Title: Scaling Agent-Based Transport Simulations via Independent Distributed Simulations building consensus of network conditions in a central database

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Introduction

Large-scale transport simulations offer crucial insights into infrastructure planning, policy assessment, and emergency preparedness. However, conventional agent-based transport simulation frameworks face significant computational and resource constraints when scaling to large geographical areas, such as entire metropolitan regions or even continental scales. These challenges primarily arise from centralized data management, extensive memory usage, and processing limitations. To address these constraints, this paper proposes a novel distributed simulation approach utilizing pseudo-simulations, significantly enhancing computational efficiency and enabling practical deployment at unprecedented scales.

Background

Multi-Agent Transport Simulation (MATSim) frameworks, though highly effective for detailed transport analysis, traditionally encounter scalability issues due to the massive number of agents and complex interaction patterns at larger scales. Conventional solutions either compromise on spatial resolution and detail or run into decomposition limits through distribution of the queue simulation. To overcome these limitations, this research leverages pseudo-simulations, distributed independently across network patches. Each pseudo-simulation computes local travel times and updates network conditions iteratively, enabling information propagation and rapid convergence without necessitating full-scale centralization.

Methodology

The proposed method decomposes the global network into smaller, manageable patches, each containing a node or intersection as its core focus. For each patch, an independent simulation runs, where agents' plans and network interactions are simulated locally. Travel times computed in each patch reflect local network conditions, congestion levels, and interactions among agents within that specific area. After each iteration, these localized travel times are aggregated and averaged in a central database across multiple overlapping patches, creating smoothed, realistic travel-time profiles that approximate global network conditions.

The iterative averaging procedure allows travel-time information to propagate outward from central nodes. Agents regularly replan their routes using updated travel times, converging toward an equilibrium where further replanning does not significantly alter agent routes or network performance. So agents update their plans in response to a growing consensus across patches of network conditions.

Implementation and Application

This approach offers advantages for very large-scale simulations. Firstly, the distributed nature of independent patch simulations drastically reduces memory consumption, enabling larger geographic coverage with higher network resolutions. Secondly, agent plans are stored in a conventional database and only the relevant, truncated plans for a patch are run, so there is no need for a central high memory machine to serve as the plan database as is currently the case in conventional MATSim.

The methodology is illustrated through a large-scale case study. The network is partitioned into numerous overlapping patches, each independently simulated using the proposed framework. The approach is compared against the results from a standard MATSim run for the whole area.

Results and Discussion

Results are forthcoming,..