Proceedings of the 2021 Winter Simulation Conference
S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, eds.

MULTI-METHOD SIMULATIONS FOR LARGE FLEET AUTONOMOUS MATERIAL HANDLING ROBOTS

Bonnie Yue

Clearpath Robotics
1425 Strasburg Rd
Kitchener, ON, N2R 1H2
CANADA

ABSTRACT

Deployment of large fleet Autonomous Mobile Robots (AMRs) for material handling have unique challenges that render a purely discrete event simulation approach insufficient in capturing AMR operations. In this case study, the use of discrete event, agent-based and physics-based simulations are used together to mimic factory operations, autonomous robot behavior as well as to understand robot path planning and navigation performance. Applications of the multi-method simulation approach are discussed, as it pertains to solving common real world problems of deploying large fleet AMRs such as fleet sizing, navigation feasibility, traffic issues, and understanding impacts of layout design.

1 INTRODUCTION

AMRs utilize laser-based perception and navigation algorithms to dynamically move through spaces. Its onboard intelligence and real-time adaptive capabilities, combined with infrastructure-free navigation, support the increasing market demand for flexibility and for agility to handle product or process changes (Anandan 2017). The fundamental differences in operation between AMRs vs traditional AGVs or conveyors for material handling has led to some unique challenges that OTTO Motors has been tackling using multi-method simulations. In this case study, each simulation method is described and applications of its combined usage are shared.

2 SIMULATION METHODOLOGY

Agent-based modeling is used to capture the highly autonomous nature of the individual agents (robots or other manual transporters) as well as the traffic interactions between the agents. This is a well-established usage in the fields of transportation and road traffic(Chouaki and Puchinger 2021). The following example demonstrates the level of agent autonomy this approach enables: A robot accepts a material delivery job and as it is enroute to its destination, it slows down to replan around a parked tugger and later comes to a stop to wait for another robot to complete a turn at an intersection. As it resumes travel, new information is obtained that its destination is currently occupied. Instead of proceeding to the destination, it will reroute to a queue spot and proceed to the original destination once it becomes available. When the job is complete and no other missions are immediately queued, it proceeds to a charger to take advantage of the availability of a charger spot and its idle state. As the robot is charging, it becomes aware that another robot in the fleet has a more urgent need to charge. No other chargers are available, so it leaves the charger and proceeds to a parking spot until another mission is requested.

To capture traffic interactions and rerouting due to spot availabilities, reservation control mechanisms have been implemented and minimum space between robots are strictly enforced. The minimum space is determined dynamically based on the individual robots current speed and payload as well as the robot type. Lastly, battery consumption and charging are modeled as a function of its current speed and payload.

Discrete event modeling is used to represent the process flow of facility operations and resources. The robots interact with the facility operations by either supplying or removing material to or from a process or by waiting for a factory input to make a decision on next steps. A custom library was created for agent components and integrated in the general-purpose discrete event simulation software, Simio.

Lastly, *physics-based simulation*, uses sensor and vehicle models together with an instance of the OTTO Fleet Manager, to test robots' autonomous performance in an environment previously mapped by an AMR in the real world. It is used to gain insight on navigational performances in tight spaces, interactions with multi-robot scenarios, and mission path planning and cycle time. It is also used to test map design - the process of designing overlaid features on top of a map to enable AMRs' awareness of traffic rules and key waypoints within a facility. Physics-based simulation was done using Gazebo.

Physics-based simulation is computationally expensive, thus when used in this context, typically only a small region of the facility is simulated and for a short duration of time. Afterwards, its' findings are implemented in the Simio model via custom code and parameters. The computationally lighter Simio model can now run weeks of simulation to understand impacts on production KPIs such as production starvation time, mission throughputs and robot response time, while capturing AMR behavior at a higher accuracy.

3 APPLICATION

This multi-method simulation approach is used to support system design and integration decisions.
Many layout decisions can be supported by simulation but the most common questions relate to AMR travel paths, queuing, parking and charging space utilization. What-if scenarios are often run to understand the tradeoff between a one vs two way aisle, to determine directionality for one way aisles, and to understand the impact that various aisle width options have on the AMRs travel speed and more importantly, its impacts on production KPIs. An often overlooked consideration is parking, queuing and charging spots. Simulation is useful in evaluating the quantity and location of these as they often have impacts on robot utilization, traffic flow and space requirements.

Another insight simulation provides is anticipated traffic. Traffic heat maps can be generated to identify high traffic regions of the facility. Focusing on high traffic areas, time-based logs of metrics such as intersection 'blockage duration' or 'max number of robots queued' can be captured to understand worst case scenarios. Events such as replanning around an obstacle may seem insignificant but at high frequencies, can lead to traffic flow issues. When traffic flow problems are observed in simulation, alternate traffic rules, routing or aisle widths can be tested until conditions are satisfactory.

Finally, fleet size is determined by running experiments with increasing number of robots until the desired fleet sizing criteria is met. A common criteria is for the fleet to achieve a certain robot mission response time, defined as time from when a mission was triggered, to when the delivery is complete. This is a critical output which informs on project return on investment.

REFERENCES

Anandan, T. M. 2017. "Industrial mobile robot safety standards on the forefront". Robotic Industries Association, Ann Arbor, Michigan, USA.

Chouaki, T., and J. Puchinger. 2021. Agent based simulation for the design of a mobility service in the Paris-Saclay area. *Transportation Research Procedia* 52: 677-683.