Knowledge Representation and Reasoning for Unmanned Aerial Vehicle Intelligence

Ivano Bilenchi, Arnaldo Tomasino, Filippo Gramegna, Saverio Ieva, Agnese Pinto, Giuseppe Loseto, Floriano Scioscia, Michele Ruta

Unmanned Aerial Vehicles (UAVs) are used in an increasing range of application domains, from search and rescue to precision farming and hazard detection. Their progress toward miniaturization and integration of embedded sensors, micro-controllers and programmable processing units are disclosing further advanced application scenarios, e.g. in logistics and smart cities. Artificial Intelligence techniques can enhance perceptive and decision-making capabilities in UAV missions. So far, data analysis and inference procedures are mostly implemented in ground control stations, communicating with UAVs through wireless links. This introduces latencies which are often incompatible with real-time use cases. Moreover, conventional machine learning (ML) methods currently require UAV payloads for accelerated computing, which come at increased cost, weight, and energy demand. Furthermore, most ML models have limited explainability, hindering their use in scenarios which require trustworthy autonomous agents.

Knowledge Representation and Reasoning (KRR) techniques can provide better interpretability, as they are based on explicit machine-understandable information modeling. Nonetheless, the majority of available tools has been designed for desktop-class devices, resulting in unsustainable computational resource requirements for embedded UAV systems. The Semantic Web of Everything is promoting the integration of Semantic Web languages and technologies in pervasive contexts by designing KRR tools which are useful and efficient enough to be deployed to embedded micro-controllers [1].

This work shows how embedding KRR capabilities into UAV autopilot platforms is beneficial in several key use cases. By annotating sensor and internal data (e.g., speed, orientation, processing load, battery level, etc.) in terms of an ontology model, reasoning is exploited for context management, in order to improve UAV operational efficiency as well as confidence on detected events. Moreover, the monitoring of hazardous environments can be automated by performing inferences on annotations of sensor data, enabling real-time identification and handling of risks and critical scenarios. In all the proposed use cases, explanation of logic-based inference outcomes allows the system to justify its decisions, thus increasing the trust in autonomous UAV platforms.

[1] Ruta, M., Scioscia, F., Bilenchi, I., Gramegna, F., Loseto, G., Ieva, S., & Pinto, A. (2022). A multiplatform reasoning engine for the Semantic Web of Everything. Journal of Web Semantics, 73, 100709.