APEM journal

Advances in Production Engineering & Management
Volume 18 | Number 4 | December 2023 | pp 475–485
https://doi.org/10.14743/apem2023.4.486

ISSN 1854-6250
Journal home: apem-journal.org
Original scientific paper

Optimizing smart manufacturing systems using digital twin

Ojstersek, R.[a,*], **Javernik, A.**[a], **Buchmeister, B.**[a]

[a]University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia

ABSTRACT

Presented paper investigates the application of digital twins for the optimisation of intelligent manufacturing systems and focuses on the comparison between simulation modelling results and real-world production conditions. A digital twin was created in the Simio software environment using a data-driven simulation model derived from a real-world production system. Running the digital twin in real time, which was displayed graphically, facilitated the analysis of key parameters, including the number of finished products, average flow time, workstation utilization and product quality. The discrepancies were attributed to the use of random distributions of input data in the dynamic digital twin, as opposed to the long-term measurements and averages in the real-world system. Despite the limitations in the case study, the results underline the financial justification and predictive capabilities of digital twins for optimising production systems. Real-time operation enables continuous evaluation and tracking of parameters and offers high benefits for intelligent production systems. The study emphasises the importance of accurate selection of input data and warns that even small deviations can lead to inaccurate results. Finally, the paper highlights the role of digital twins in optimising production systems and argues for careful consideration of input data. It highlights the importance of analysing real-world production systems and creating efficient simulation models as a basis for digital twin solutions. The results encourage extending the research to different types of production, from job shop to mass production, in order to obtain a comprehensive optimisation perspective.

ARTICLE INFO

Keywords:
Smart manufacturing;
Digital twin;
Optimisation;
Simulation modelling;
Simio;
Case study

**Corresponding author:*
robert.ojstersek@um.si
(Ojstersek, R.)

Article history:
Received 19 July 2023
Revised 17 December 2023
Accepted 20 December 2023

Content from this work may be used under the terms of the Creative Commons Attribution 4.0 International Licence (CC BY 4.0). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

References

[1] Jones, D., Snider, C., Nassehi, A., Yon, J., Hicks, B. (2020). Characterising the digital twin: A systematic literature review, *CIRP Journal of Manufacturing Science and Technology*, Vol. 29, Part A, 36-52, doi: 10.1016/J.CIRPJ.2020.02.002.

[2] Zhuang, C., Liu, J., Xiong, H. (2018). Digital twin-based smart production management and control framework for the complex product assembly shop-floor, *The International Journal of Advanced Manufacturing Technology*, Vol. 96, 1149-1163, doi: 10.1007/s00170-018-1617-6.

[3] Lu, Y., Liu, C., Wang, K.I.-K., Huang, H., Xu, X. (2020). Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues, *Robotics and Computer-Integrated Manufacturing*, Vol. 61, Article No. 101837, doi: 10.1016/j.rcim.2019.101837.

[4] Pattanaik, L.N. (2021). Simulation optimization of manufacturing takt time for a leagile supply chain with a decoupling point, *International Journal of Industrial Engineering and Management*, Vol. 12, No. 2, 102-114, doi: 10.24867/IJIEM-2021-2-280.

[5] Tao, F., Qi, Q., Liu, A., Kusiak, A. (2018). Data-driven smart manufacturing, *Journal of Manufacturing Systems*, Vol. 48, Part C, 157-169, doi: 10.1016/J.JMSY.2018.01.006.

[6] Workneh, A.D., Gmira, M. (2022). Scheduling algorithms: Challenges towards smart manufacturing, *International Journal of Electrical and Computer Engineering Systems,* Vol. 13, No. 7, 587-600, doi: 10.32985/ijeces.13.7.11.

[7] Tao, F., Qi, Q., Wang, L., Nee, A.Y.C. (2019). Digital twins and cyber-physical systems toward smart manufacturing and industry 4.0: Correlation and comparison, *Engineering*, Vol. 5, No. 4, 653-661, doi: 10.1016/j.eng.2019.01.014.

[8] Tao, F., Cheng, J., Qi, Q., Zhang, M., Zhang, H., Sui, F. (2018). Digital twin-driven product design, manufacturing and service with big data, *The International Journal of Advanced Manufacturing Technology*, Vol. 94, 3563-3576, doi: 10.1007/S00170-017-0233-1.
[9] Qi, Q., Tao, F. (2018). Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison, *IEEE Access*, Vol. 6, 3585-3593, doi: 10.1109/ACCESS.2018.2793265.
[10] Ojstersek, R., Buchmeister, B., Herzog Vujica, N. (2020). Use of data-driven simulation modeling and visual computing methods for workplace evaluation, *Applied Sciences*, Vol. 10, No. 20, Article No. 7037, doi: 10.3390/app10207037.
[11] Hauge, J.B., Zafarzadeh, M., Jeong, Y., Li, Y., Khilji, W.A., Larsen, C., Wiktorsson, M. (2021). Digital twin testbed and practical applications in production logistics with real-time location data, *International Journal of Industrial Engineering and Management*, Vol. 12, No. 2, 129-140, doi: 10.24867/IJIEM-2021-2-282.
[12] Fuller, A., Fan, Z., Day, C., Barlow, C. (2020). Digital twin: Enabling technologies, challenges and open research, *IEEE Access*, Vol. 8, 108952-108971, doi: 10.1109/ACCESS.2020.2998358.
[13] Tao, F., Zhang, M. (2017). Digital twin shop-floor: A new shop-floor paradigm towards smart manufacturing, *IEEE Access*, Vol. 5, 20418-20427, doi: 10.1109/ACCESS.2017.2756069.
[14] Ojstersek, R., Javernik, A., Buchmeister, B. (2022). Importance of sustainable collaborative workplaces - simulation modelling approach, *International Journal of Simulation Modelling*, Vol. 21, No. 4, 627-638, doi: 10.2507/IJSIMM21-4-623.
[15] Rasheed, A., San, O., Kvamsdal, T. (2020). Digital twin: Values, challenges and enablers from a modeling perspective, *IEEE Access*, Vol. 8, 21980-22012, doi: 10.1109/ACCESS.2020.2970143.
[16] Maddikunta, P.K.R., Pham, Q.-V., Prabadevi, B., Depa, N., Dev, K., Gadekallu, T.R., Ruby, R., Liyanage, M. (2022). Industry 5.0: A survey on enabling technologies and potential applications, *Journal of Industrial Information Integration*, Vol. 26, Article No. 100257, doi: 10.1016/J.JII.2021.100257.
[17] Liu, M., Fang, S., Dong, H., Xu, C. (2021). Review of digital twin about concepts, technologies, and industrial applications, *Journal of Manufacturing Systems*, Vol. 58, Part B, 346-361, doi: 10.1016/J.JMSY.2020.06.017.
[18] Huo, L., Wang, J.Y. (2022). Flexible job shop scheduling based on digital twin and improved bacterial foraging, *International Journal of Simulation Modelling*, Vol. 21, No. 3, 525-536, doi: 10.2507/IJSIMM21-3-CO14.
[19] Trebuna, P., Pekarcikova, M., Edl, M. (2019). Digital value stream mapping using the tecnomatix plant simulation software, *International Journal of Simulation Modelling*, Vol. 18, No. 1, 19-32, doi: 10.2507/IJSIMM18(1)455.
[20] Marc, I., Kušar, J., Berlec, T. (2022). Decision-making techniques of the consumer behaviour optimisation of the product own price, *Applied Sciences*, Vol. 12, No. 4, Article No. 2176, doi: 10.3390/app12042176.
[21] Passath, T., Huber, C., Kohl, L., Biedermann, H., Ansari, F. (2021). A knowledge-based digital lifecycle-oriented asset optimisation, *Tehnički Vjesnik – Technical Gazette,* Vol. 15, No. 2, 226-234, doi: 10.31803/tg-20210504111400.

APEM journal

Advances in Production Engineering & Management
Letnik 18 | Številka 4 | December 2023 | Strani 475–485
https://doi.org/10.14743/apem2023.4.486

ISSN 1854-6250
Spletna stran: apem-journal.org
Izvirni znanstveni članek

Optimizacija pametnih proizvodnih sistemov z uporabo digitalnega dvojčka

Ojstersek, R.[a,*], Javernik, A.[a], Buchmeister, B.[a]

[a]University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia

POVZETEK

Prispevek obravnava uporabo digitalnih dvojčkov za optimizacijo inteligentnih proizvodnih sistemov in se osredotoča na primerjavo med rezultati simulacijskega modeliranja in dejansko proizvodnjo. Digitalni dvojček je bil ustvarjen v programskem okolju Simio z uporabo podatkovno podprtega simulacijskega modela, ki izhaja iz realnega proizvodnega sistema. Izvajanje digitalnega dvojčka v realnem času, ki je bil prikazan grafično, je olajšalo analizo ključnih parametrov, vključno s številom izdelanih izdelkov, povprečnim pretočnim časom, izkoriščenostjo delovnih postaj in kakovostjo izdelkov. Ugotovljene razlike so bile pripisane uporabi naključne porazdelitve vhodnih podatkov v dinamičnem digitalnem dvojčku v nasprotju s povprečji dolgotrajnih meritev v realnem sistemu. Kljub omejitvam v študiji primera rezultati kažejo na finančno upravičenost in sposobnost digitalnih dvojčkov za optimizacijo proizvodnih sistemov. Delovanje digitalnega dvojčka v realnem času omogoča neprekinjeno vrednotenje in sledenje parametrov kar zagotavlja velike koristi za inteligentne proizvodne sisteme. Študija poudarja pomen natančnega izbora vhodnih podatkov in opozarja, da lahko že majhna odstopanja privedejo do netočnih rezultatov. Na koncu članek poudarja vlogo digitalnih dvojčkov pri optimizaciji proizvodnih sistemov in zagovarja skrbno obravnavo vhodnih podatkov. Raziskava poudarja pomen analize realnih proizvodnih sistemov in oblikovanja učinkovitih simulacijskih modelov kot podlage za izboljšave z uporabo digitalnih dvojčkov. Rezultati spodbujajo razširitev raziskav na druge tipe proizvodnje, kot so velika in množična proizvodnja, da bi pridobili celovito perspektivo optimizacije.

PODATKI O ČLANKU

Ključne besede:
Pametna proizvodnja;
Digitalni dvojček;
Optimizacija;
Simulacijsko modeliranje;
Simio;
Študija primera

**Kontaktna oseba:*
robert.ojstersek@um.si
(Ojstersek, R.)

Zgodovina članka:
Prejet 19. julija 2023
Popravljen 17. decembra 2023
Sprejet 20. decembra 2023

Content from this work may be used under the terms of the Creative Commons Attribution 4.0 International Licence (CC BY 4.0). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.