Exploring the Frontiers of Generative AI in Classical Production Line Research

Sencer YERALAN

Global Academics Coalition, Gainesville, Florida, USA, yeralan@globalacademicscoalition.net

Cathal HEAVEY University of Limerick, Limerick, V94 T9PX, Ireland, cathal.heavey@ul.ie

Amir GHASEMI

Institute AIFB, Karlsruhe Institute of Technology, Kaiserstr. 89, Karlsruhe, 76133, Germany, amir.ghasemi@kit.edu

The realm of production line research has recently leveraged machine learning techniques to address its classical problems. However, the integration of Generative Artificial Intelligence in this field remains notably underexplored. Our study aims to fill this gap by examining the applicability and limitations of Generative AI in the context of a conventional tandem queueing model, a staple in production line analysis. We embarked on an experimental investigation where Generative AI was employed to propose empirical functional forms. These AI-generated forms were designed to offer curve-fit-type approximations for the model under study. The core objective was to evaluate how these AI-driven approximations perform in comparison to the exact solutions. This comparison sheds light on the efficacy of Generative AI in capturing the complexities and nuances of classical production models. Our findings offer significant insights into the potential roles and boundaries of Generative AI in this specialized research area. This study not only contributes to the existing body of knowledge by introducing an innovative approach to an established field but also opens new avenues for further research in employing advanced AI techniques in the realm of production line and general queueing theory.

Key words: Generative AI; Classical Production Line Research

1. Introduction

Artificial Intelligence (AI) has been used in the analysis of manufacturing and service operations. For example, machine learning can greatly enhance the efficiency and productivity of production lines (Kang et al. 2020), where it can be used to predict equipment failures and schedule maintenance, thus reducing downtime. Such models are discriminate AI models, rather than Generative AI (GenAI) models. GenAI refers to a subset of artificial intelligence technologies that have the ability to create new content. Any model that produces output can be technically seen as generative, with García-Peñalvo and Vázquez-Ingelmo (2023) defining "Generative AI' as the production of previously unseen synthetic content, in any form and to support any task, through generative modeling."

GenAI has made great advances, leading in recent years to the development of Large Language Models (LLMs) that can analyse inputs such as text or images (Kumar et al. 2023). These tools, such as ChatGPT (*ChatGPT* Accessed 22 March 2024), are predicted to have a significant effect on businesses and society due to their ability to perform tasks, while others are more skeptical (Rogers 2024). However, even with the current developments with LLMs, how we lecture and work has changed. In this paper, our focus is not on the development of these models but on how they

can enhance the efficiency of manufacturing and service systems, the development of analytical formulae or simulation models for the analysis of these systems. In the remainder of this article, ChatGPT 4.0 is used (*ChatGPT* Accessed 22 March 2024).

2. GenAI: Queuing Models of Production Lines

In ChatGPT 4.0 an input is entered, denoted as the prompt (English language used), with new knowledge generated. ChatGPT 4.0 uses the prompt to identify what knowledge to generate. The details of each prompt can cause different output from ChatGPT 4.0, as the outputs are probabilistic. In ChatGPT 4.0 the following prompt is entered:

"Create a queuing model in Python of a two station production line with blocking."

The above prompt generates the following knowledge from ChatGPT 4.0

"Creating a queuing model of a two-station production line with blocking involves setting up a system where there are interactions between the stations due to limited buffer capacities. This type of model is often referred to in operations research and industrial engineering for analyzing the flow of items through a production process where stations can block each other if one station gets full and cannot accept more items until another station clears some space. Here's a step-by-step setup of such a model:

- 1. Define the Stations
- Station 1 (S1): Processes items and passes them to Station 2.
- Station 2 (S2): Receives items from Station 1 and further processes or finishes them.

etc"

This answer is only a partial output from ChatGPT 4.0. In the full reply approximately 45 lines of general information on queuing models is provided for the analysis of production lines.

3. GenAI: DES Models of Production Lines

There are several articles written on the use of ChatGPT to assist in the writing of programming languages. Sun et al. (2023) compare the use of ChatGPT for automatic code summarization against other state-of-the-art code summarization existing models. Bucaioni et al. (2024) evaluating Chat-GPT's abilities in two different programming languages, namely C++ and Java. They found that compared to code written by humans, ChatGPT provides lower quality with regards to runtime nad memory usage. Another article is by Kazemitabaar et al. (2023) who examined 69 novice programmers who examined ChatGPT and Codex for Python code tasks and found it improved authoring tasks. Jackson et al. (2024) focused on the use of ChatGPT 3.0 and Codex to develop discrete event simulation models (DES) for logistic models.

Using ChatGPT 4.0 we inserted the following prompt:

"Write a discrete event simulation model for a two station production line with finite buffers." The output from ChatGPT 4.0 is:

"To create a discrete event simulation model for a two-station production line with finite buffers, we'll use Python and the simpy library, as it's broadly used and well-suited for such simulations. This model will simulate a production line where parts go through two sequential processing stations with a buffer in between. Here's a step-by-step guide and the necessary Python code: etc"

The above answer is only a partial output from ChatGPT 4.0. In addition, it also provided a documented SimPy (*Overview* — *SimPy 4.1.1 documentation* 2024) model of a two station line of a production line.

4. Observations and Conclusions

GenAI can only provide very high-level documentation and no model for a queueing model of a production line. It can also assist in programming and provide basic DES models for production lines. However, it is necessary for the user to understand key programming and system concepts to successfully implement solutions. GenAI tools such as ChatGPT 4.0 provides basic supports in such tasks. While GenAI needs to be integrated into education, engineering intuition, by grounding the model in its expected use and considering the properties of the system, offers insights currently overlooked by GenAI.

References

Bucaioni, A., Ekedahl, H., Helander, V. and Nguyen, P. T. (2024). Programming with ChatGPT: How far can we go?, *Machine Learning with Applications* **15**: 100526.

URL: https://www.sciencedirect.com/science/article/pii/S2666827024000021

- ChatGPT (Accessed 22 March 2024).
 - URL: https://chat.openai.com
- García-Peñalvo, F. and Vázquez-Ingelmo, A. (2023). What Do We Mean by GenAI? A Systematic Mapping of The Evolution, Trends, and Techniques Involved in Generative AI, *International Journal of Interactive Multimedia and Artificial Intelligence* 8(4): 7.
 URL: https://www.ijimai.org/journal/sites/default/files/2023-11/ijimai8₄₁.pdf
- Jackson, I., Ivanov, D., Dolgui, A. and Namdar, J. (2024). Generative artificial intelligence in supply chain and operations management: a capability-based framework for analysis and implementation, *International Journal of Production Research* pp. 1–26. URL: https://www.tandfonline.com/doi/full/10.1080/00207543.2024.2309309
- Kang, Z., Catal, C. and Tekinerdogan, B. (2020). Machine learning applications in production lines: A systematic literature review, *Computers & Industrial Engineering* 149: 106773. URL: https://linkinghub.elsevier.com/retrieve/pii/S036083522030485X
- Kazemitabaar, M., Chow, J., Ma, C. K. T., Ericson, B. J., Weintrop, D. and Grossman, T. (2023). Studying the effect of AI Code Generators on Supporting Novice Learners in Introductory Programming, *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, CHI '23, Association for Computing Machinery, New York, NY, USA, pp. 1–23. URL: https://dl.acm.org/doi/10.1145/3544548.3580919
- Kumar, S., Musharaf, D., Musharaf, S. and Sagar, A. K. (2023). A Comprehensive Review of the Latest Advancements in Large Generative AI Models, *in* R. N. Shaw, M. Paprzycki and A. Ghosh (eds), *Advanced Communication and Intelligent Systems*, Springer Nature Switzerland, Cham, pp. 90–103.
- Overview SimPy 4.1.1 documentation (2024). URL: https://simpy.readthedocs.io/en/latest/
- Rogers, R. (2024). What's AGI, and Why Are AI Experts Skeptical? Section: tags. URL: https://www.wired.com/story/what-is-artificial-general-intelligence-agi-explained/
- Sun, W., Fang, C., You, Y., Miao, Y., Liu, Y., Li, Y., Deng, G., Huang, S., Chen, Y., Zhang, Q., Qian, H., Liu, Y. and Chen, Z. (2023). Automatic Code Summarization via ChatGPT: How Far Are We? arXiv:2305.12865 [cs]. URL: http://arxiv.org/abs/2305.12865