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PREDICTIVE TRAFFIC BLOCKING TO AVOID CONGESTION IN LARGE-SCALE AUTOMATED MATERIAL HANDLING SYSTEMS

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ABSTRACT

This study focuses on resolving traffic among autonomous vehicles in large-scale semiconductor manufacturing plants. Although automated material handling systems (AMHSs) provide rapid wafer transfer services by controlling thousands of autonomous vehicles between facilities in real time, traffic congestion is a significant issue, which increases the probability of slow wafer transfer, resulting in a failed production schedule, and idleness of bottleneck production machines. Therefore, to avoid sudden, inevitable heavy congestion and prevent systematic bottlenecks, this study proposes a method based on a machine learning technique that prevents the expansion of local traffic congestion by predicting and blocking the extension boundary of the congestion area. High fidelity simulations showed that the proposed method effectively reduced the transfer inefficiency of AMHSs due to traffic congestion, compared to existing rule-based methods, and can ultimately preserve semiconductor productivity in manufacturing plants and ensure stable wafer delivery.

1 INTRODUCTION

Over the last two decades, automated material handling systems (AMHS) have contributed to improving productivity in semiconductor plants by using autonomous vehicles. Recently, the increase in the number of production process steps owing to the miniaturization of the semiconductor process has led to the development of larger plants, thereby increasing the amount of wafers delivery. A semiconductor plants comprises multiple bays containing equipment of the same type and center and outer loops that connect the bays. Fig. 1 illustrates that an vehicle failure for less than 10 minutes increased the average delivery time by over 37%, which took over two hours to recover, leading to production losses. Moreover, in reality, owing to the limited resources of the vehicle controller, the vehicle cannot re-route itself. Moreover, frequent computations in control indicate an overload on the control system, resulting in a system breakdown. Fig. 2(a) shows that the rerouting is hard to prevent the entry of the V7, V8, and V9 vehicles because their destinations are in the loop. Meanwhile, Fig. 2(b) shows that V11 and V12 continue to enter and occur heavy congestion.

Here, we propose using rail blocks, which are generally used to block edges during rail installation and replacement, to resolve the given vehicle deadlocks, as shown in Fig. 3. On detecting a deadlock, the entering lanes are blocked, and vehicles that can exit the deadlock are selected to find an alternative destination such as other production or storage facilities. The rail block is released once the deadlock is resolved. While previous studies on traffic control focus on finding vehicle pathways, research on unified fabrications is rare (Bartlett et al. 2017). One approach to overcome this challenge is to select and switch dispatching rules depending on the dynamic production conditions (Kim et al. 2020).

In this study, we propose a congestion prediction and traffic detouring control method based on machine learning. In particular, we aim to preventing a local congestion from expanding to entire layout by temporarily blocking the expected future boundary of the congestion. Further, to show the applicability and effectiveness of the proposed system, we conducted simulations with a high-fidelity AMHS simulator.

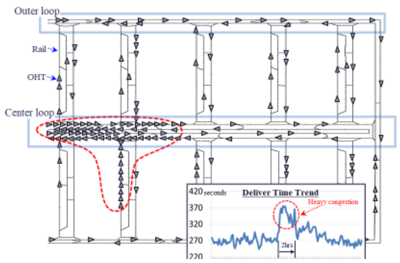

Figure 1: A semiconductor plant with vehicle congestion.

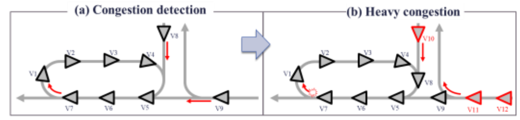

Figure 2: Example for deadlock with rail blocks.

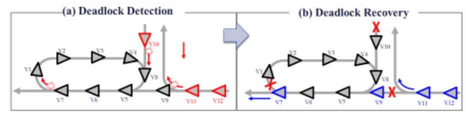

Figure 3: Example for deadlock recovery with rail blocks.

2 PROPOSED APPROACH

Fig. 3 shows the proposed traffic blocking procedure containing the rail block mechanism based on the congestion predictions. Fig. 6 depicts the procedure of the proposed method. The prediction was made for the target edge, the fault rail, irrespective of whether congestion occurs or not. When expecting congestion, the procedure conduct the 'BLOCK' operation for the current target and is repeated for the adjacent edges. The search operation continues until detecting congestion ends or it reaches the predefined threshold.

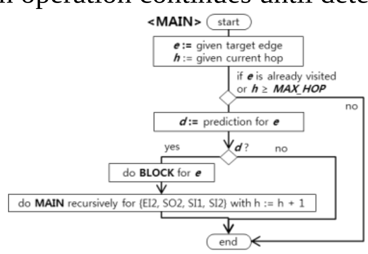

Figure 4: Proposed traffic blocking procedure.

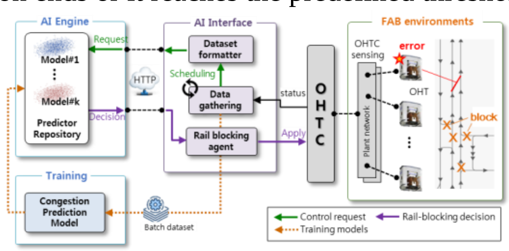

Figure 5: Proposed system architecture for deployment.

3 RESULTS AND CONCLUSIONS

Fig. 6 shows a comparison of the predictors in terms of accuracy, precision, recall, and F1 and the random forest, showing outperformance, was selected. Regarding the simulation results, Fig. 7 showed that the proposed method outperformed the existing 'RULE' system in terms of the loss in delivery amount by 60.4% and decreased the ratio of delayed delivery (over 10 minutes) by 35.9%. In the future, we plan to conduct the sensitivity analysis to optimize the proposed system setting and deploy this approach to the real plants.

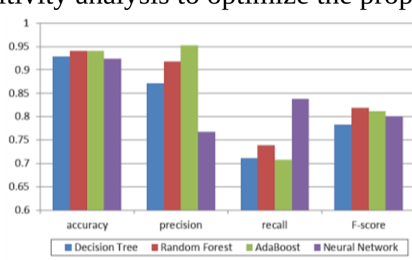

Figure 6: Comparison of the trained prediction models.

Figure 7: Comparative results in terms of delayed delivery and delivery loss in simulations.

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