HYBRID UAV ARTIFICIAL INTELLIGENCE

Georgi Georgiev[1], Dimo Zafirov[2]

[1]*Georgi Georgiev-Consulting GmbH*
[2]*Space Research and Technology Institute – Bulgarian Academy of Sciences*
e-mail: georgi@georgiev-consulting.de; zafirov@big97.com

Keywords: *Hybrid Intelligence, Drones, Positioning, Navigation & Timing, AI Agents*

Abstract: *Hybrid UAV Intelligence is an intelligent computing architecture that integrates various artificial intelligence methods, physical models, sensory data, and logic rules in order to achieve reliable perception, decision-making, planning, and autonomous UAV functioning. The main idea is to combine learnable models with physical knowledge and formalized logic so that the system can adapt to changing conditions while respecting predetermined safety limits.*

ХИБРИДЕН ИЗКУСТВЕН ИНТЕЛЕКТ НА БОРДА НА БЕЗПИЛОТЕН ЛЕТАТЕЛЕН АПАРАТ

Георги Георгиев[1], Димо Зафиров[2]

[1]*Georgi Georgiev-Consulting GmbH*
[2]*Институт за космически изследвания и технологии – Българска академия на науките*
e-mail: georgi@georgiev-consulting.de; zafirov@big97.com

Ключови думи: *Хибриден интелект, Безпилотни летателни апарати, Позициониране, навигация и синхронизация по време, AI агенти*

Резюме: *Хибриден интелект за безпилотни летателни апарати представлява интелигентна изчислителна архитектура, която обединява различни методи на изкуствения интелект, физически модели, данни от сензори и логически правила, с цел постигане на надеждно възприемане на средата, вземане на решения, планиране и автономно функциониране на безпилотните летателни апарати. Основната идея е да се съчетаят модели, способни на самообучение, с физически познания и формализирана логика, така че системата да може да се адаптира към променящите се условия, като същевременно спазва предварително зададени граници за безопасност.*

CAD - Computer Added Design
CAM – Computer Added Manufacturing
MBSE - Model Based System Engineering
PNT - Positioning, Navigation, and Timing
R&D Research and Development
SoS – System of Systems
UAV - Unmanned Aerial Vehicle
UAS - Unmanned Aerial System

Introduction

Hybrid UAV Intelligence is an intelligent computing architecture that integrates various artificial intelligence methods, physical models, sensory data, and logic rules in order to achieve reliable perception, decision-making, planning, and autonomous UAV functioning.

The main idea is to combine learnable models with physical knowledge and formalized logic so that the system can adapt to changing conditions while respecting predetermined safety limits.

Materials and methods

Hybrid UAV Intelligence can be represented by five principal components:

Component	Function
Data-Driven Intelligence	Machine learning, deep learning and computer vision
Physics-Based Intelligence	Aerodynamics, flight dynamics and energy modelling
Symbolic Intelligence	Rules, logical reasoning and knowledge representation
Decision Intelligence	Planning, prediction and selection of actions
Planning, prediction and selection of actions	Constraint enforcement, fault handling and operational monitoring

These components interact with the UAV's flight-control system and its digital representation, or Digital Twin.

The PNT (Positioning, Navigation, and Timing) system is used by autonomous unmanned robots to navigate and communicate in manipulated environments.



Fig. 1. Autopilot



Fig. 2. Baseboard Bundle Autopilot and Onboard Computer



Fig. 3. Elements of a PNT System

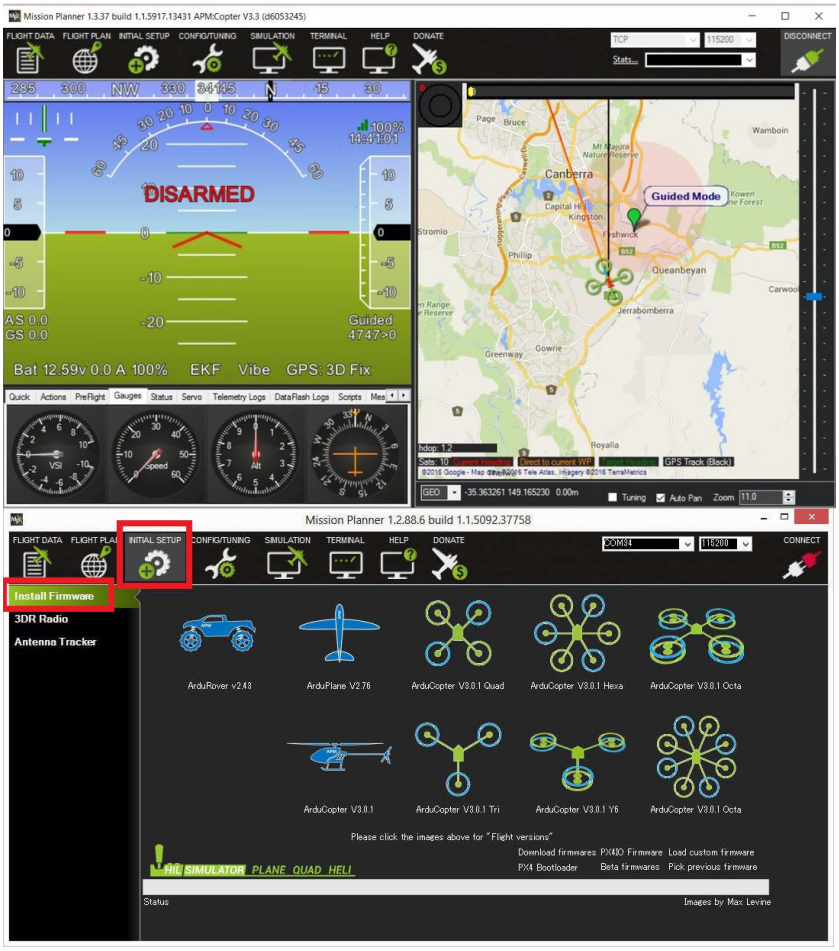


Fig. 4. UAVs Flight Test Software

Research on **positioning, navigation, and timing (PNT) of unmanned aerial vehicles (UAVs)** is aimed at increasing autonomy, absolute accuracy, and resilience in environments challenged or denied by the Global Navigation Satellite System (GNSS).

Assured Positioning, Navigation and Timing (A-PNT)

A-PNT stands for Guaranteed Positioning, Navigation and Weather. It is a combination of technologies and architectural solutions that provide reliable PNT services even in the event of jamming, spoofing GNSS signals or loss of satellite navigation. The A-PNT system is particularly important for autonomous UAVs (Table 1).

Table 1

Characteristics	PNT	A-PNT
Main objective	Positioning, navigation and timing	Support these features for various failures and interference
GNSS	It is often a major source	One of several possible sources
Reservation	Optional	Adaptive
Integrity control	Optional	Essential architectural principle
GNSS Loss Operation	Depends on the components available	Provided by appropriate backup solutions

The basic principle in the operation of A-PNT is the use of multiple complementary sources, instead of complete dependence on GNSS. The specific architecture depends on the requirements of the system.

The main technologies used are:

- GNSS: GPS, Galileo and other satellite navigation systems.
- INS/IMU: inertial navigation and measurement of accelerations and angular velocities.
- Visual-Inertial Odometry: estimating movement via camera and IMU.

- LiDAR/Radar Odometry: estimating movement by laser or radar measurements.
- Iternative Timing: backup time sources and local clocks.
- Integrity Monitoring: assessment of the reliability of the navigation solution.
  It is important to note that none of these components alone guarantee A-PNT.

AI can support:

1. Detection of discrepancies between sensors.
2. Recognition of degraded navigational measurements.
3. The assessment of uncertainty.
4. The choice between eligible navigation solutions.
5. Predicting the probability of loss of navigational reliability.

In critical applications, AI must be supplemented with verifiable integrity control algorithms, error limits, and safe failure behavior.

Hybrid UAV Intelligence can use a multi-agent system to integrate artificial intelligence, sensors, navigation, diagnostics, and UAV lifecycle management into a single architecture. The main idea is for different AI agents to work together, with each responsible for a specific function, and a coordinating agent pooling the results.

The key test indicators are:

- Positioning error;
- Error in orientation assessment;
- Accumulation of odometric drift;
- Failure detection time;
- Duration of operation without gnss;
- Reliability of the integrity assessment;
- Loss or contradiction behavior between sensors.
  The described system will be used in future development of UAS.

Conclusion

A-PNT is not just an alternative to GPS, but an architecture for reliable positioning, navigation and synchronization under different operating conditions.

For Hybrid UAV Intelligence, the most important thing is for the system not only to calculate its position, but also to assess how much it can trust this calculation.

Acknowledgments

The authors gratefully acknowledge support for the development and publication of this article from the Erasmus+ programme, project KA220-HED-2EF8D879 SUstainable Disaster and Emergency Management processes digitization (SUDEM).

References:

1. Caroline I. Samson-Onuorah, Felix Adebayo Bakare Dynamic Strategic Foresight Using Predictive Business Analytics: Modeling Competitive Advantage Under Volatile Market and Technological Conditions. May 2025 International Journal of Research Publication and Reviews 6(5):1044-1060 DOI:10.55248/gengpi.6.0525.1627
2. Rubén San-Segundo, Lucía Angulo, Manuel Gil-Martín, David Carraminana and Ana M. Bernardos Hybrid Artificial Intelligence Strategies for Drone Navigation
3. Relative Vessel Motion Tracking using Sensor Fusion, Aruco Markers, and MRU Sensors Modeling, Identification and Control (MIC) 38(2):79-93 DOI:10.4173/mic.2017.2.3, https://www.google.com/search?q=%22Hybrid+Artificial+Intelligence+Strategies+for+Drone+Navigation%22&oq=%22Hybrid+Artificial+Intelligence+Strategies+for+Drone+Navigation%22&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIICAEQABgWGB7SAQoxMjc4OGowajE1qAIIsAIB&sourceid=chrome&source=chrome.rb&ie=UTF-8