

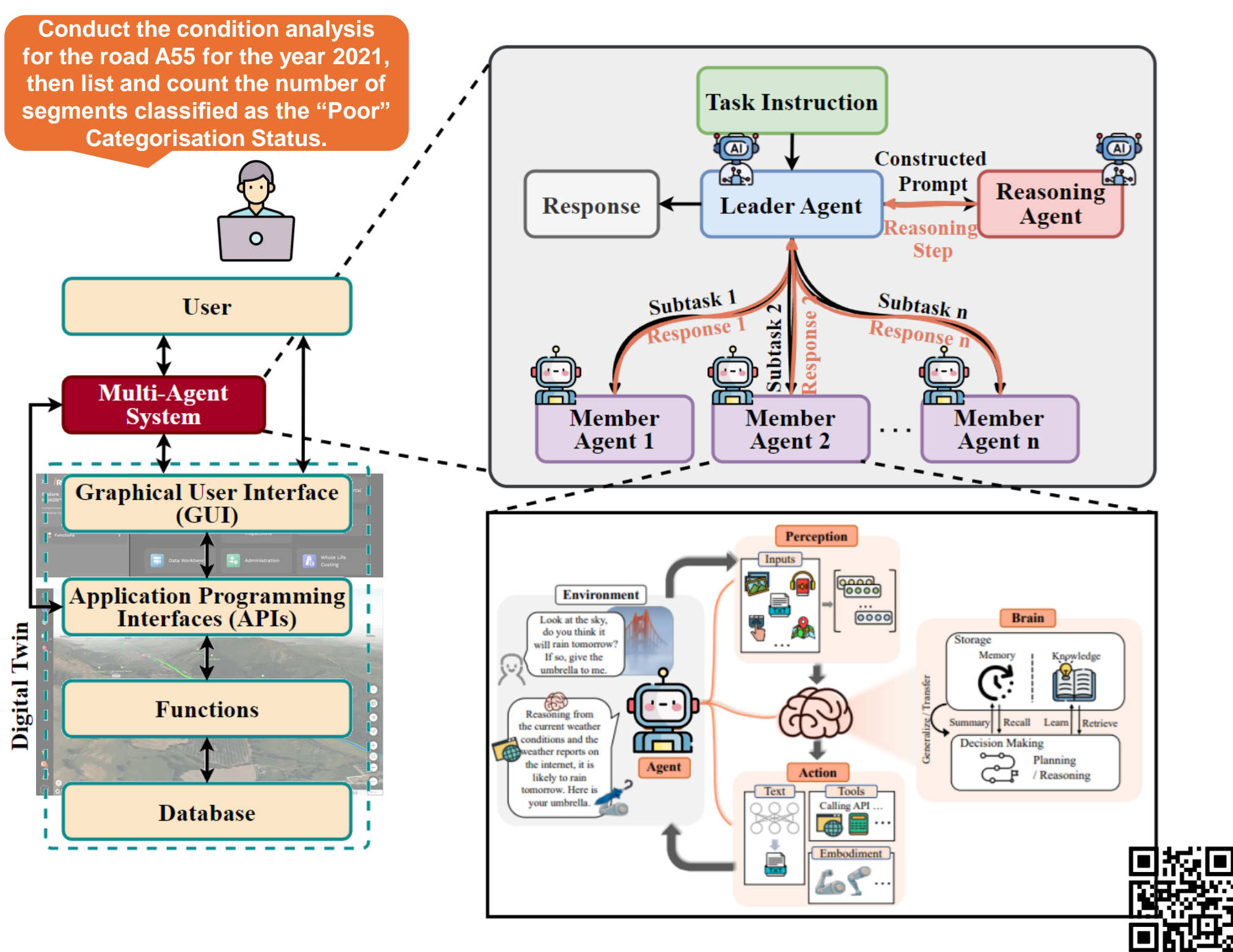
Enhancing Human-DT Interaction Through an LLM-Driven Multi-Agent System for Infrastructure Management

Linjun Lu, Peihang Luo, Brian Sheil, Ioannis Brilakis

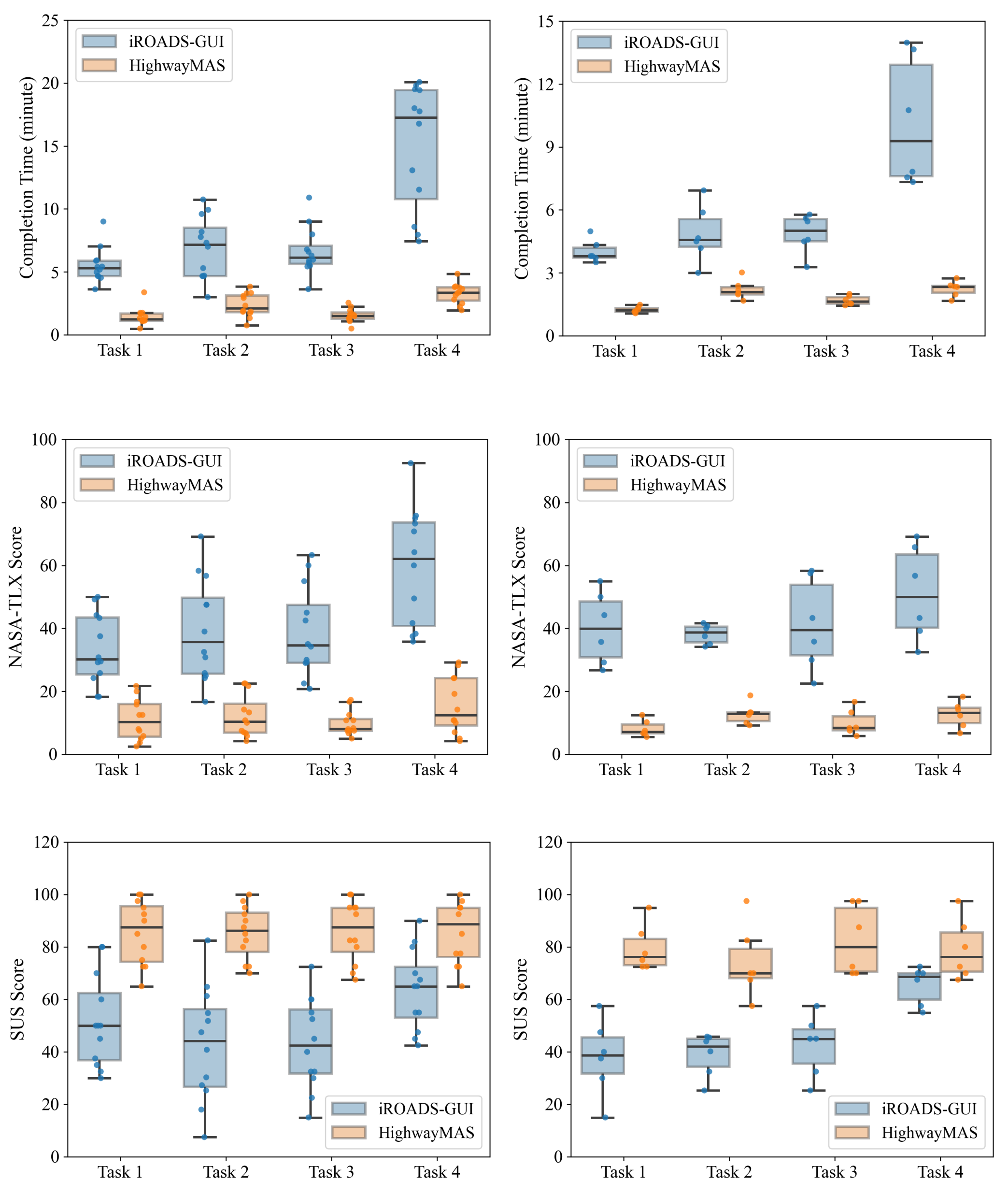
Introduction

Digital twins (DTs) are reshaping infrastructure management, but traditional GUIs limit accessibility due to steep learning curves and high cognitive load. We propose an LLM-driven multi-agent system (MAS) for human-DT interaction, where coordinated agents decompose tasks and orchestrate complex DT functions. A prototype, HighwayMAS, was evaluated with 18 highway experts and significantly reduced cognitive workload while improving performance and usability. Even users without prior DT experience completed tasks successfully, demonstrating MAS as a scalable, intuitive interaction paradigm for DTs.

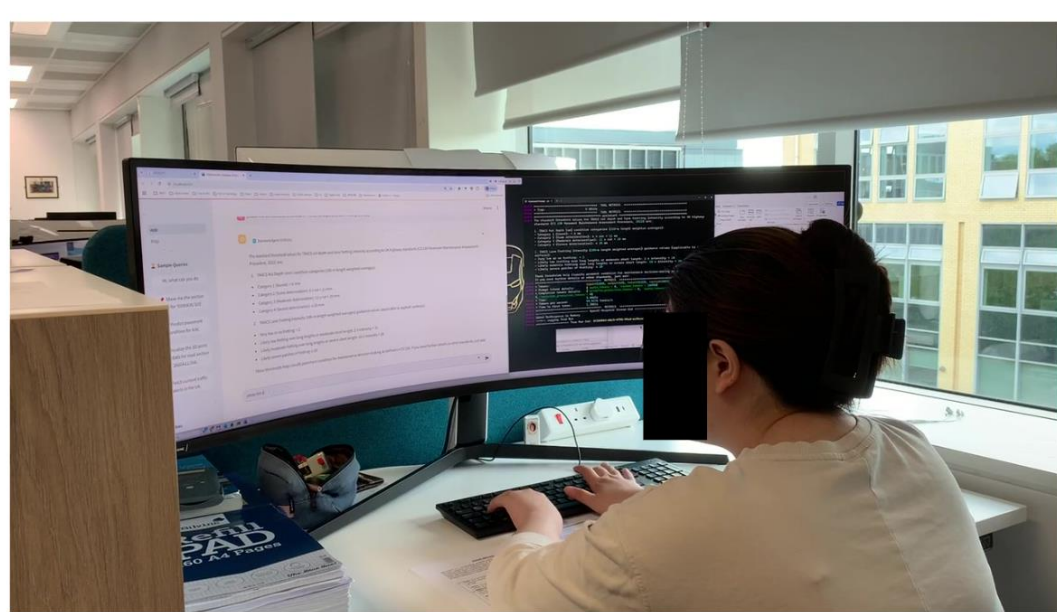
LLM-Driven Multi-Agent System



Experiment Results



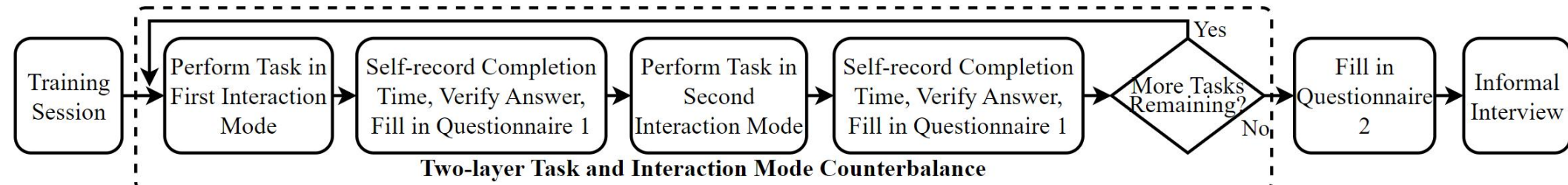
User Experiment



- Task (data modification):** You are working with highway section data and need to modify the **speed limits** of specific sections. Locate the road sections "2200A20/170" and "4200M62/335" and update their speed limit to 50 mph.
- Task (condition assessment):** Your objective is to evaluate **rut severity** for a specific road section. First, retrieve the rut depth data for lane **CL1** of road section "5090A1/232" from the year 2020. Then, list all segments having a rut depth **greater than or equal to 3.5**. Finally, assess the **overall road condition**.
- Task (standard search):** You are reviewing how condition data is interpreted. Please search for the standard threshold values that define the categories for **1) TRACS rut depth** and **2) lane fretting intensity**.
- Task (KPI analysis and visualization):** You are tasked with evaluating the performance of a road section. First, conduct the **KPI analysis** for the road section "0600A55/108" for the year 2021. Once the analysis is complete, please visualize the analysis result, then list and count the number of segments classified as the "Poor" Categorisation Status.

(a)

(b)



(c)

Without DT Experience

With DT Experience

What next?

- Multi-modal interaction modes
- hybrid interaction mode such as the LLM-Agent User Interface (LAUI)
- Transparent, cybersecure, explainable mechanisms

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101034337.