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Author(s):
Tchervenkov, Christopher; Hörl, Sebastian; Balać, Miloš; Dubernet, Thibaut Jean Pierre; Axhausen, Kay W.

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An improved replanning strategy for congested traffic conditions in MATSim

Christopher Tchervenkov[a,*], Sebastian Hörl[a], Milos Balac[a], Thibaut Dubernet[a], Kay W. Axhausen[a]

[a] *Institute for Transport Planning and Systems, ETH Zürich, Stefano-Franscini-Platz 5, 8093 Zürich, Switzerland*

Abstract

Agent-based transport models such as MATSim have been developed and used for the past few decades to simulate transportation systems in different cities and are capable of accurately reproducing travel patterns at different levels of aggregation. Given their disaggregate representation of both travel demand and supply as well as the high level of spatial and temporal detail, agent-based transport models also have the potential to allow for unprecedentedly detailed and disaggregated analysis.

When simulating large study areas, it is often common to increase the replanning rate to achieve a quicker convergence. However, this comes at the cost of causing substantial oscillations in link-level dynamics which render disaggregate analysis difficult, if not impossible.

This paper tries to reconcile both objectives: favour quicker convergence as with higher replanning rates while mitigating the strong oscillations of the link-level dynamics.

Keywords: agent-based transport simulations; MATSim; replanning strategy; link dynamics; congestion; user equilibrium

1. Introduction

Agent-based transport models such as MATSim [6], SimMobility [1], POLARIS [2] and mobiTopp [9] have been developed and used for the past few decades to simulate the transportation systems of several different cities and are capable of accurately reproducing travel patterns at different levels of aggregation. Given their disaggregate representation of both travel demand and supply as well as the high level of spatial and temporal detail, agent-based transport models also have the potential to allow for unprecedentedly detailed and disaggregated analysis.

* Corresponding author. Tel.: +41 44 633 30 92
E-mail address: christopher.tchervenkov@ivt.baug.ethz.ch

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As a coevolutionary algorithm, MATSim works by allowing some agents to innovate by altering their existing travel plans. Higher replanning rates favour quicker convergence, which is often desirable when simulating large study areas such as an entire country. However, the drawback of using higher replanning rates is the often substantial variation of the simulation dynamics at higher levels of disaggregation over the simulation iterations.

Recent work in analysing congestion in Switzerland at the individual link level at different times of day have further exposed this inherent compromise between the speed of convergence and the stability of the link dynamics. The current paper tries to reconcile both objectives: favour fast convergence as with higher replanning rates while mitigating the strong oscillations of the link-level dynamics.

This paper is structured as follows. First, the sandbox simulation setup used for analysis is described and the dynamics of the baseline scenario are presented. Then, the different steps of our solution strategy are described and their impacts on the simulation outcome are presented. Finally, the overall effect of our replanning strategy on the simulation dynamics are discussed and some conclusions are provided.

2. Problem definition

The standard MATSim simulation flow chart is shown in Fig. 1. MATSim simulates individual agents, each with a finite set of travel plans, traveling on a detailed representation of the transportation network. The initial travel demand is obtained by combining data from different sources to generate a synthetic representative population within the area of study.

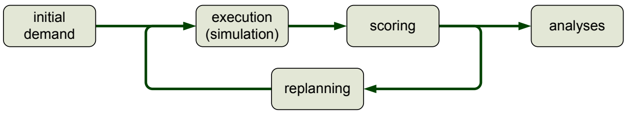

Fig. 1. MATSim flow chart

The agents are then simulated on the transportation network, carrying out their initial plans and interacting with one another. The execution of each agent's plan is then scored according to a defined scoring function. At the replanning phase, a fraction of the agents are allowed to randomly modify their plans, thus generating and selecting an entirely new plan, whereas the rest select one plan from their existing set. The set of plans is kept to a finite size, typically by dropping the plan having received the lowest score to date. Each with their new selected plan in hand, the agents are once again simulated across the transportation network, their executed plans are scored, and new plans are generated and selected. This loop continues for several iterations until the agents can no longer improve their scores, thus reaching the user equilibrium.

2.1. Sandbox simulation

To better analyze the problem as well as test different proposed solutions, we construct a sandbox simulation setup consisting of N links of different flow capacities. All links have the same length, freeflow speed and number of lanes and start and end at the same node. The setup is such that all agents arrive at the first node at the exact same time. The baseline parameters are summarized in Table 1.

Table 1. Sandbox baseline parameters

Number of agents	600
Number of links	3
Flow capacities	[300, 200, 100]
Replanning weight	0.2
Innovation strategy	ReRoute
Selection strategy	ChangeExpBeta
Traffic dynamics	Queue

In this setup, the replanning rate indicates the share of agents that are randomly selected to carry out the innovation strategy. The *ReRoute* innovation strategy determines the new shortest-path route for the agent given the mean travel times at each time bin from the previous simulation iteration. The remaining agents perform the *ChangeExpBeta* selection strategy, which selects a different plan with a probability equal to the exponential value of the difference between the scores of the current and new plan [5]. For the mobility simulations, we use the MATSim default queue-based and time-step based QSim, implemented as a single-queue model [3][5].

2.2. Current dynamics

Given this setup, we would expect the equilibrium to be reached when the agents distribute over the links proportionally to the flow capacities, i.e 300 agents on the first link, 200 on the second and 100 on the third. In this state, the mean travel time on each link would be equal. The agents would thus not have any incentive to deviate from this distribution, as doing so would result in longer travel times. Fig. 2 shows the number of agents, the travel time estimated by the router and the actual mean observed travel time in seconds per link per iteration in the baseline scenario described in Table 1. Although the number of agents on each link seem to oscillate around the expected target values, we see that the exact count varies quite substantially through the iterations. Similarly, the mean observed travel times oscillate heavily around a same value.

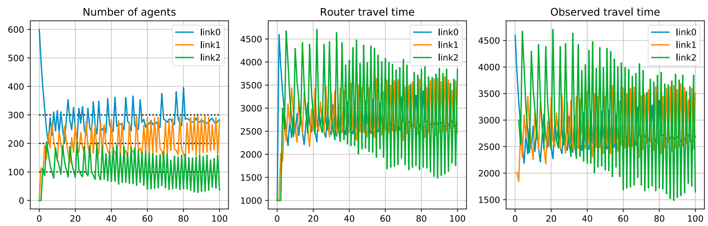

Fig. 2. The baseline setup with 20% replanning rate

Decreasing the replanning rate can dramatically supress these oscillations as shown in Fig. 3 and 4, where the same baseline scenario has been simulated with a replanning rate of 5% and 1% respectively. However, up to 80 iterations are now required to reach the user equilibrium in the 1% case, which in the case of simulating larger scenarios or using more innovation strategies could lead to a substantially longer computation time.

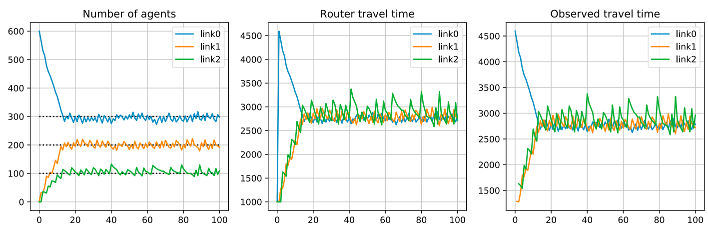

Fig. 3. The baseline setup with 5% replanning rate

It is often common practice to turn off the innovation strategy after a specified number of iterations to help the simulation stabilize toward equilibrium [5]. This prevents the agents from generating entirely new plans, effectively limiting the choice set from which they can choose from. The results of turning off innovation in the base setup with a 1% replanning rate after 150 iterations can be seen in Fig. 5. Although all three metrics had previously stabilized to equilibrium, they start to deviate once innovation is stopped, which is an undesirable side-effect.

Ultimately, there must be a way to improve the replanning strategy to suppress these oscillations while maintaining a rapid convergence toward the user equilibrium.

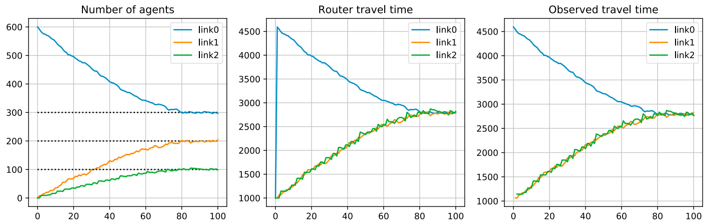

Fig. 4. The baseline setup with 1% replanning rate

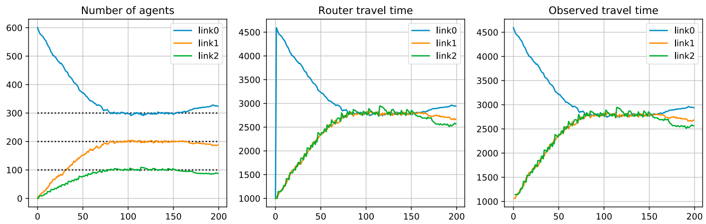

Fig. 5. The baseline setup with 1% replanning rate and innovation turned off after 150 iterations

3. Solution strategies

The following section describes different elements of our proposed replanning strategy to reconcile both quick convergence and supressed oscillations of the link-level dynamics.

3.1. Unbiasing estimation of travel times

During replanning, the routing relies on travel time estimates from the previous iteration. When no agents have travelled on a given link, the travel time in freeflow conditions is used. However, the travel time in freeflow conditions are not computed the same way the actual travel times are in QSim. Indeed, the travel time computed by QSim is always rounded up to the nearest integer, whereas the travel time given freeflow conditions is taken as the ratio between the link length and freeflow speed.

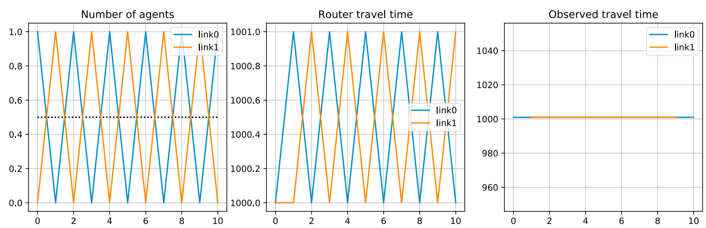

Fig. 6. Dynamics of single agent with biased travel time estimates

To demonstrate the effects of this discrepancy, we build a toy setup with two links of equal length, freeflow speed and flow capacity and a single agent. We set the replanning rate to 100%, meaning the agent will select the shortest path at each iteration. Fig. 6 clearly shows the agent continuously oscillating between the two links as a result of the difference in travel times due to rounding. By rounding up the travel times in freeflow conditions, the agent always chooses the same link.

3.2. Making rerouting dependent on expected travel time gain

Until now, routing was directly based on minimal travel cost (i.e. minimal travel time). Hence, at each iteration, the agents who innovated selected a new route with shorter travel time, independently of how much shorter this time really was. Instead, we propose to compare the actual observed travel time t_{obs} of each rerouting agent in the previous iteration with the new updated travel time t_{new} on the new route proposed by the router.

We first define the travel time gain as

$$\Delta t = t_{obs} - t_{new} \tag{1}$$

For positive Δt, we define the probability of an agent selecting the new proposed route as

$$P = 1 - \exp\left(\frac{-\Delta t}{\beta}\right) \tag{2}$$

with $\beta >= 0$ being the inertia of switching. As $\beta \rightarrow 0$, $P \rightarrow 1$ and the agent is likely to choose the new route in the case of low inertia, independent of the difference in travel time. As $\beta \rightarrow \infty$, $P \rightarrow 0$ and the agent is likely to keep its previous route in the case of high inertia. If the time difference is small for a given β, the probability for switching to the new route is low and increases only if there is a large expected decrease in travel time. If the travel time is expected to increase, then the probability of switching is zero. This simple model resembles the inertia of real travellers.

This new rerouting strategy is then added to the other elements of our solution and an example result with $\beta = 1000$ is shown in Fig. 7. The magnitude of the oscillations is similar to the baseline scenario with a 5% replanning rate shown in Fig. 3; however, the user equilibrium is reached faster.

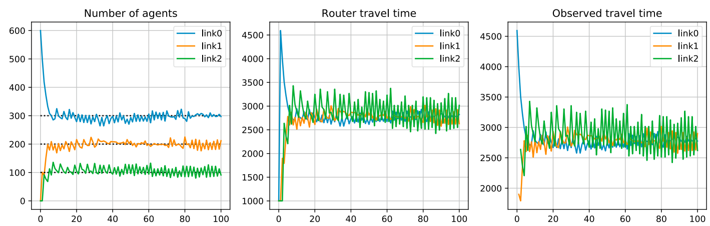

Fig. 7. Results with 20% replanning rate and $\beta = 1000$

3.3. Storing only one plan per agent

Interestingly, further increasing β causes the simulation dynamics to first overshoot the expected equilibrium values before finally converging (Fig. 8). Although the exact reason is not clear, we suspect that this is somehow related to the agents storing multiple plans. By forcing the agents to keep a single plan (i.e. their previous route or the new route), this overshoot is avoided, as shown in Fig. 9. Applying this additional fix to our replanning strategy reduces the oscillations to a level similar to the baseline scenario with a 1% replanning rate (Fig. 4) while reaching the user equilibrium much quicker. For completeness, we tried setting $\beta = 0$ while maintaining a single plan, but the oscillation level increased again, confirming that the results in Fig. 9 are indeed a combined effect.

4. Discussion and Conclusion

While increasing the replanning rate to reach the user equilibrium quicker when simulating large scale scenarios with many innovation strategies can be desirable from a computational point of view, this comes at the cost of causing substantial variations between iterations in link-level dynamics which render disaggregate analysis difficult, if not impossible. This work proposes an improved replanning strategy to reach convergence quickly while supressing these oscillations in the link-level dynamics by making rerouting dependent on the expected travel time gain. We have

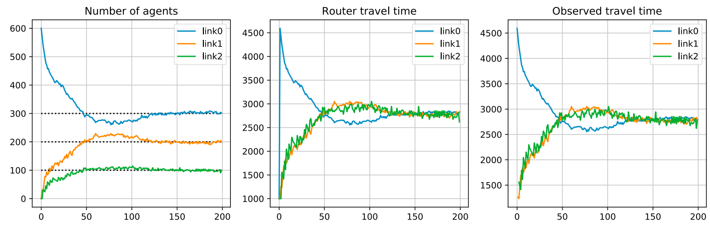

Fig. 8. Results with 20% replanning rate and β = 10000

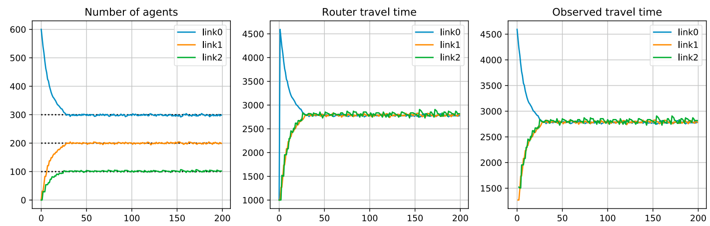

Fig. 9. Baseline scenario with 20% replanning rate, β = 10000 and single plan in memory

demonstrated we can reach oscillation levels similar to those of a 5% replanning rate while reaching the equilibrium quicker in the case of our baseline sandbox setup.

It remains to be seen whether this proposed replanning strategy yields the same results in the context of a full-scale transport simulation scenario. Some initial exploratory work has been started on applying these strategies for the MATSim Switzerland scenario, but further experiments need to be carried out.

When additionally limiting each agent to a single plan, oscillation levels comparable to a 1% replanning rate are attained while converging much quicker. Further theoretical work is needed to better understand the dynamics behind this. Nevertheless, this result can be extremely useful in the context of coupling Discrete Mode Choice models with MATSim [4][8], as is done in the eqasim framework [7], as the agents naturally have a single plan.

References

[1] Adnan, M., F. C. Pereira, C. M. L. Azevedo, K. Basak, M. Lovric, S. Raveau, Y. Zhu, J. Ferreira, C. Zegras and M. Ben-Akiva (2016) SimMobility: A multi-scale integrated agent-based simulation platform, paper presented at the *95th Annual Meeting of the Transportation Research Board Forthcoming in Transportation Research Record*, Washington, D.C., January 2016.

[2] Auld, J., M. Hope, H. Ley, V. Sokolov, B. Xu and K. Zhang (2016) POLARIS: Agent-based modeling framework development and implementation for integrated travel demand and network and operations simulations, *Transportation Research Part C: Emerging Technologies*, **64**, 101–116.

[3] Dobler, C. (2010) Implementation of a time step based parallel queue simulation in MATSim, paper presented at the *10th Swiss Transport Research Conference (STRC 2010)*, Ascona, Switzerland, September 2010.

[4] Hörl, S., M. Balac and K. W. Axhausen (2018) A first look at bridging discrete choice modeling and agent-based microsimulation in MATSim, *Procedia Computer Science*, **130**, 900–907.

[5] Horni, A. and K. Nagel (2016) More about configuring MATSim, in A. Horni, K. Nagel and K. W. Axhausen (eds.) *The multi-agent transport simulation MATSim*, chap. 4, 35–44, Ubiquity Press, London.

[6] Horni, A., K. Nagel and K. W. Axhausen (2016) *The multi-agent transport simulation MATSim*, Ubiquity Press, London.

[7] Hörl, S., M. Balac and K. W. Axhausen (2019) Dynamic demand estimation for an AMoD system in Paris, paper presented at the *2019 IEEE Intelligent Vehicles Symposium (IV)*, 260–266, Paris, June 2019.

[8] Hörl, S., M. Balac and K. W. Axhausen (2019) Pairing discrete mode choice models and agent-based transport simulation with MATSim, paper presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, D.C., January 2019.

[9] Mallig, N., M. Kagerbauer and P. Vortisch (2013) mobiTopp – a modular agent-based travel demand modelling framework, *Procedia Computer Science*, **19**, 854–859.