routes based on specific mission requirements to ensure precise task execution.

3.2.2 Support from intelligent decision algorithms

In the upgrade process of the decision module for COMAC aircraft, the deep integration of artificial intelligence and knowledge graph technology has effectively enhanced the aircraft's real-time response capability to complex scenarios. On one hand, machine learning algorithms, through deep learning on vast amounts of flight data (such as real-time flight parameters under different weather conditions, historical fault handling cases, etc.), endow the decision module with predictive decision-making ability, identifying potential fault risks in advance and proactively adjusting flight strategies before faults occur, achieving proactive risk management. On the other hand, knowledge graph technology converts information such as civil aviation regulations, aircraft maintenance manuals, and standard fault handling procedures into quickly accessible system knowledge, providing rule support for the decision module. When encountering complex scenarios like multiple concurrent faults, the decision module can quickly find countermeasures that comply with safety regulations and compliance requirements, effectively avoiding potential judgment errors in manual decision-making. The synergistic effect of these two technologies effectively strengthens the safety and timeliness of the COMAC aircraft's decision module in complex scenarios, providing more reliable guarantees for flight operations.

3.3 Control Module: Achieving the Execution Loop for Precise Flight

The control module is the guarantee for intelligent flight. Its core goal is to translate the commands from the decision module into the actual movements of the aircraft. The key to achieving precise execution of decisions lies in high precision, high response speed, and high reliability.

3.3.1 Core control vehicle: fly-by-wire flight control system

COMAC employs a three-axis, full-authority Fly-by-Wire (FBW) flight control system in its main aircraft models like the C919. This system is the core of the aircraft's control module and exhibits three main advantages compared to traditional mechanical flight control systems. First is the ability for precise command conversion. The system can directly convert attitude adjustment commands from the decision module into electrical signals, precisely controlling the deflection angles of control surfaces such as elevators, ailerons, and rudders, strictly controlling errors, and effectively avoiding backlash errors common in traditional mechanical transmissions. Second, it possesses active stability control functions. Relying on built-in control law algorithms, the system can sense and counteract external disturbances in real-time. For example, when encountering sudden gusts causing turbulence, the FBW system can quickly automatically adjust control surfaces to maintain stable flight attitude, significantly improving passenger comfort. Finally, in terms of operation and safety, the system not only supports "automatic coordinated turns" to simplify pilot procedures but also adopts a redundant design with three independent systems. Even if one system fails, the other two can immediately take over seamlessly, ensuring uninterrupted flight control and fully meeting the stringent safety requirements of civil aviation.

3.3.2 Execution layer technologies: flight control actuators and control algorithms

In the execution layer technologies, the synergistic action of flight control actuators and flight control algorithms jointly ensures the precise implementation of flight commands. Among them, flight control actuators are the "last mile of command execution." After receiving electrical signals from the FBW system, they directly control the movement of key components such as control surfaces, engine throttles, and landing gear through hydraulic or electric drive devices. For example, when the decision module issues a "climb command," the actuators simultaneously drive the elevators to deflect upward and adjust the engine throttle to increase thrust, thereby achieving a smooth climb. Flight control algorithms provide the "precise motion parameters" for the actuators. Taking the automatic landing phase as an example, these algorithms integrate "runway distance data" obtained by the perception module with attitude data collected by the IMU to accurately calculate the control surface deflection speed and throttle adjustment amplitude, ultimately ensuring a smooth touchdown.

4. Improvements and Prospects for Core Technologies of Intelligent and Unmanned Flight in COMAC Aircraft

For the perception module, a single sensor may have data blind spots. COMAC aircraft can use multi-source information fusion algorithms to integrate data from the aforementioned sensors. For example, fusing LiDAR's '3D distance data' with visual sensor's target classification data can simultaneously determine obstacle location and 'obstacle type', significantly enhancing the safety of COMAC aircraft through this method.

When traditional flight management systems face abnormal situations, such as pilot incapacitation, the decision system can adopt dynamic A* algorithms, combine waypoints and route information from the navigation database, and consider real-time constraints like weather, no-fly zones, and ATC instructions to perform emergency route planning for safe diversion [14].

For flight scenarios requiring the completion of multiple specific tasks,trajectory planning needs to comprehensively consider multiple objectives such as distance, fuel consumption, task completion degree, and threat avoidance. A two-stage solution algorithm can be used, first planning the task sequence, then using an improved A* algorithm to solve the multi-objective optimization problem.

The signal acquisition accuracy of sensors is crucial for aircraft control, as it directly determines the control precision of the FBW system. In practical engineering applications, a significant portion of measurement errors does not originate from the manufacturing precision of the sensor itself but from its working conditions, such as unstable excitation power supply and mechanical installation errors. For signal acquisition deviations caused by unstable excitation power and mechanical installation errors, signal compensation techniques can be employed. These techniques utilize causal compensation methods and electrical zero-adjustment strategies to improve acquisition accuracy. These technologies can reduce the system's dependence on high-precision excitation power supplies and mechanical zero-position adjustment, relax the stringent requirements for mechanical installation, simplify the design, installation, and debugging process of sensor components, and simultaneously significantly improve the accuracy of command and feedback signal acquisition throughout the control range [15].

5. Conclusion

This paper focused on researching the intelligent and unmanned driving modes of COMAC aircraft. Against the backdrop of AI and 5G communication technologies promoting the transformation of aviation towards automation and remote operation, it elaborated on COMAC's three-stage technological development path of Assisted Intelligence → Enhanced Intelligence → Full Intelligence. The analysis indicates that this model can create core value by enhancing flight safety, improving operational efficiency, and reducing operating costs. Simultaneously, it detailed the synergistic mechanism of the three core technology modules—Perception, Decision, Control—and proposed improvement directions such as multi-source information fusion, route optimization algorithms for abnormal scenarios, and sensor signal compensation. This provides technical reference and practical ideas for COMAC to break through technological blockades, capture market share in the aviation market, and promote the sustainable development of the aviation industry.

References

[1] Yang ZG, Zhang J, Li B, et al. Overview of Intelligent Flight Technology for Civil Aircraft [J]. Journal of Aviation, 2021, 42(04): 265-274.
[2] Zhang J, Zeng R. Design and Testing of Single-Pilot Operation Mode for Commercial Aircraft [J]. Aeronautical Science and Technology, 2020, 31(06): 42-49.
[3] Ma CY, Zhang YH. Design of a Flight Control Training System Combining Virtual Reality and Augmented Reality [J]. Heilongjiang Science, 2025, 16(02): 34-37.
[4] Kang SL, Miao DS, Suo SQ, et al. System Design and Key Technologies for Integrated Space-Air-Ground Networks Towards 6G [J]. Information and Communications Technology and Policy, 2022, (09): 18-26.
[5] Luo Y, Wang M, Xiao G, et al. Conceptual Architecture of Remote Pilot Mode for Commercial Aircraft [J]. Transactions of Nanjing University of Aeronautics and Astronautics, 2020, 37(02): 274-287.
[6] Li H, Guo SL, Zhou Y. Dynamic Rerouting Planning Integrating Dynamic Risk Map and Improved A* Algorithm [J]. Aeronautical Science and Technology, 2021, 32(05): 61-71.
[7] Zhang HH, Zou YY, Zhang QQ, et al. Review of Research on Future Urban Air Traffic Management [J]. Acta Aeronautica et Astronautica Sinica, 2021, 42(07): 82-106.
[8] Wu JD, Wei ZQ, Nie RT. Calculation and Analysis of Cost Index Based on Remote Cruise Method [J]. Journal of Civil Aviation University of China, 2007, (03): 17-20.
[9] Sun Y, Wang CQ, Han L, et al. Research on Intelligent Vehicle Positioning Based on LiDAR and Feature Map [J]. Laser Journal, 2023, 44(12): 190-195.
[10] Zhang HP, Fang JC. Structural Design Method of MIMU System for Micro Aerial Vehicles [J]. Acta Aeronautica et Astronautica Sinica, 2009, 30(07): 1248-1255.
[11] Shangguan W, Chen JJ, Xie ZX, et al. Magnetometer-Enhanced Integrated Positioning Method Based on IMU Error Compensation [J]. Journal of the China Railway Society, 2022, 44(07): 80-90.
[12] Zhang X, Li Z, Wang YJ. Simulation Research on Optimal Attitude Stability Control of Unmanned Aerial Vehicle [J]. Computer Simulation, 2017, 34(12): 49-54.
[13] Wang YT, Liu H, Tang JX, et al. Application of Dynamic Prediction Technology in Flight Operation Risk [J]. Control and Decision, 2019, 34(09): 1946-1954.
[14] Chi Y, Yu L. Research on Intelligent Route Planning Technology for Civil Aircraft [J]. Aeronautical Science and Technology, 2020, 31(10): 46-50.
[15] Du YL, Gao YK. Signal Compensation Technology for Fly-by-Wire Flight Control System [J]. Computer Measurement & Control, 2017, 25(12): 64-67.