AutoSpec: A Multi-Agent Framework for Formal Specification of Robotic Vehicle Control Software

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Motivation

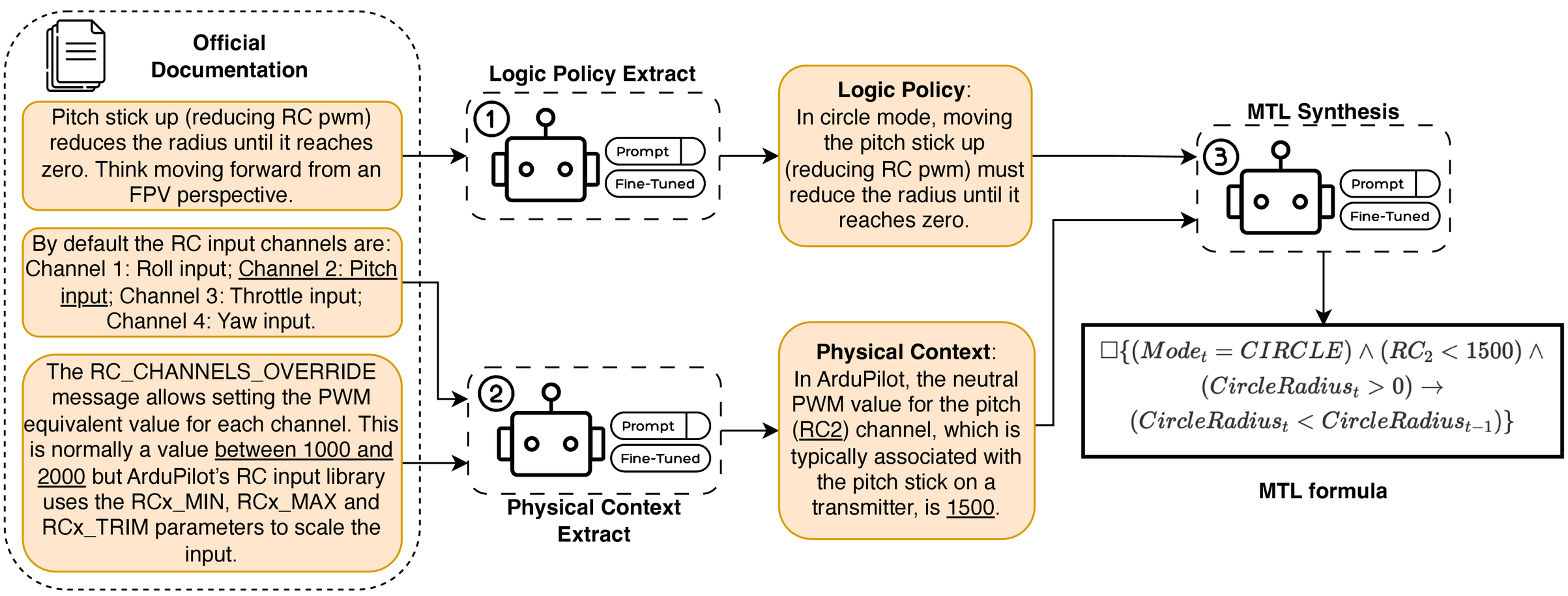
Background: Metric temporal logic (MTL) is a formal specification language used to verify behaviors of robotic vehicle control software, such as ArduPilot and PX4.

Problems:
- Manually writing MTL formulas is time-consuming and error-prone, making it difficult to scale—for example, two experts spent an entire day to create 56 formulas.
- A single large language model (LLM) performs poorly at automatically generating MTL, achieving only 18% accuracy.

Key Idea: Multi-Agent LLM Framework

We introduce **AutoSpec**, a modular multi-agent framework that automatically generates MTL formulas from natural language documentation by decomposing the task into *logic extraction*, *context identification*, and *synthesis*.

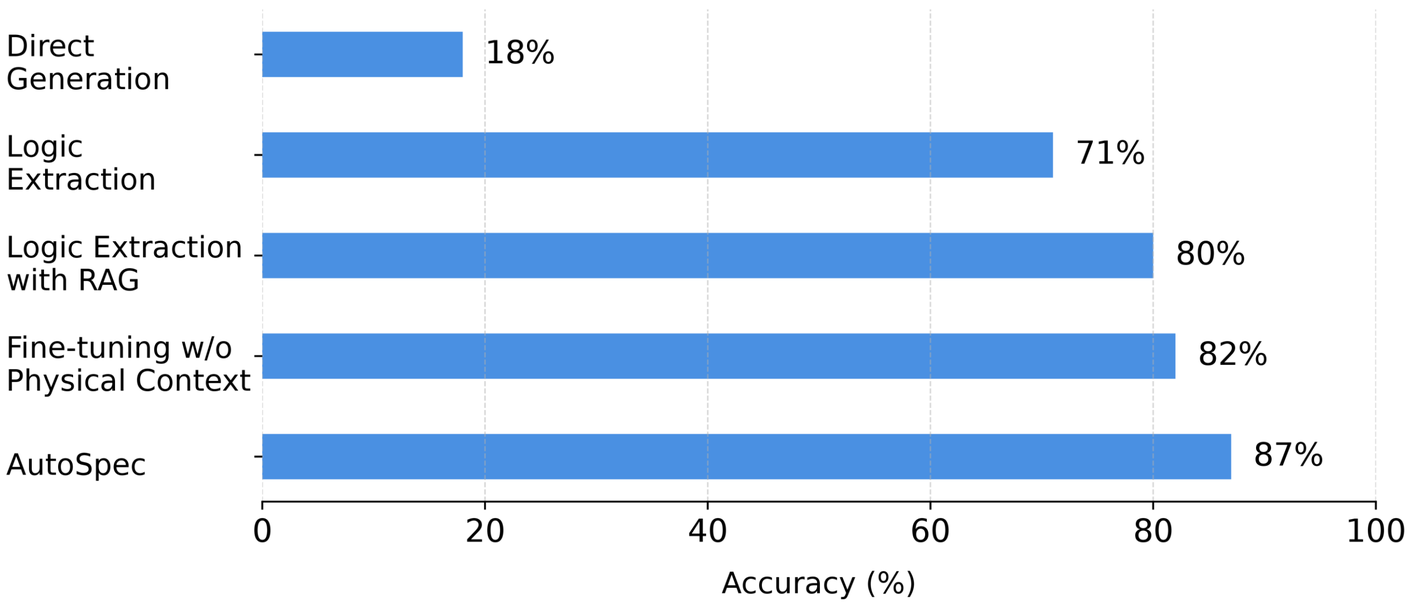
Overview



AutoSpec leverages three specialized LLM agents:

1. **Logic Policy Extraction Agent**:
   Extracts high-level control logic from documentation
2. **Physical Context Extraction Agent**:
   Identifies physical/environmental/configuration constraints or conditions (e.g., PWM thresholds)
3. **MTL Synthesis Agent**:
   Combines logic and context into syntactically correct and semantically meaningful MTL formulas

Evaluation



Conclusion

- Structured multi-agent decomposition
- Significant accuracy improvement—from 18% to 87%
- Scalable formal specification for RV control software