Newcastle University

Engineering and Physical Sciences Research Council

GEOSPATIAL SYSTEMS CENTRE FOR DOCTORAL TRAINING

LLM-Driven Agents for Evacuation Simulation in SUMO

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1 MOTIVATION

RESEARCH GOAL

Evacuation planning relies on understanding how people behave under emergency conditions. Traditionally, physical drills have been used to study this, but they are costly, disruptive, and difficult to scale. Computer simulation offers an alternative, modelling each person as an autonomous agent controlled by predefined rules. Here we explore replacing that rule-based decision-making with a large language model (LLM), allowing agents to reason from their individual personality, goals, and perception of their environment.

LIMITATIONS OF EXISTING APPROACHES

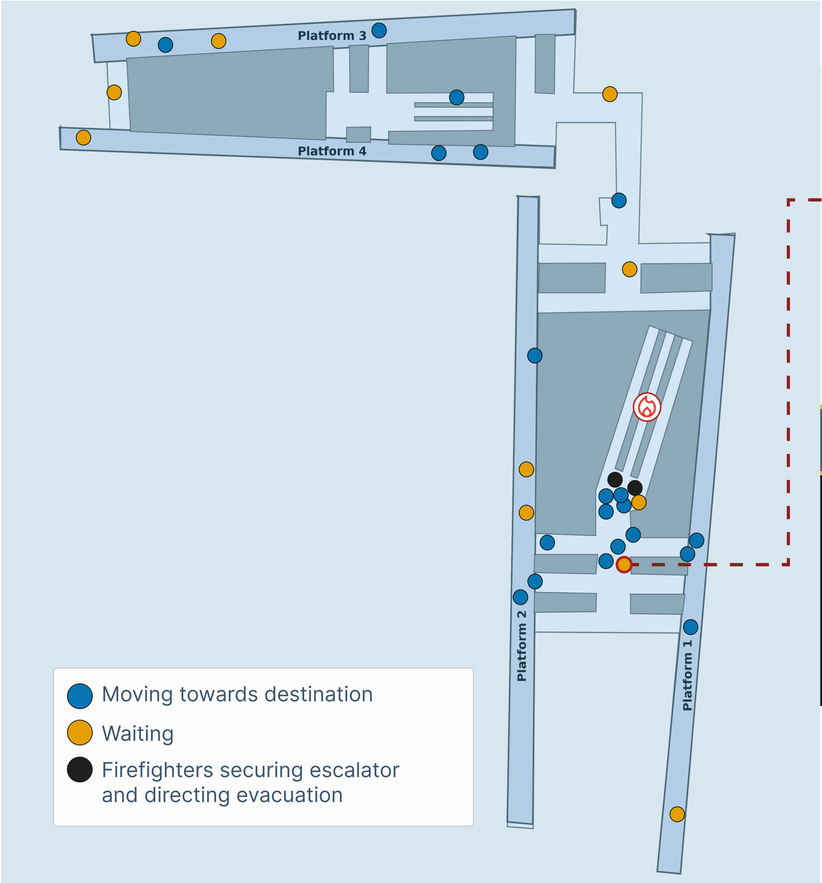
- Physical drills are costly and disruptive
- Drills cannot systematically vary conditions such as crowd size, time of day, or information available to passengers
- Rule-based agents must anticipate every behaviour in advance — they cannot generalise to novel situations
- Capturing realistic behaviour requires an ever-growing set of hand-coded rules

WHY LLM AGENTS

- Agents reason in natural language — no hand-coded rules required
- Novel situations are handled naturally without needing to be foreseen by the modeller
- Personality, goals and environment interact organically through reasoning
- Hundreds of scenario variations can be run

2 SUMO INTEGRATION

1. SUMO advances one timestep
2. Agent observes environment via TraCI
3. State serialised to LLM prompt
4. LLM returns reasoning + action
5. Action applied back via TraCI



INPUT *simplified - full prompt includes personal knowledge, memory and other details*

AGENT PROFILE

age: 34, male
personality: cautious
authority: high deference
goal: board train at Platform 1

ENVIRONMENT

alarm: fire bell sounding
exits: escalators blocked
crowd: ~10 waiting nearby
PA: not heard
train: not yet arrived

LLM REASONING

OUTPUT

"The fire alarm is sounding and firefighters are blocking the escalators right in front of me. They are the authority here — I will wait at the foot of the escalators for their instruction."

action: wait

At each decision interval, agent context and observations are assembled into a natural-language prompt. The LLM generates chain-of-thought reasoning and selects an action. Actions are either to wait or to move, in which case the agent must also select a destination such as an exit, a platform, or another agent to follow.

3 EXPERIMENTS

FACTORS TO VARY

- LLM
- Decision interval
- Input population (size, demographics)
- Scenario conditions

METRICS TO MEASURE

- Time to first movement
- Station clearance time
- Appropriateness of behaviour
- Number waiting at blocked escalators

4 VALIDATION

GROUND TRUTH: PROULX (1991)

- 5 unannounced evacuation drills
- Monument station, Tyne & Wear Metro
- ~250 passengers per drill

Drill	Condition	Key behaviour
E1	Alarm only	Alarm ignored
E2	+ staff	Rapid; immediate compliance
E3	+ minimal PA	Partial; group waited inside
E4	+ staff + directive PA	Best; rapid evacuation
E5	+ directive PA only	Near equal to E4

5 DISCUSSION

CHALLENGES

LATENCY / SCALE	Large numbers of LLM calls are slow and costly
VALIDATION DATA	Real evacuation behaviour data is rare
PROMPT SENSITIVITY	Behaviour can vary with prompt wording
GENERALISATION	Results may be specific to Monument Station

Scan for more info

- Source code
- Contact details