

TRUSTWORTHY MULTI-AGENT SYSTEMS

LÁSZLÓ Z. VARGA

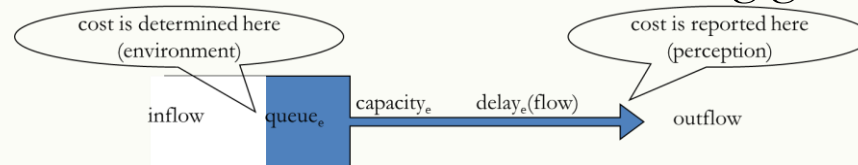


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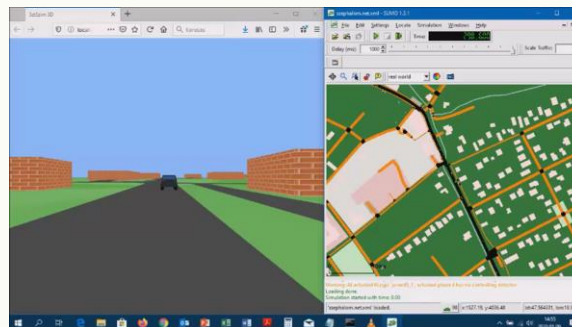
PROGRAM
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Trustworthy Algorithmic Routing of Autonomous Vehicles

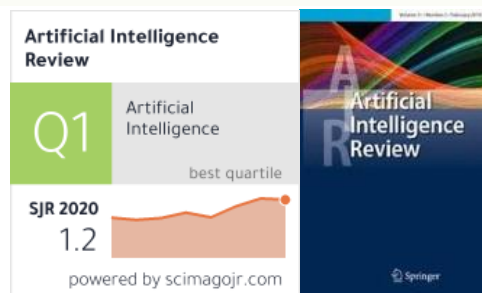
- development of the intention-aware online routing game model for trustworthy routing



- development of the routing model evaluator software to evaluate the routing model in a simulation environment



- multi-agent paradigm in software engineering and trustworthiness: comparison of the online routing model and other routing models



Dynamics – Why?

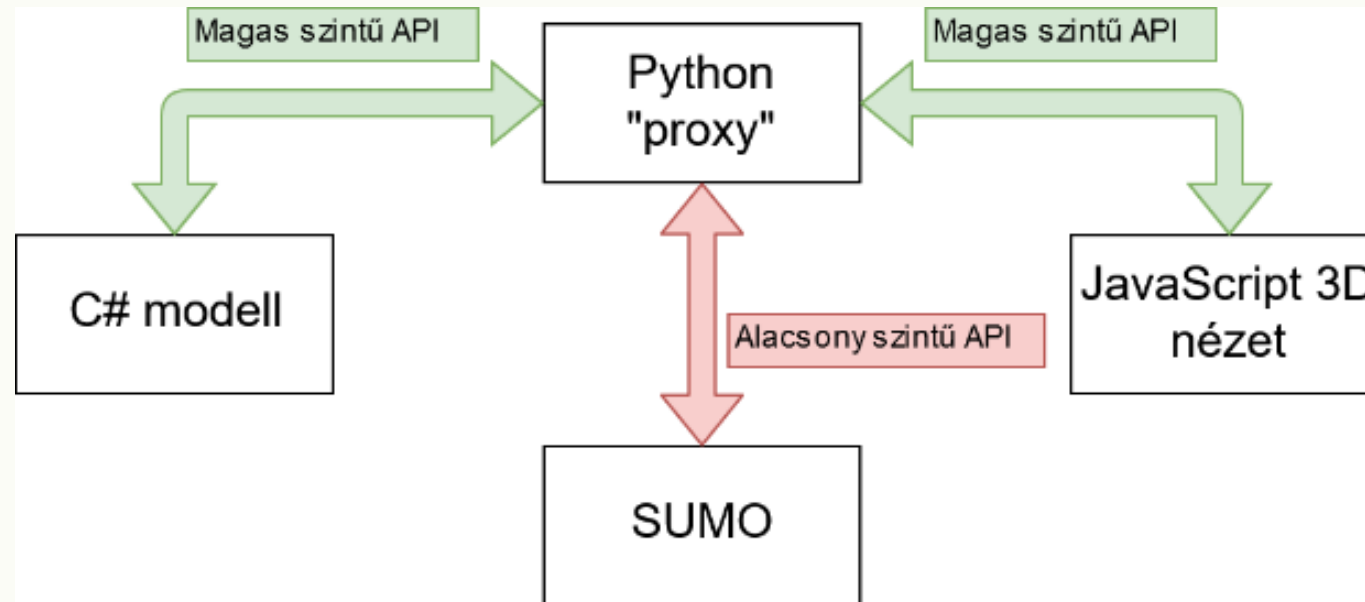
- the agent behaviour goes in cycles:
 - the agents perceive their environment (possibly communicating with other agents),
 - decide what action to perform, and then
 - perform the action
- Will the multi-agent system go to the equilibrium through these feedback cycles and stay in the equilibrium?

Intention-Aware Online Routing Games

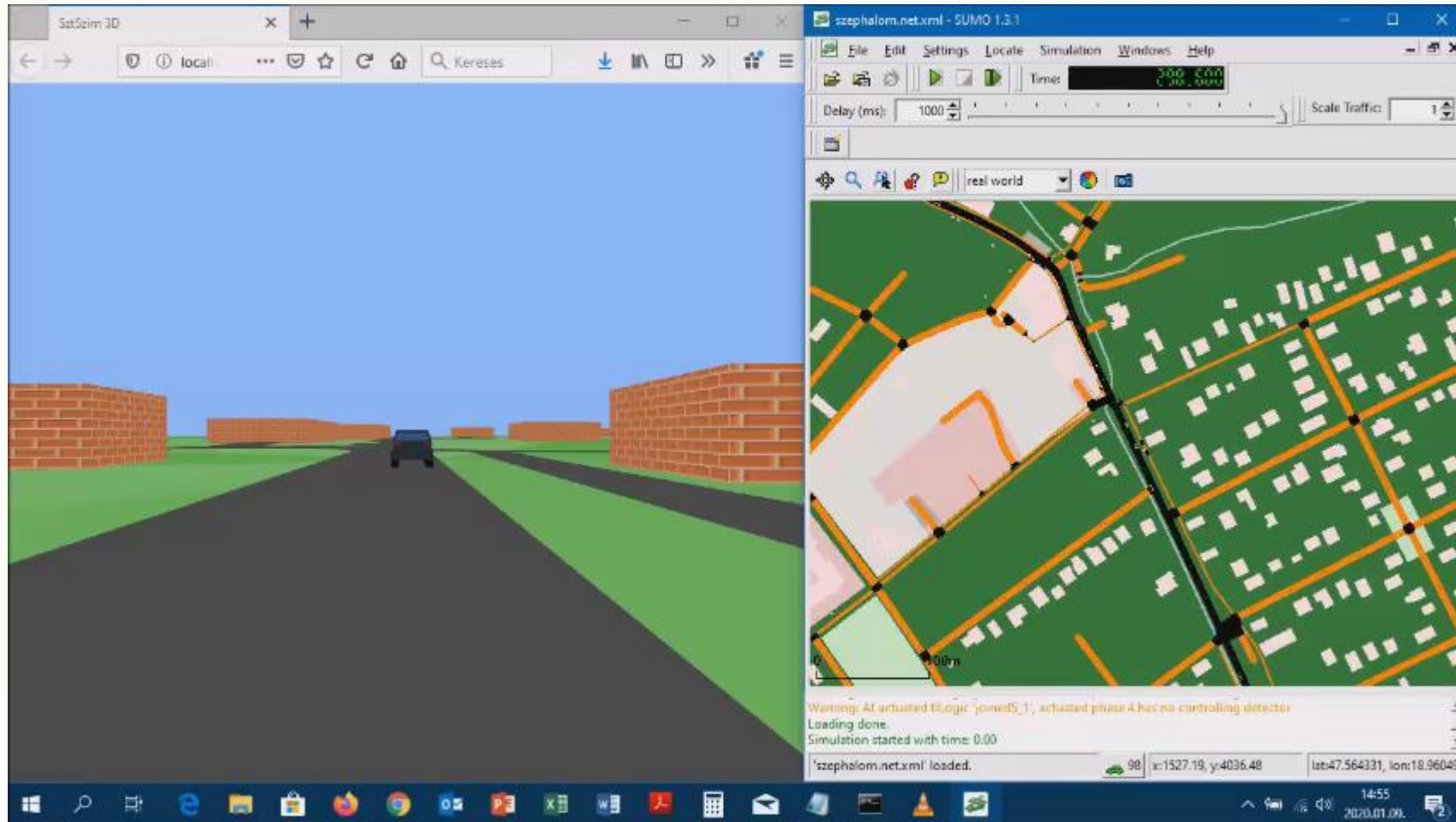
- intention-aware online routing games are online routing games where
 - the decision making agents of the flows are the vehicle agents
 - the delegate MAS predicts the travel times for each path of the trip
 - the decision is to select the path with the shortest predicted travel time
- several properties are proved, but now we want to know how it works in the real world

László Z. Varga. On Intention-Propagation-Based Prediction in Autonomously Self-adapting Navigation. Scalable Computing: Practice and Experience, 16(3):221–232, 2015. [link](#)

System Developed by Four BSc Students on their Laptops



System Developed by Four BSc Students on their Laptops



Routing Model Evaluation: Achieving Dynamic Equilibrium

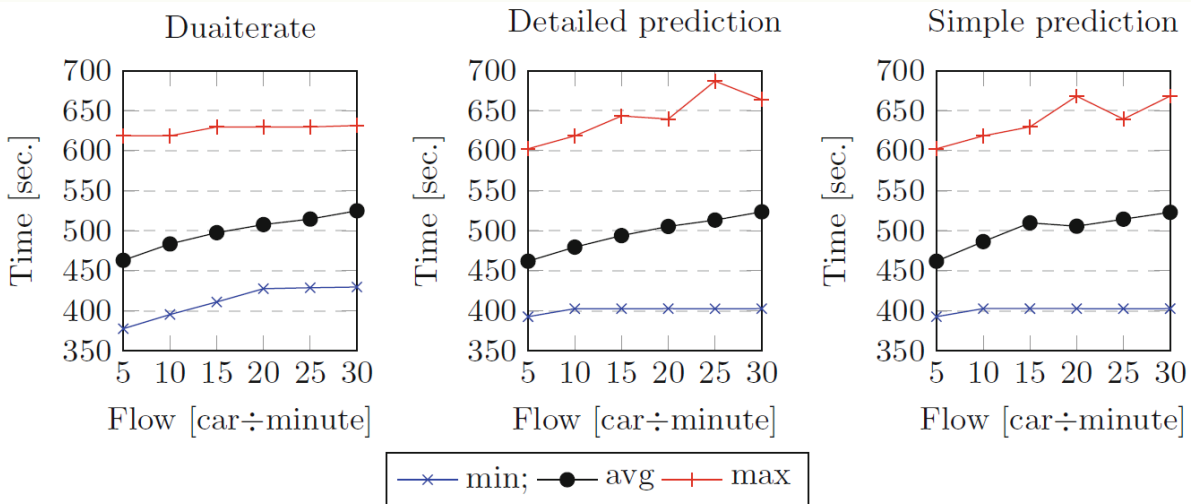


Fig. 5. Travel durations in the experiments.

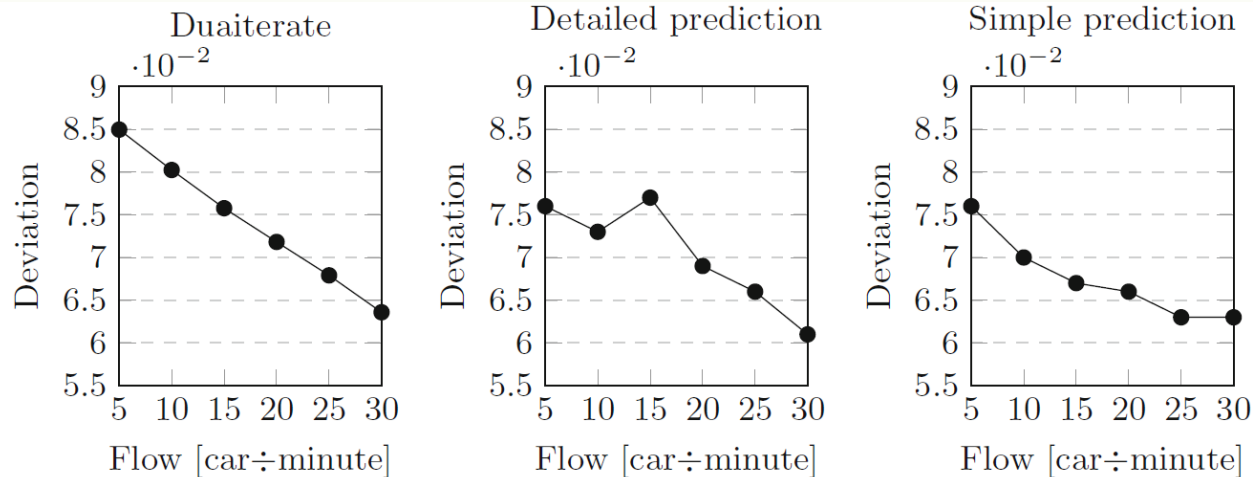


Fig. 6. Relative deviations of the travel durations in the experiments.

SUMO Duaiterate: 30 minutes
 Predictive Model: faster than real-time

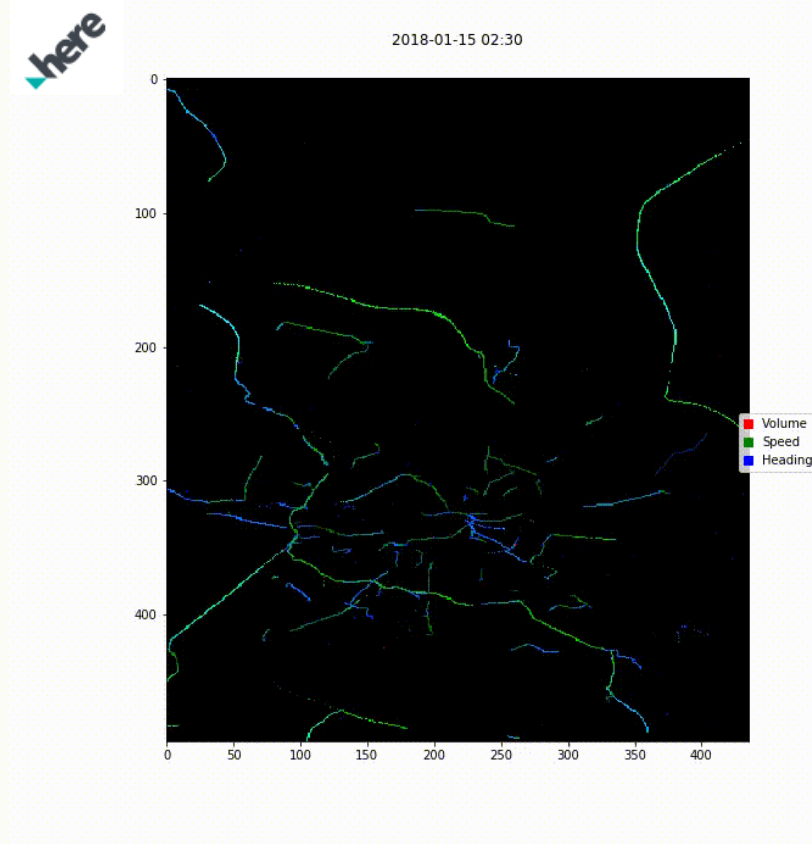
Models of Trustworthy Routing



- L. Z. Varga,
“Solutions to the Routing Problem - Towards Trustworthy Autonomous Vehicles,”
Artificial Intelligence Review, Open Access, Published: 08 January 2022,
<https://doi.org/10.1007/s10462-021-10131-y>
- trustworthy multi-agent systems
- route selection of autonomous vehicles
- comparison of the online routing model and other routing models

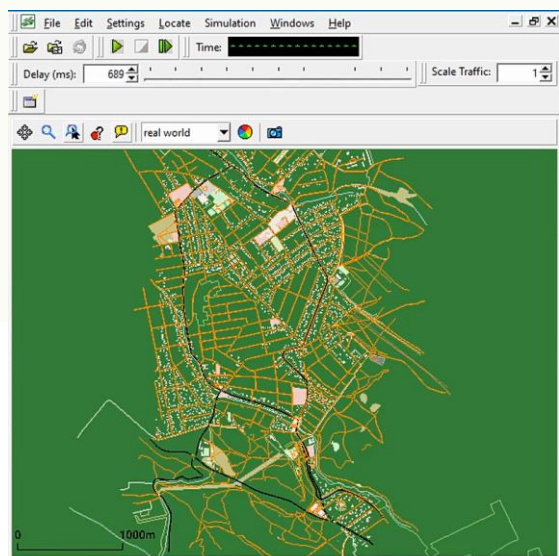
Evaluation of machine learning prediction

- HERE Technologies: mapping, location data and related automotive services (Zürich research centre)
- tensor data: for each city a grid of approximately 100m x 100m cells, 5 min time intervals, high-resolution GPS trajectories mapped to spatiotemporal cells
- forecasting tensor data for 6 periods: 5min, 10min, 15min, 30min, 45min és 60min
- our evaluation goal:
 - using these forecasts in our intention aware online routing game model
 - evaluation results: 5 min period prediction is too large



Damping in dynamic multi-agent systems

- introducing damping into SUMO ("Simulation of Urban MObility") simulator
- software technology issues and performance problems
- periodic updates to eliminate performance problems, but it spoils the routing algorithm
- the intention aware online routing game model is still the best !!!



Adapted travel time

Damping software

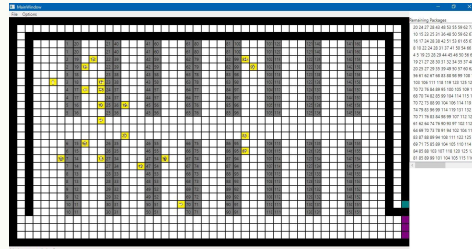
Travel time

Results

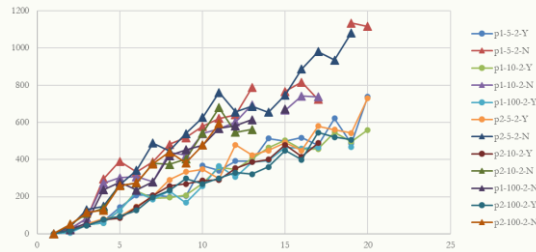
- Publications
 - Laszlo Z. Varga. “Prediction capabilities for cyber physical vehicles”. International Journal of Cyber-Physical Systems, 1(1):45-70, 2019
 - Antal, V.; Farkas, T. G.; Kiss, A.; Miskolczi, M. & Varga, L. Z.: “Routing Model Evaluator” Advances in Practical Applications of Agents, Multi-Agent Systems, and Trustworthiness. The PAAMS Collection, Springer International Publishing, 2020, 30-41
 - Antal, V.; Farkas, T. G.; Kiss, A.; Miskolczi, M. & Varga, L. Z.: “A Demonstration of the Routing Model Evaluator” Advances in Practical Applications of Agents, Multi-Agent Systems, and Trustworthiness. The PAAMS Collection, Springer International Publishing, 2020, 384-387
 - Antal, V.; Farkas, T. G.; Kiss, A.; Miskolczi, M. & Varga, L. Z.: “Intention-Aware Model to Support Agent Deliberation in a Large-Scale Dynamic Multi-Agent Application” Artificial Intelligence XXXVII, Springer International Publishing, 2020
 - László Z. Varga „The autonomous agent and multi-agent paradigm in software engineering” Annales Universitatis Scientiarum Budapestinensis De Rolando Eotvös Nominatae Sectio Computatorica 52 pp. 349-368. , 20 p. (2021)
 - L. Z. Varga, “Solutions to the Routing Problem - Towards Trustworthy Autonomous Vehicles,” Artificial Intelligence Review, Open Access, Published: 08 January 2022, <https://doi.org/10.1007/s10462-021-10131-y>
- Software
 - Routing Model Evaluator (EFOP +TKP)
- Resources
 - 1 investigator (TKP)
 - 4 BSc students (EFOP)
 - 1 laptop (ELTE) 4 laptops (students)

Multi-agent Optimizations to Increase Trustworthiness (with TTK)

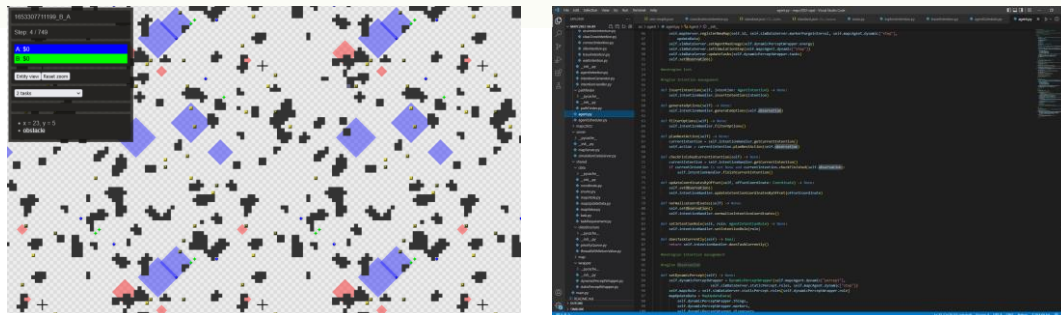
- agents in a grid world, simulation software for a warehouse



- enhancement of multi-agent algorithms to improve warehouse operation

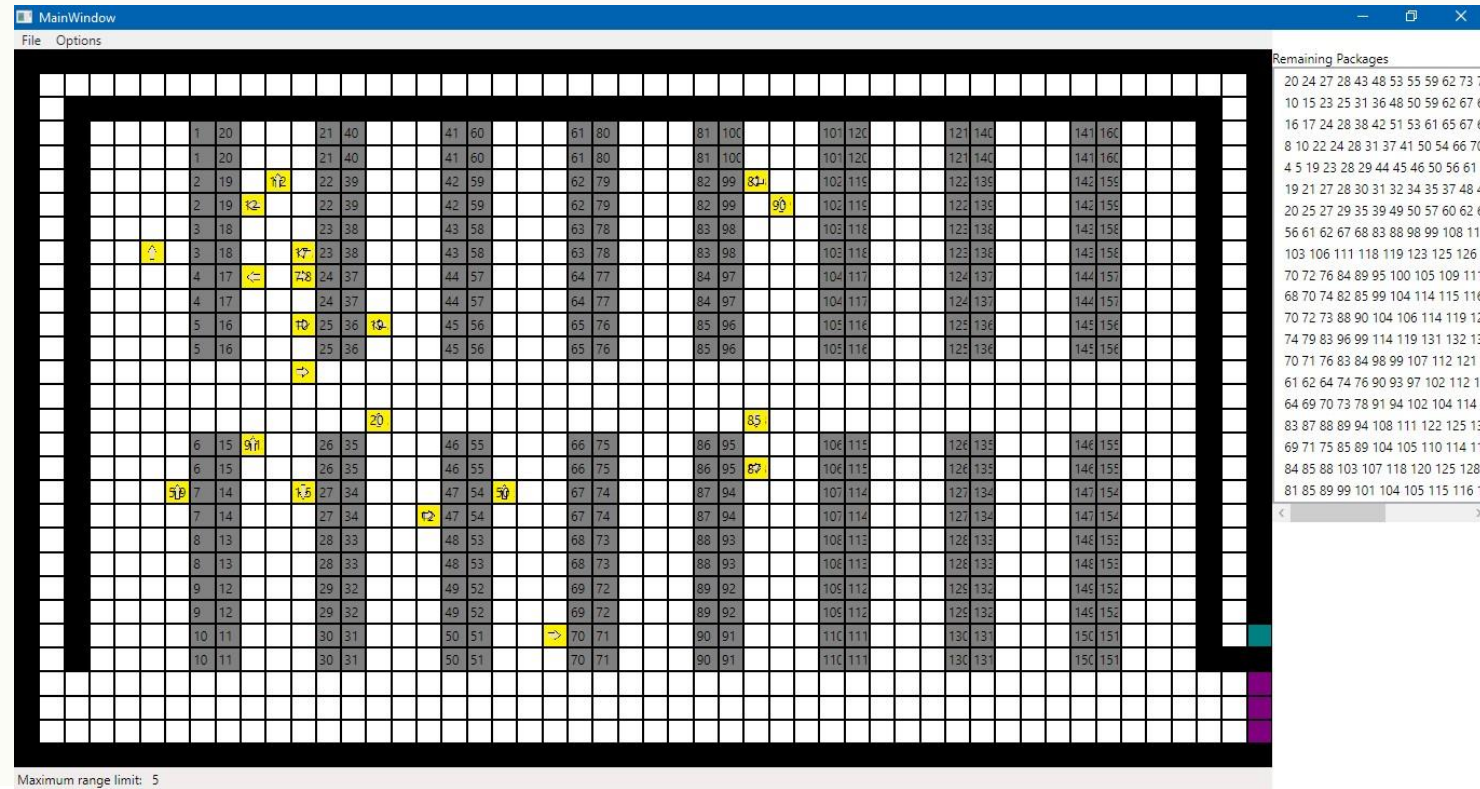


- development of agent architecture for a grid world multi-agent system

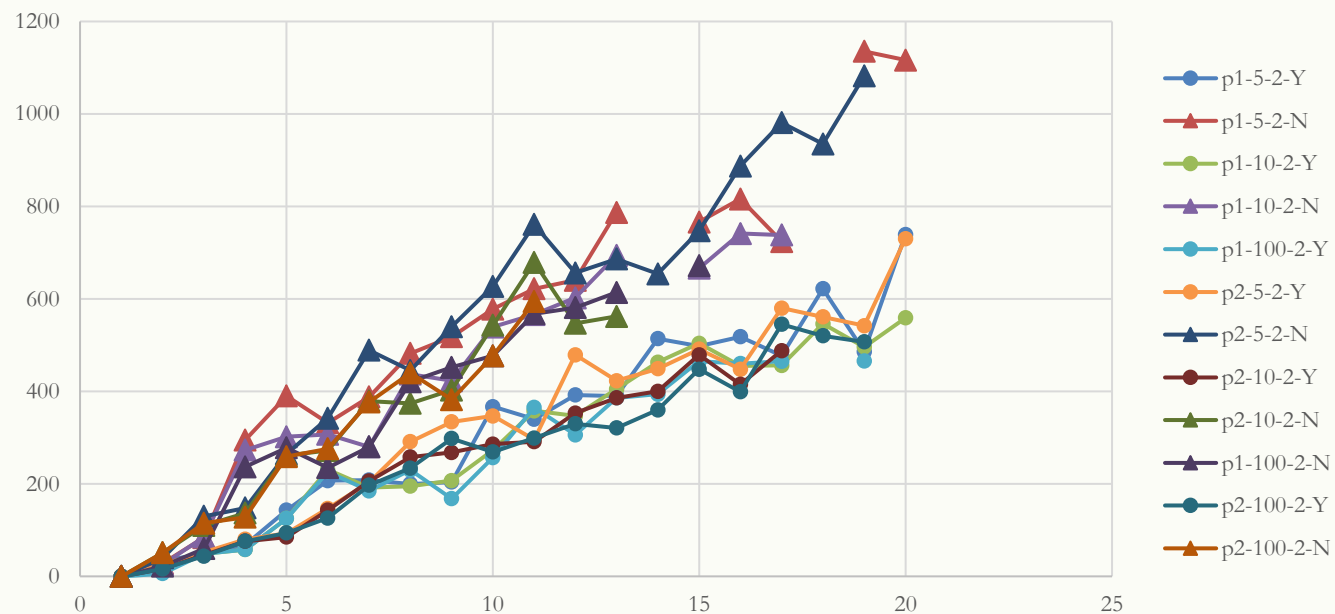


Simulation program for a traditional warehouse

- implementation of the Conflict-Based Search (CBS) algorithm
- extending CBS with waiting at shelves
- CBS for life-long operation
- CBS lookahead only for x steps
- task assignment optimization



Simulation results: considerable reduction of “irritation”



Results

- Publications

- Ács, Botond ; Dóra, László ; Jakab, Olivér ; Varga, László Z. “Multi-agent Techniques to Solve a Real-World Warehouse Problem” 2021 Dignum, Frank ; Corchado, Juan Manuel ; De La Prieta, Fernando (Eds.) Advances in Practical Applications of Agents, Multi-Agent Systems, and Social Good. The PAAMS Collection Lecture Notes in Computer Science Springer International Publishing: Cham p. 1-13
- Ács, Botond ; Dóra, László ; Jakab, Olivér ; Jüttner, Alpár ; Madarasi, Péter ; Varga, László Z. “Optimizations of a Multi-Agent System for a Real-World Warehouse Problem” 2022 SN Computer Science p. 19 Comment: submitted on 31st January 2022

- Software

- Warehouse simulator (EFOP +TKP)

- Resources

- 1 investigator (TKP)
- 3 BSc students (EFOP)
- 3 researchers from TTK (parttime)
- 1 laptop (ELTE) 3 laptops (students)

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