Response to Reviewer's Opinion - #Doctoral Dissertation

Reviewer: Dr. Dávid Csaba Mezőfi

Title: Development of machine learning, process modeling and optimization algorithms for supporting Industry 4.0

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Dear Dr. Dávid Csaba Mezőfi,

I would like to express my sincere gratitude for your thorough review and valuable feedback on my doctoral dissertation titled *"Development of machine learning, process modeling and optimization algorithms for supporting Industry 4.0 / Ipar 4.0 támogató gépi tanulási, folyamatmodellezési és optimalizációs algoritmusok fejlesztése."* I greatly appreciate the time and effort you have invested in providing such detailed and constructive feedback. Your comments and suggestions are extremely valuable and will contribute significantly to improving the quality of my research. I am particularly grateful for your insightful observations, which have helped me identify key areas for further refinement and development. I provide detailed responses to the questions in this letter. I hope my answers will be satisfactory.

Yours sincerely,

András Rácz-Szabó

1. *Was there a case study conducted investigating the utilization of RTLS for layout planning? In the presented case were there hidden production steps in the temporary station?*

Thank you for your questions. The layout planning process is highly dependent on the technology used and the specific environmental conditions. While this thesis provides a general approach to the use of RTLS (Real-Time Location Systems) data, it does not focus specifically on layout planning. However, there are publications available that address this topic in detail and provide insights into how RTLS can be used to optimize layout design in various contexts.

The methodology presented is capable of identifying unnecessary, omitted, or potentially problematic operations by analyzing process times and production sequences. In the specific case discussed, no hidden production steps were identified. However,

production scheduling was suboptimal, resulting in an accumulation of semi-finished and finished goods in the intermediate storage area. This accumulation indicates a scheduling inefficiency, which is also an important issue to identify and address.

2. *In the use case of the proposed data reconciliation approach could the physical dimensions of the forklifts be used beside the computed velocity as constraints? Suppose that the distance between two received positional data record (around the same time instance) belonging to two different forklifts contradicts the physical dimensions of those forklifts.*

Thank you for your valuable suggestion and question. The thesis presents the methodology and its application using a single, simple balance equation, emphasizing that the more balance equations applied, the more accurate the position data can be refined. The proposed suggestion is also an excellent idea for introducing additional equations to further improve the data matching process.

3. *What were the minimal and maximal efficiency of the networked process in the taxi case study?*

Thank you for your questions. Figure 4.8 summarizes the comparison of the total optimized and reconstructed idle times during the analyzed period. In this case study, idle times were reduced by a minimum of 59.14% (Tuesday, 7:00 AM) and a maximum of 91.54% (Tuesday, 2:00 PM). The thesis highlights that the optimization did not account for potential congestion and overload during route assignment, nor did it account for congestion avoidance due to time-of-day characteristics. In addition, the optimization considered average zone-to-zone travel times. Obviously, the optimization process can be further refined by incorporating more accurate position data and considering traffic dynamics.

4. *Was the reconstructed and the optimized cumulated idle time investigated in the forklift case study? What are the benefits of using DBSCAN instead of just classification based on Table 6.1?*

Thank you for your questions. The thesis focuses on the development of the methodology, specifically the identification of non-value added activities using position data through the DBSCAN approach. Optimization is not part of the current scope; however, it can certainly be applied to investigate and reduce idle time. It should be noted that the case study is limited in its suitability for optimization due to the small data set available (three

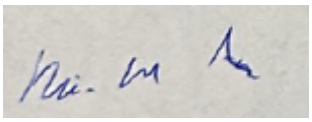
days of data tracking only five forklifts). A larger and more comprehensive data set would be required to achieve objective optimization results.

The modified DBSCAN algorithm analyzes the position data sequentially (in chronological order) based on the features defined in Table 5.1 (Note: The numbering of the tables has been updated based on revision suggestions provided during the preliminary review). It does so by requiring a minimum number of positional data points to fall within a specified distance to form a cluster associated with one of the four cluster types defined in the table (excluding the third type, which is not applicable and did not yield any clusters in this case). Unlike static classification using only the features in the table, this approach dynamically identifies clusters, revealing patterns and insights that would otherwise go undetected.

5. *Was there any data of the AGVs available which would enable to construct a state transition matrix of probabilities?*

Thank you for your question. Yes, the necessary data is available to construct a state transition matrix of probabilities for the AGVs, and optimization could also be performed. However, this is not included in the thesis for two main reasons. First, it would have required precise data on AGV dynamics, such as turning times, tray pickup and drop times, which would have to be determined through testing. Second, the issues identified in the case study related to logistics and inventory strategies, as well as production scheduling optimization, effectively address the problem. By solving these issues, task scheduling does not require any further optimization, as even in the worst-case scenario, tasks handled in arrival order would not cause problems for the AGVs.

Veszprém, 2025.01.06.



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