ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
CAMPUS DI CESENA

STRIPS-based Multi-Drone Delivery in a Horn-Shaped Map

Jing Yang, Yiming Li, Tianyu Qu

Motivation & Problem Statement

Intelligent System Engineering enables the creation of autonomous agents capable of complex decision-making and planning.

Drones, as intelligent agents, are deployed in real-world scenarios requiring advanced autonomy and adaptability.

Integrating AI planning techniques, such as STRIPS, with real-time simulation and control is a key challenge

- Efficient path planning
- Multi-agent coordination
- Task allocation

- **Logistics & Delivery**
- **Search & Rescue**
- **Agriculture**
- **Surveillance**

Project Overview

- **STRIPS based Autonomous Path Planning:** Drones can compute and follow optimal paths while avoiding obstacles.
- **Multi-Agent Coordination Framework:**

Support for multiple drones working together to accomplish complex tasks.

- **Real-Time Simulation & Visualization:**

The system responds dynamically to changes in the environment or mission objectives.

- **Extensible research platform for AI planning :**

Build an open-source platform for future development using LLM based planning.

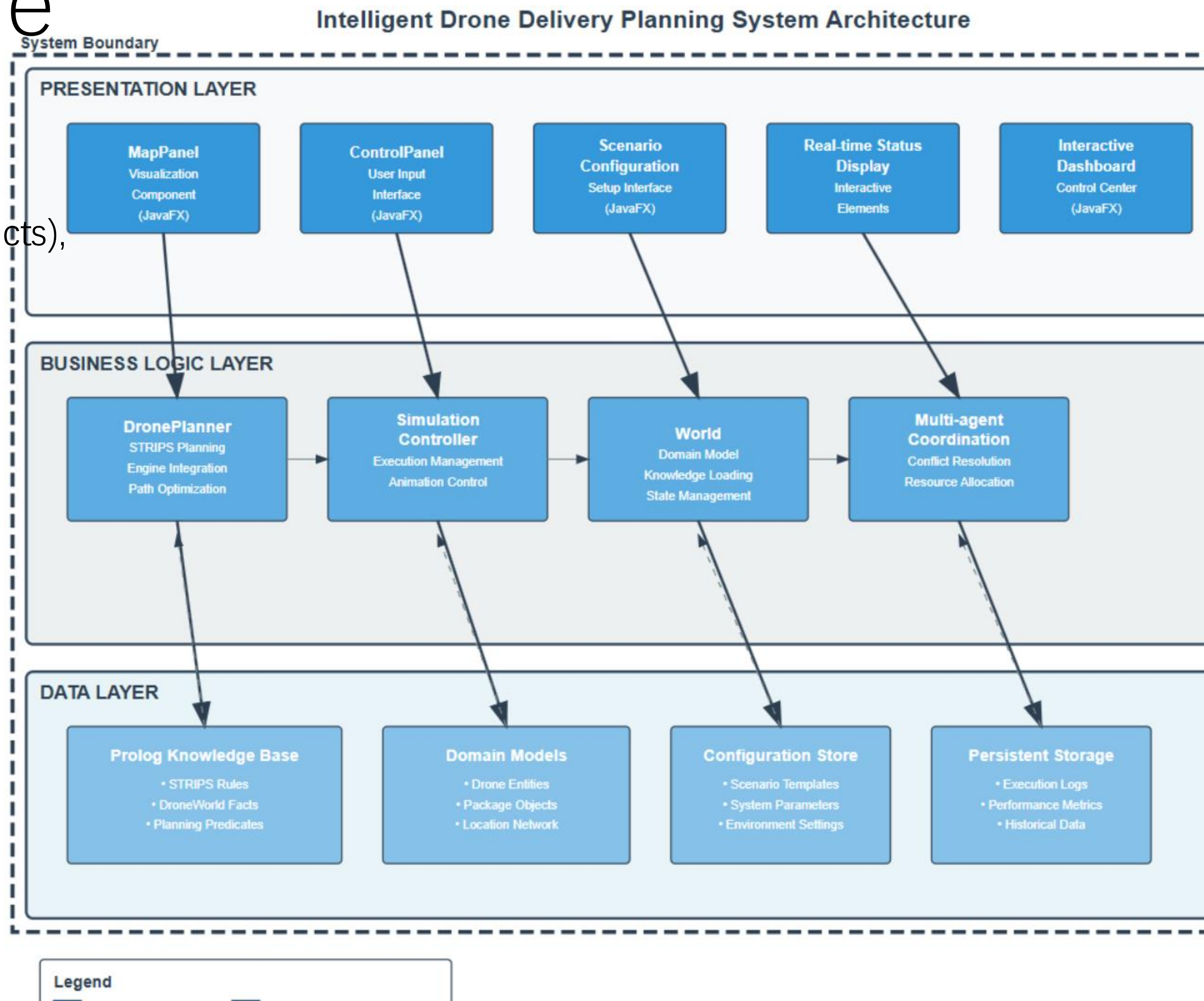
System Architecture

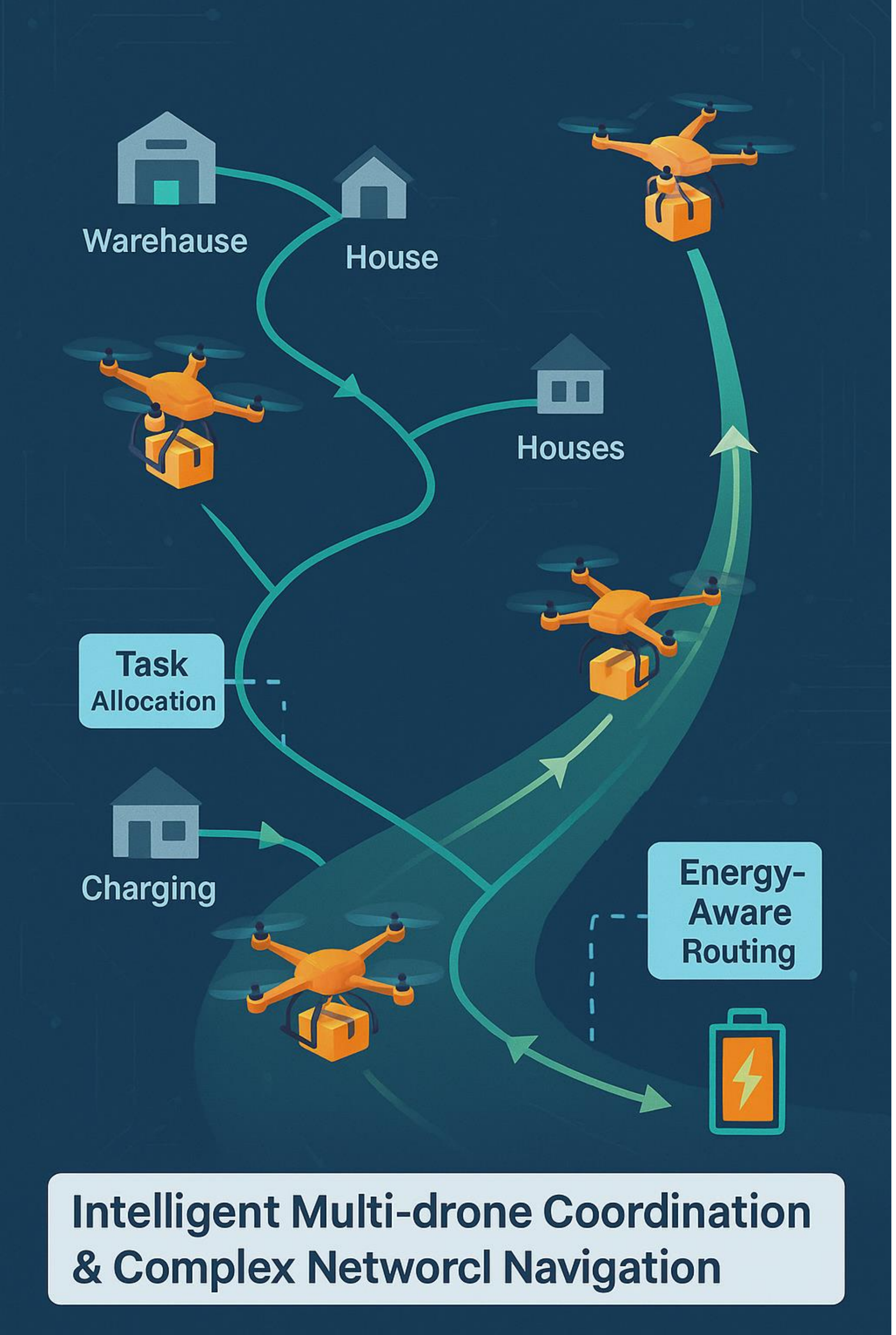
Layered Architecture

Knowledge Base layer
with Prolog modules (planning logic and facts),
Application Logic layer
in Kotlin/Java (simulation control)
Presentation layer
in JavaFX (GUI).

Hybrid Prolog–Kotlin Integration

Prolog	Kotlin
declarative planning	imperative execution





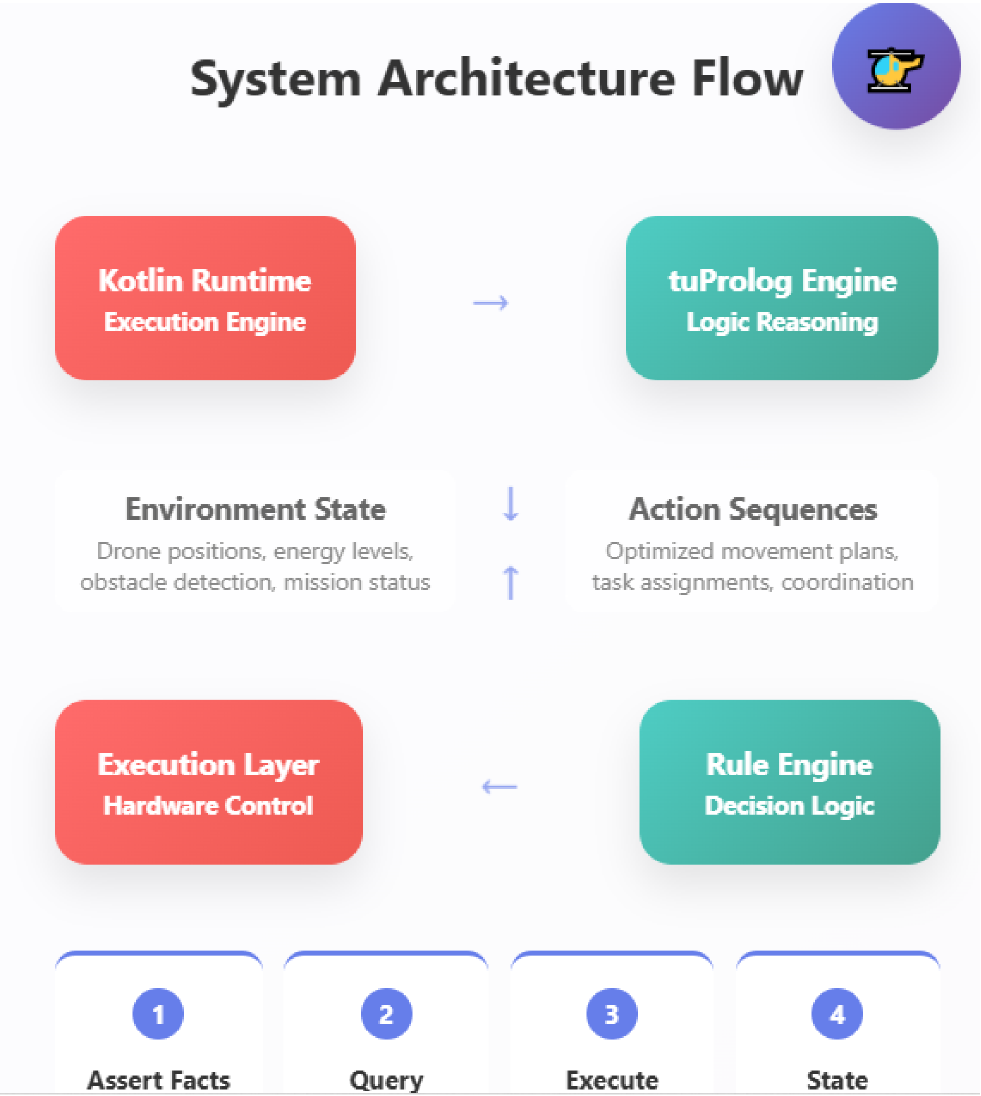
Multi-Drone Coordination Horn-Shaped Map

Multi-Agent Coordination: The planner and framework support multiple drones operating simultaneously in a shared network. Conflict Avoidance & Task Allocation

Horn-Shaped Map Topology: A custom complex map graph (shaped like a horn) models a realistic urban delivery network with branching paths and varied distances.

Energy-Aware Routing: Coordination includes managing battery constraints – drones may need to plan recharge stops route. The system ensures no drone runs out of energy mid-mission by incorporating recharge actions and energy checks in planning.

Kotlin–Prolog Integration Details



tuProlog Engine Embedded:

✓ STRIPS planning integration
✓ Dynamic fact assertion
✓ Real-time query execution

Declarative + Imperative Synergy:

✓ Transparent rule-based logic (Prolog)
✓ Efficient computation & concurrency (Kotlin)

Bidirectional Communication :

✓ State synchronization: Kotlin ↔ Prolog
✓ Action retrieval & execution
✓ Adaptive replanning capability

Graphical User Interface & Visualization

JavaFX GUI

Rich interactive interface for real-time scenario setup and drone delivery visualization

Scenario Setup

Define warehouses, delvypoints, packages, drones, deadlines, and energy limits

Real–Time Simulation

Animates drone paths, pickups/drop-offs, battery levels, and positions during execution

Visual Feedback

Alerts for critical events like low battery, charging, or delivery completion for clear insights

Testing & Validation

•**Comprehensive Testing**: Includes unit and integration tests to verify correctness across all components and delivery scenarios.

•**Scenario Coverage**: Evaluated on simple and horn-shaped maps, with cases ranging from basic single-drone tasks to complex multi-drone operations involving low-energy and coordination stress-tests.

•**Outcome**: Results validate the system's correctness, adaptability, and reliability, supporting the use of the STRIPS-based approach for multi-drone delivery with complex constraints.

test \ kotlin \ it \ unibo \ ise \ lab \ strips

- TestDroneWorld.kt
- TestHornDroneWorld.kt
- TestMultiDronePlanning.kt

Test Summary

42	0	0	23.564s	100%
tests	failures	ignored	duration	successful

Packages | Classes

Class	Tests	Failures	Ignored	Duration	Success rate
it.unibo.ise.lab.strips.TestDroneWorld	16	0	0	13.937s	100%
it.unibo.ise.lab.strips.TestHornDroneWorld	24	0	0	9.543s	100%
it.unibo.ise.lab.strips.TestMultiDronePlanning	2	0	0	0.084s	100%

Demo


腾讯会议
Quint的快速会议
会议号：839 797 005
开始录制时间：2025/07/23 10:50:28
创建者：Quint

Conclusions & Next Steps

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- **Conclusion**:
- We integrated classical symbolic planning with modern software engineering to build a fully autonomous multi-drone delivery system. Tests confirm the STRIPS-based approach remains effective under complex real-world constraints.

- **Future Work:**
- **Probabilistic Modeling**: Add uncertainty handling for energy and environment.
- **Decentralized Coordination**: Enable drone-to-drone communication.
- **Scenario Expansion**: Create richer maps and integrate real hardware.
- **Smarter Planning**: Use heuristics, ML, or A* to boost planning efficiency.