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Integration of Large Language Model Agents with Robot Operating System for Human-Robot Interaction and Task Allocation in Complex Environments

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Motivation

- Robots operate in complex, unpredictable environments
- ROS requires structured commands
- LLMs enable natural language understanding

Problem Statement

- Gap between human language and ROS commands
- Need for safe, optimal, real-time task allocation

Contributions

- Proposed architecture for LLM + ROS integration
- Two agent approaches: Prompt-only & Prompt-with-tools
- Experimental evaluation in Webots

Case Study

- Mobile robots delivering objects
- Natural language commands from human operator
- Requirement: closest available robot performs task

System Architecture Overview

- Speech-to-text (optional)
- LLM agent interprets commands
- ROS nodes for scheduling, monitoring, execution
- Web interface for visualization and input

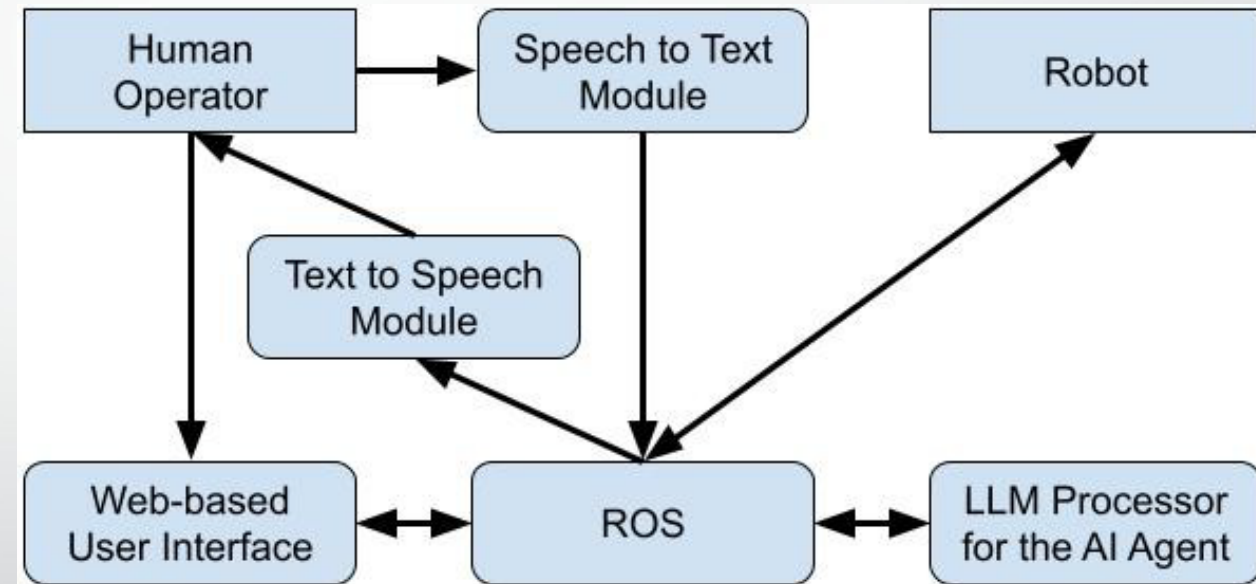


Fig. 1. System architecture overview.

ROS 2 Architecture

- robot_X_driver – motor control
- prompt_executor – input & planning
- stations_monitor – tracks stations & objects
- LLM communicates via HTTP

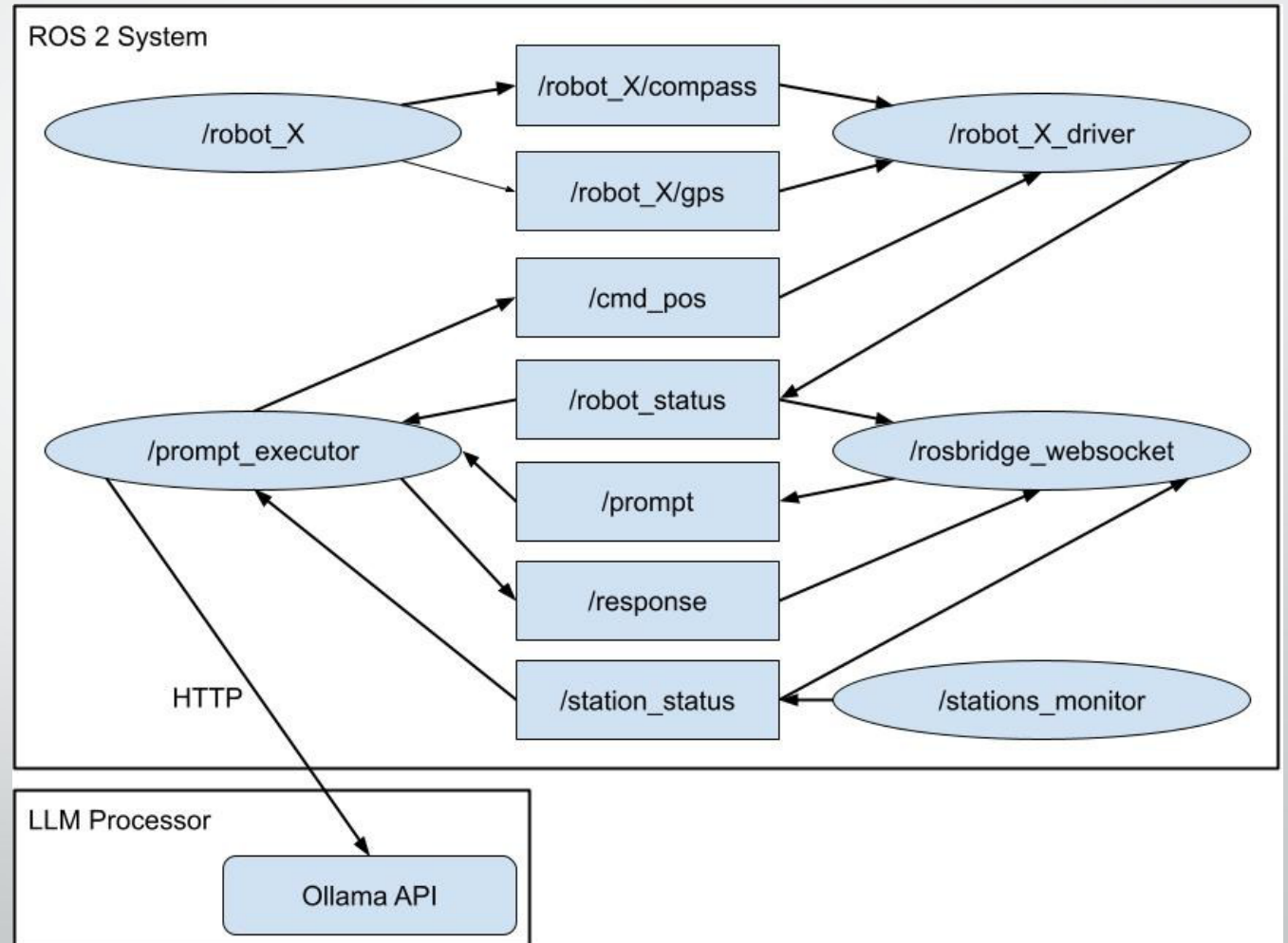


Fig. 2. ROS 2 architecture with external HTTP LLM processor.

LLM Agent Approaches

- Prompt-only programming
- Prompt-with-tools (e.g. `dispatch_robot` function)
- Tool usage improves reliability & efficiency

Prompt Examples

- Simple prompt – object & destination only
- Advanced prompt – includes robot/station states
- Expert prompt – requires distance calculations
- Tool-based prompts delegate calculations externally

Experiments Setup

- Simulation in Webots
- Three robots, different availability configs (C_1 , C_2 , C_3)
- Tested models: llama3.2:3b, deepseek-r1:1.5b, deepseek-r1:8b, gemma3:4b, mistral:7b, mistral-small:24b, mistral-small3.2:24b.
- Online GPT-4o included for comparison

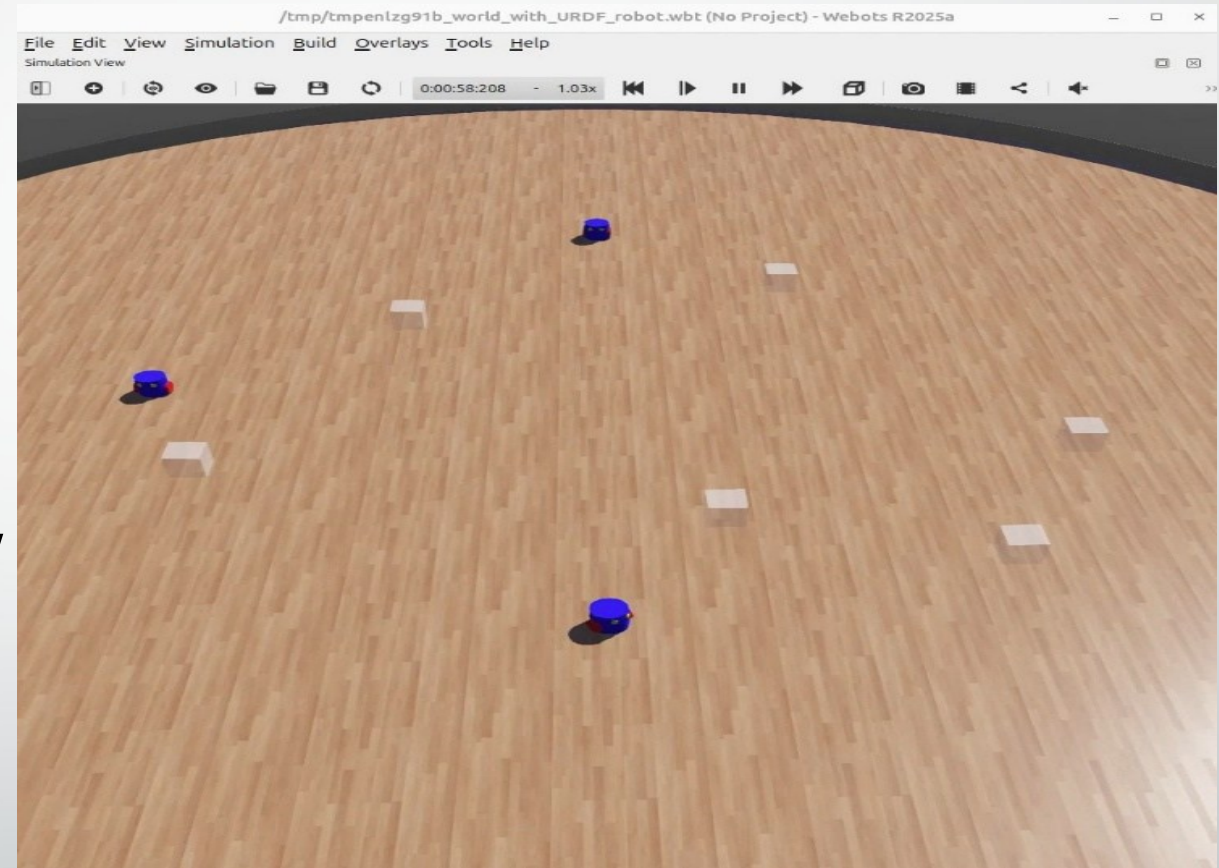


Fig. 8. Webots simulation screenshot showing the initial positions of the robots (blue objects) and the delivery stations (transparent white cubes).

Results: Prompt-only

- Simple prompts most effective
- Models struggle with deterministic calculations
- Best offline: mistral-small3.2:24b
- High resource requirements

Results: Prompt-with-tools

- Best model: llama3.2:3b
- Low resources, fast responses
- Supports real-time dialogue
- External tools improve performance

Prompt for Tool

You are a robot dispatcher assistant. Extract the item to be moved and the destination station from the user's instruction if they exists. Then use the dispatch robot tool to generate navigation instructions.

User instruction: **Bring B to S5**

Fig. 7. Prompt instruction for external tool usage.

Demonstration

The image displays a web browser window on the left and a 3D simulation window on the right. The browser window, titled "Intelligent Robot Dispatcher", shows a top-down view of a workspace with three robots (robot_1, robot_2, robot_3) and six items (S1-S6). Below the workspace, there are dropdown menus for "Mode" (set to "prompt with tool") and "Model" (set to "llama3.2:3b"). At the bottom, there is a text input field labeled "Write a task..." and a "Send" button. The simulation window, titled "/tmp/tmpenlzg91b_world_with_URDF_robot.wbt (No Project) - Webots R2025a", shows a 3D perspective view of the same workspace with two blue robots and several white blocks on a wooden floor. The simulation window includes a menu bar (File, Edit, View, Simulation, Build, Overlays, Tools, Help) and a toolbar with various simulation controls.

Discussion

- Trade-off: Large models vs. small + tools
- Offline models improve security vs. online models
- Smaller tool-augmented models more practical

Conclusion & Future Work

- LLMs enable natural and flexible HRI
- Best approach: LLMs + external tools
- Future: real-time deployment, multi-robot coordination, speech modules
- Towards hybrid robotic systems combining language & control

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THANK YOU FOR YOUR ATTENTION!

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