

Literature Review: Ontology-Based UAV Autonomy

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1 Literature Review: Ontology-Based UAV Autonomy

This folder contains literature relevant to our Flyby F-11 research on ontology-constrained autonomous navigation.

1.1 Research Question

What is the most effective approach for leveraging SUMO ontology to enable autonomous UAV mission execution?

Specifically, should we use: 1. Ontology-constrained reinforcement learning (RL + ontology hybrid) 2. Pure ontology-based planning (knowledge-driven) 3. Other hybrid approaches (imitation learning, inverse RL, etc.)

1.2 Papers Collected

1.2.1 Core Ontology-RL Integration Papers

1. [Ontology-driven RL for Student Support](#) (2024)
 - Multi-agent RL structured by ontology
 - Shows modular approach to RL-ontology integration
2. [Using Ontology to Guide RL in Unseen Situations](#) (2021)

- Ontology-Guided MDP framework
- Traffic control case study
- Focus on generalization to novel scenarios

1.2.2 UAV/Robotics Ontology Applications

3. **Survey: Ontology-Enabled Robot Autonomy** (2024)
 - **CRITICAL:** Comprehensive survey of ontology in robotics
 - Covers SUMO, OWL vs Prolog, ROS integration
 - Discusses dependability, safety, action selection
4. **Collision Avoidance Ontologies for UAS**
 - **CRITICALLY RELEVANT:** Ontology-based collision avoidance for UAVs
 - Safety-critical constraint encoding and decision-making
 - Direct application to our SUMO-constrained RL approach
5. **UAV-ON Benchmark** (2024/2025)
 - Semantic navigation benchmark
 - Shows limitations of pure learning approaches (30%+ collision rate)
 - Demonstrates need for safety constraints

1.2.3 Autonomous Vehicle Planning Approaches

6. **Knowledge vs Data-Driven Methods Survey** (2025)
 - **KEY FINDING:** Hybrid approaches (knowledge + learning) recommended
 - Compares rule-based, MDP, search-based vs RL, imitation learning
 - Explicitly advocates for integrated methods

1.3 Key Findings So Far

1.3.1 Strong Support for Hybrid Approach

- **2025 autonomous vehicle survey** explicitly recommends knowledge-driven + data-driven integration
- **Ontology-guided RL papers** (2021, 2024) show successful implementations
- **UAV-ON benchmark** shows pure learning approaches have critical safety gaps (30%+ collision)

1.3.2 Collision Avoidance as Canonical Problem

- **Collision avoidance** is a proven application domain for UAV ontologies
- Demonstrates clear integration of ontological constraints with autonomous decision-making
- Provides concrete vocabulary examples for our ONTOLOGY_FOUNDATION.md (spatial relations, safety constraints, maneuver types)

1.3.3 Multiple Integration Strategies

Papers show different ways to combine ontology and learning: 1. **State abstraction:** Ontology provides semantic state representation 2. **Action filtering:** Ontology constrains valid action space 3. **Reward shaping:** Ontology violations contribute to reward penalties 4. **Multi-agent structure:** Ontology organizes different RL agents by capability 5. **Ontology-Guided MDP:** Formal framework for semantic constraints

1.3.4 Open Questions

1. **Which integration approach is best for UAV missions?** (Likely hybrid/multiple)
2. **How to balance ontology generality vs. domain specificity?** (SUMO subset design with Adam Pease)
3. **What reasoning engine?** (OWL recommended over Prolog for robots; real-time performance critical)
4. **Where is the ontology/RL boundary?** (High-level planning vs low-level control?)
5. **How to handle sensor uncertainty in ontological reasoning?** (Probabilistic extensions to description logic?)

1.4 Next Steps

1. **Download full PDFs** where access was blocked
2. **Search for more papers** on:
 - Ontology-based collision avoidance (specific papers/implementations)
 - Ontology-based motion planning for UAVs
 - SUMO applications in robotics
 - Behavior trees + ontology integration
 - Sim-to-real transfer with ontology constraints
 - Real-time OWL reasoning performance benchmarks
3. **Have fresh agent synthesize findings** into recommendations
4. **Discuss SUMO subset design with Adam Pease** (collision avoidance as canonical problem)

1.5 Sources

All papers include source URLs in their respective markdown files. Primary search sources: - arXiv (machine learning, robotics) - Springer (Applied Intelligence) - Frontiers (Robotics and AI, Neurorobotics) - IEEE (robotics standards, conferences) - MDPI (sustainability, applied sciences) - GitHub (Dronetology open-source ontology)