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MODELING AN AGV BASED FACILITY LOGISTICS SYSTEM TO MEASURE AND VISUALIZE PERFORMANCE AVAILABILITY IN A VR ENVIRONMENT

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ABSTRACT

Performance availability is an approach to rate the performance of material flow systems. Since the data necessary to determine the performance availability can only be obtained by observing the system in operation, planning towards a certain performance availability is a challenging task. In this paper, we present an approach to model an AGV (Automated Guided Vehicle) based logistics facility to ultimately measure and visualize the performance availability of the system within VR environments. We employed 3-D laser scans to create a visual representation of the facility and modelled the mechanical components using the simulation system's kinematic mechanisms. An interface to the real system's control architecture makes it possible to incorporate real world data and scenarios. Data not readily visible or not visible at all such as vehicle health, waiting times, and running times is surveyed and presented in a comprehensive VR environment for evaluating overall system performance and performance availability.

1 INTRODUCTION

Performance availability is a standardized measurement to rate the performance of material flow systems by monitoring the system in operation and measuring waiting and running times of the system's constituents at significant junction points. Since the measurement is done while the system is in operation, it is not a trivial task to plan a system towards a certain degree of performance availability and to decide on certain aspects like control architecture or floor layout to reach this goal. This becomes especially apparent when dealing with highly dynamic agent based systems like AGV based logistics facilities. The complexity of the problem is furthermore increased, since one of the advantages of such a system is its scalability which allows for adaption to future scenarios and which may require subsequent planning phases while the facility is already in operation.

Simulating a system before commissioning as well as while it is already in operation and measuring internal data and states to derive the performance availability under different conditions, allows the planning entity to devise new control and sorting strategies and to plan changes to the layout or components of the system without the need to have access to an already operating system or the need to modify an already running system.

Our goal is to develop a simulation model for an AGV based facility logistics system that gathers data influencing the performance availability and that displays the current system state in an accessible manner on desktop PCs as well as in VR environments like CAVE systems as can be seen in Figure 1. Advanced interaction methods and metaphors are to be developed to ease the access to the collected data and to facilitate a thorough understanding of the inner workings of the system to support the development and improvement of similar systems.

We selected an existing logistics facility as a reference system to base our simulation on. To bootstrap the process of modelling the environment of the facility, we decided to create a 3-D laser scan of the proposed reference system. This allowed us to quickly produce a visually pleasing and at the same time accurate digital representation of the facility. The mechanical components of the system were modelled with stock kinematic mechanisms our simulation system offers. The system is controlled either by the real controller attached via a TCP/IP interface or by a basic internal control system.

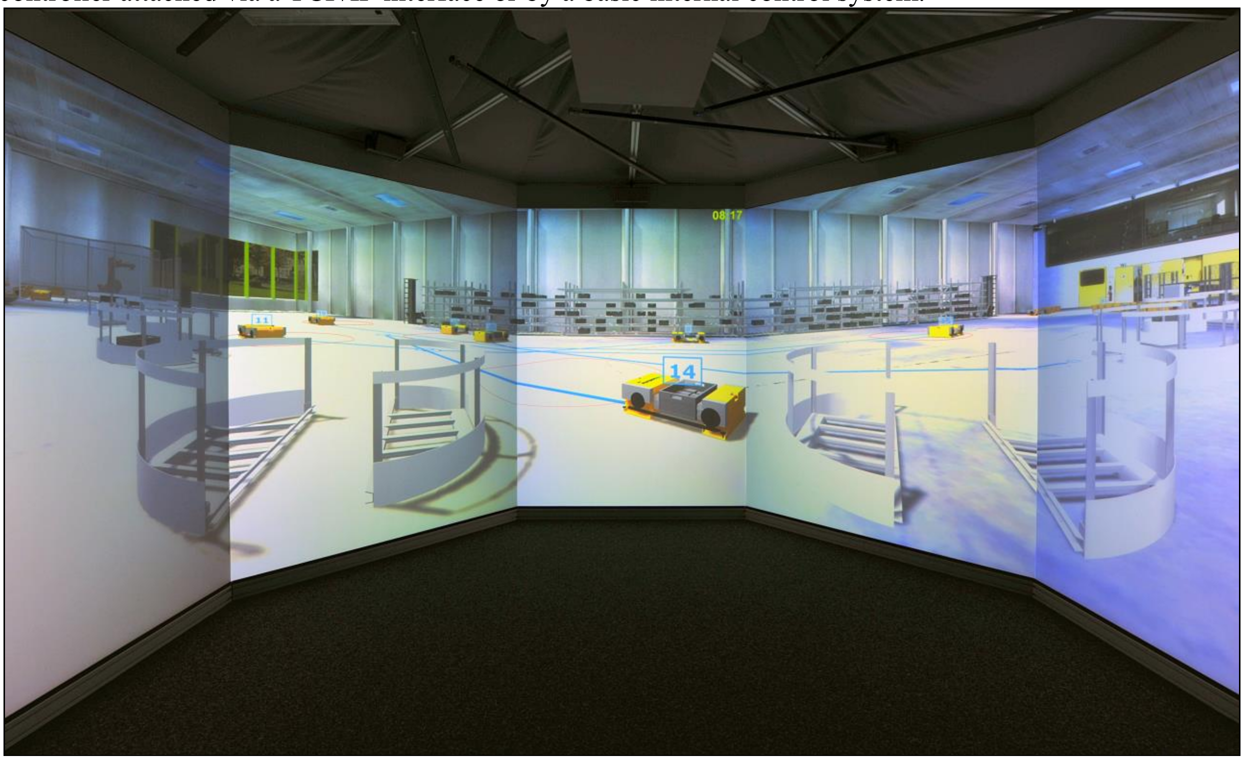

Figure 1: Simulation model in a CAVE environment.

Data that is collected during the simulation is visualized with specialized metaphors, which enables users to evaluate and observe the simulated system in real time in a VR environment.

Newly developed algorithms analyze the collected data and derive a measure for the performance availability under the current conditions.

2 STATE OF THE ART

Since performance availability is a rather new concept, there are only a few publications dealing with this topic (VDI 2012, Maier 2010, Nagel 2010). Only the latter one touches the topic of simulation albeit without focusing on the VR aspect.

Other publications relate to topics presented in this paper, but never paint the whole picture of a VR capable real time simulation of an AGV based facility logistics system for the measurement of its performance availability.

In the realm of simulating agent based logistics systems, one can find numerous publications like the ones by Günther et al. (2001), Raffel (2005), Raffel and Wagner (2011), and Roidl and Follert (2007). However, none of these consider VR techniques.

Publications such as Günthner et al. (2010), Günthner and Tenerowicz (2010), and Günthner et al. (2012) focus on the simulation of AGVs and their sensors but never touch the topics of VR or real time capabilities.

Craighead et al. (2007) describe numerous commercially available solutions for the dynamic simulation of AGVs that are, due to the computationally intensive nature of dynamic simulations, also not applicable to real time VR solutions.

Furthermore, the works by Poupyrev et al. (1998) and Steinicke, Ropinski, and Hinrichs (2004) are focused on interaction and metaphors within VR environments of facility logistics systems but do not consider the evaluation or visualization of performance availability.

None of the presented works describes a comprehensive real time simulation system for determining the performance availability of a logistics facility without interfering with a real world system while offering the user the means to interact with the system intuitively to determine any optimization potential or to find potential bottle necks either in the control architecture, the floor layout or the dimensioning of the system.

The simulation system used in this work features a high grade of modularity and was the central part of numerous research projects already (Rossmann and Alves 2009; Freund, Rossmann, and Turner 2003; Rossmann, Ruf, and Schlette 2009; Rossmann, Schluse, and Schlette 2009). It provides VR capabilities and features several interfaces, including a TCP/IP interface which can later be utilized to connect the simulation system to the real world system.

3 PERFORMANCE AVAILABILITY

Performance availability is defined in the standard VDI (2012) as the "degree of fulfilment of processes agreed between contract parties (manufacturer and user) in accordance with the requirements and deadlines and in compliance with the agreed basic conditions". This means, that in contrast to the regular availability, which is a measure of the performance and reliability of a single component, the performance availability is a measure of the performance of a system as a whole.

It can be calculated based on either waiting times or running times of certain constituents of the system. Since the performance availability takes the whole system into account, it can be influenced by static parameters such as the availability of single components or the overall design of the system as well as by dynamic parameters such as the volume of the current work load, or even parameters of the work load itself (weight, dimensions, distribution, order etc.). So, waiting and running times can currently only be determined accurately by taking measurements while the system is already running which makes it hard to determine the performance availability of a future system, a fact that interferes with the guide line's goal to define a metric for planning purposes to ensure legal security for manufacturer and user alike.

To calculate the performance availability of a given system, the waiting or running times of critical components are gathered during one or more periods of a defined length. For this measurement, only the actual system performance is taken into account, therefore even the failure of any equipment can be regarded as inconsequential as long as the overall system still performs within the boundaries defined by manufacturer and user, decoupling the performance availability from the availability of individual components.

If the performance availability is to be calculated based on the waiting times of certain processes, the equation

$$\eta_W = \frac{T_B - T_W}{T_B}$$

is taken into account, where η_W represents the performance availability, while T_B and T_W represent the observation interval and the waiting times respectively.

If it is not feasible to measure the waiting times, the following equation to calculate the performance availability based on the running times will be used:

$$\eta_L = \frac{N - n}{N}$$

In this case, η_L represents the performance availability, while N and n are measures for the amount of delayed loading units and the planned number of loading units for the observation interval respectively.

The performance availability η amounts to a value between 0 and 1 in both cases, with 1 (or 100%) representing the degree of maximum fulfillment.

4 DEVELOPING THE SIMULATION MODEL

The real world reference system that is used as the foundation for our project is a facility logistics system by the Fraunhofer Institute for Material Flow and Logistics (IML) in Germany. It is a 17 m by 55 m hall which features a storage shelf, capable of storing 520 transport bins on five levels. Up to 50 autonomous vehicles populate the hall and the shelf, which they can access via three entrances and two lifts. The bins can be picked up and put down in the shelf and in the picking stations by the vehicles with a specialized telescopic gripper that can expand and retract to either the left or the right side. Lined up opposite to the shelf are seven manual picking stations that are also accessible to the vehicles. Another vehicle accessible station with a depalletizing robot acts as the warehouse's input. A schematic of the reference system's floor can be seen in Figure 2. The depalletizing robot is not shown and resides in the north-eastern corner.

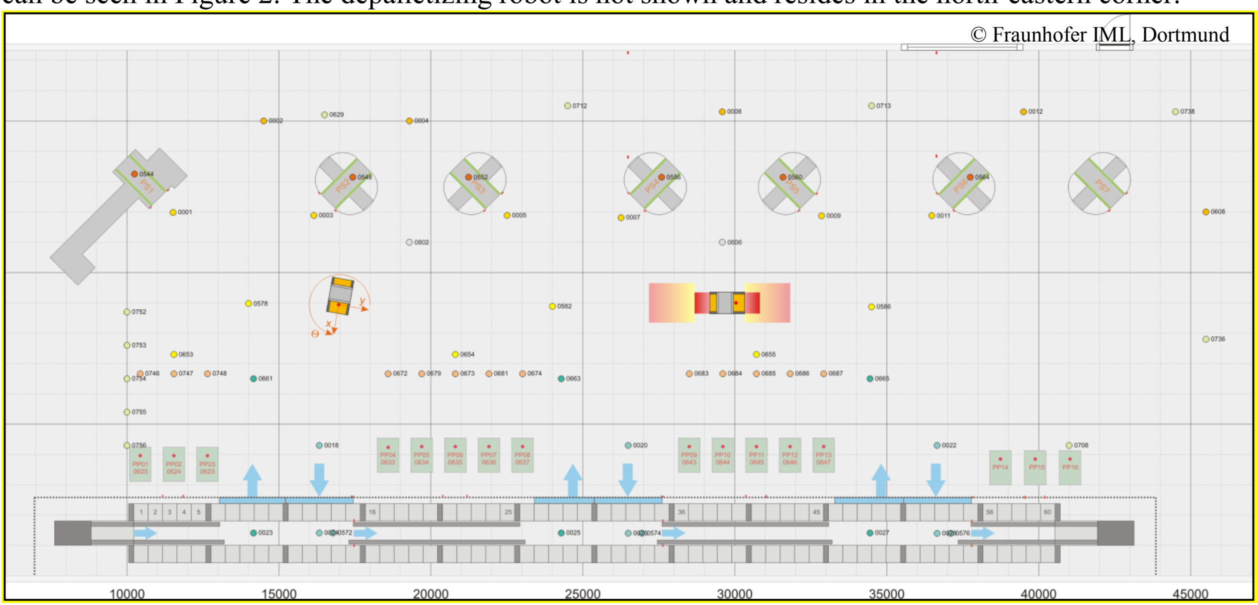

Figure 2: Floor plan of the reference system.

In order to quickly generate an accurate visualization, we decided to use a combination of a digital camera and a 3-D laser scanner to produce a digital representation of the hall. In the time span of two and a half hours, we conducted four scans along the axis of the hall and another fifth inside the shelf. The result of these scans were five point clouds as can be seen in Figure 3 as well as five colored point clouds, for which the color information from the camera was merged with the depth information from the raw point clouds. We pruned the five colored point clouds of runaway points and aligned them to form one continuous point cloud. We then imported the resulting point cloud into the simulation system to recreate an accurate visual representation of the reference system that is depicted in Figure 4. Although the actual resolution of the colored point cloud is lower than the raw data, due to limits of the camera used for obtaining the color information, we were able to recreate the interior of the hall with enough detail to present it in a VR environment without sacrificing immersion.

Since the autonomous vehicles are equipped with laser scanners to get a sense for their surroundings, we made the point clouds opaque to the laser scanners of the simulated vehicles to allow them to navigate the hall without bumping into any obstacles.

Of course, solely having an accurate geometric representation of the surroundings is not sufficient to simulate the reference system. Any movable parts and input devices of the original system have to be recreated as well.

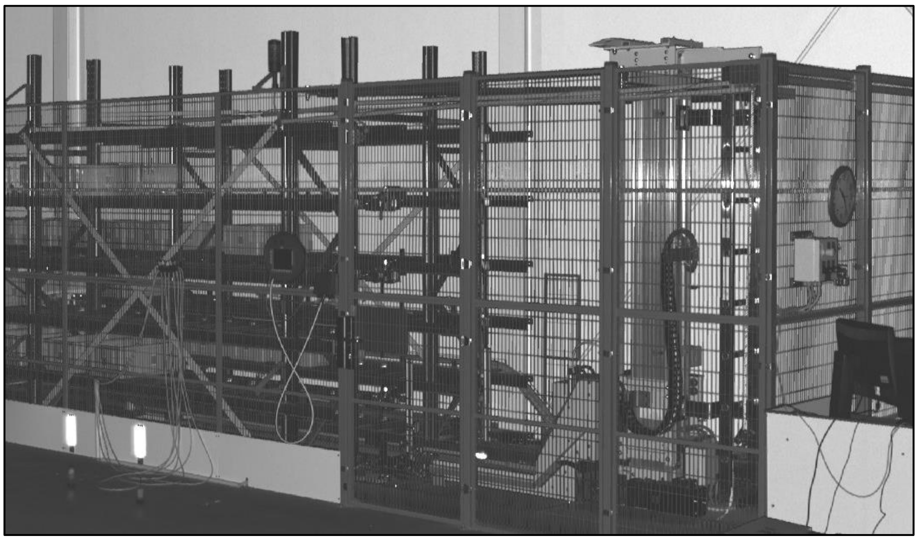

Figure 3: Raw laser scanner data.

The vehicles have dimensions of approximately 1.2 m by 0.7 m. They move across the floor with two wheels driven by a differential drive and a third passive supporting wheel at the back. Due to the nature of the drive they can rotate on the spot and move forwards as well as backwards. Movement in the shelf is achieved with an additional four wheels at the sides of the vehicles which hook into rails in the shelf.

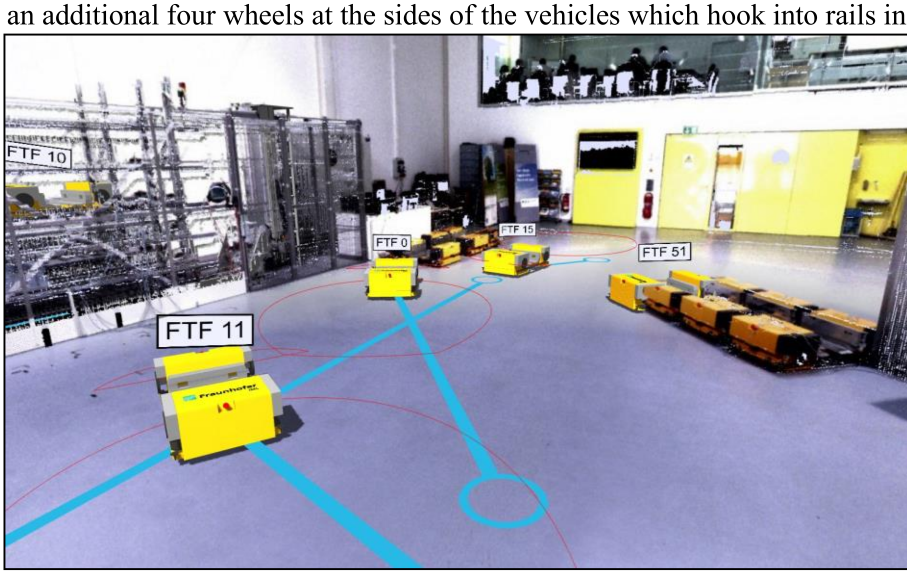

Figure 4: Colored representation of the laser scanner data within the simulation system.

Two laser scanners at the front and rear each with a field of view of 180° allow the vehicles to get a sense of their surroundings and act as fail safe to prevent any collisions with vehicles and other obstacles (Kamagaew et al. 2011).

Since the simulation system we use offers a range of basic kinematic mechanisms, a library of industrial robots, and various customizable laser sensors, we were able to model the mechanical components of the lifts and vehicles, the robot cell, and the sensor systems that match the ones from the real world to obtain a fully working mechanical representation of the reference system.

5 CONTROL AND DATA AQUISITION

The real reference system is controlled by an agent system that consists of three layers of software that communicate via TCP/IP. The last element in this chain is formed by the individual vehicles that receive target positions that are based on the interaction in the two layers above (order generation and agent based order allocation).

One of our goals is to implement a fully working interface to these software layers to have the simulated vehicles react to the same input data as their real world counter parts. However, we also implemented a simplified version of the control software for testing purposes which leaves out the agent based order allocation method and generates orders from random or predetermined data and assigns those orders in a centralized manner.

Since our main goal is to determine the performance availability of a certain system under certain circumstances, the simulation must be able to gather the data relevant to calculating the current performance availability. For this purpose, any object relevant to the calculation of the performance availability is equipped with a logic of its own to gather the relevant data. Picking stations accumulate their waiting times and measure their throughput, bins also accumulate waiting times as soon as they become the target of a transport order, and vehicles can track their down times, be it related to congestions, the need to reload the battery, or equipment failure.

This data is tracked in real time and can be visualized during a simulation run or presented afterwards in a summary. Furthermore, it is possible to save and replay a simulation run to perform a detailed analysis afterwards.

6 VISUALIZATION, INTERACTION, AND EVALUATION

When transferring a simulation to a VR environment, additionally to the real-time capability of the simulation, two features are highly significant: Visualizing the data obtained during the simulation in a well-arranged and consistent manner and offering intuitive methods for interacting with the system.

When it comes to visualization, it is imperative to not only visualize the gathered data and results but also the most important inner states of the system that are not perceivable in the real world system so that any problems or shortcomings of the simulated system can be observed and evaluated as soon as possible.

For this purpose, we utilize a set of new metaphors that show internal states in an intuitive manner, some of which can be seen in Figure 5. The arc-shaped detection ranges of the laser scanners as well as the shapes of detected objects are visualized alongside the vehicles' battery capacities (not pictured) or individual markers displaying the current state of the vehicles' collision avoidance mechanism. Target positions are visualized on the floor together with any action the associated vehicle should take upon reaching the target such as loading or unloading a bin or requesting a lift.

Simulation results and inferred data such as waiting times are displayed near the corresponding objects and unusual values such as long waiting times or a low throughput are highlighted to indicate potential problems.

Being able to interact with the simulation is crucial for detecting problems within the simulated logistics facility or for actually inducing them, so it is helpful if one can intervene in the running simulation to simulate failures and provoke emergency situations. To test the system's reaction to dynamic input and events, the simulation system allows for the manipulation of all the system's parameters including the vehicles'. Manipulating the maximum acceleration of the drives for instance can reveal problems with the handling of worn or defective motors while reducing the battery capacity might expose any flaws in the recharging logic.

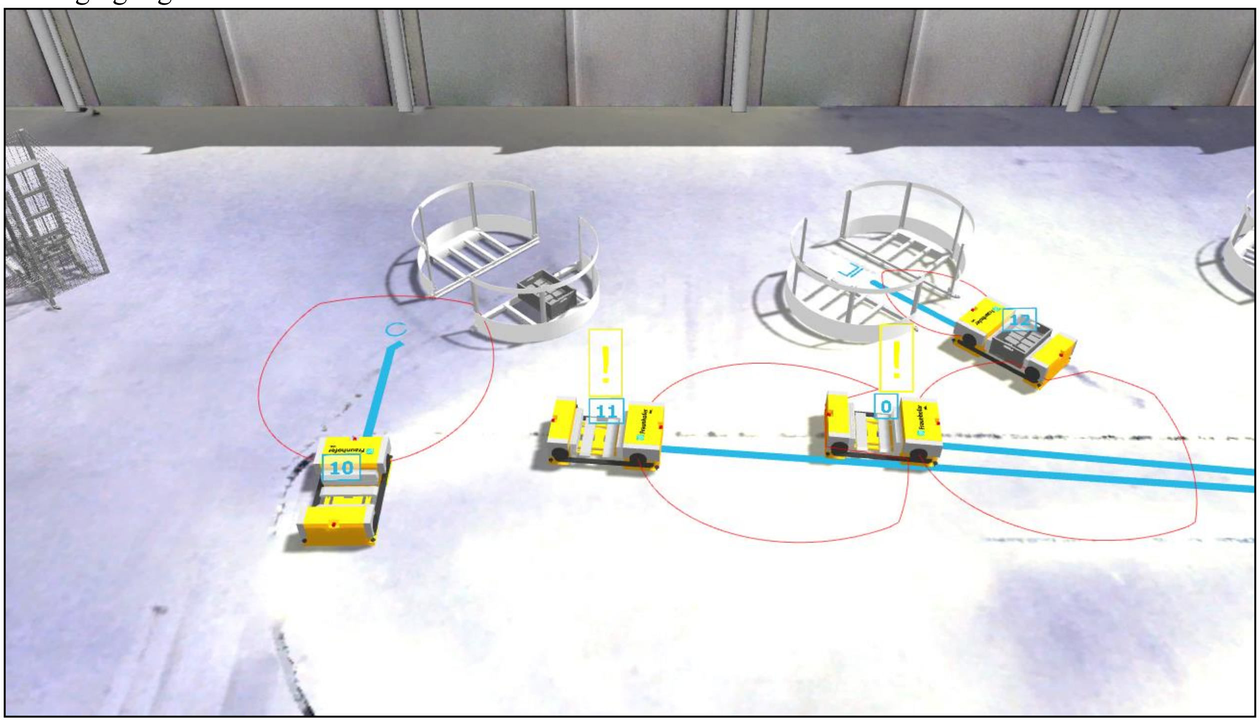

Figure 5: Metaphors used to visualize inner states of the system.

It is also possible to take control of individual vehicles so that they can be moved into the range of other vehicles to stress the security system or test the system's robustness when it comes to delays.

Deactivating picking stations and thus removing them from the order generation queue to simulate unavailable stations or employees is also possible.

These methods of visualization and interaction allow the user to develop a sense for how much of an influence on the overall performance availability certain aspects of the simulated system have and where to look for optimization potential.

7 CONCLUSION AND FUTURE WORK

We presented a simulation model of an agent based facility logistics system to determine the system's performance availability. We modelled the interior of the simulated hall in a visually pleasing and accurate manner by incorporating the results of a 3-D laser scan into the simulation and we modelled the kinematic and behavioral models of the mechanical components of the reference system. Furthermore, we added an order generating system in addition to the proposed interfacing with the reference system's software stack.

To present the simulation in a VR environment in an intuitive manner and to visualize the inner states of the simulation system, we developed several metaphors and provided interaction methods.

To make it possible to take full advantage of the simulation system, we are going to develop methods for the automatic analysis of the obtained data, so that different ways of modifying or planning a system can be easily rated and compared.

Due to the nature of a simulation, the system is currently aware of the exact location of the AGVs but realistically the localization is always plagued with at least a slight error. To take this into account, a heuristic error model or even better, a realistic simulation of the actual localization system should be integrated into the model. Most of the components needed for this task are already present in the simulation system (Rossmann et al. 2010).

As soon as it is possible to interface the simulation with the reference system's software stack, we will connect the two systems to compare the results of our simulation with the observed reality and apply potential modifications to the simulation, should it diverge too much from reality.

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