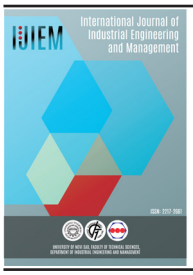

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Digital twin testbed and practical applications in production logistics with real-time location data

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References

[1] V. Tamás, P. Bányai, and B. Illés, Intelligent Transportation Systems to Support Production Logistics. Cham, Switzerland, 2016.
[2] M. Christopher, Logistics & supply chain management, 5th ed. Harlow, United Kingdom : Pearson Education, 2016.
[3] M. Forcolin, E. Fracasso, and P. Tumanischvili, Francesco Enterprising, "EURIDICE- IoT applied to Logistcst using the intelligent Cargo concept," in ICE proceedings, 2011.
[4] T. Zunder, H. Westerheim, R. Jorna, and J. T. Pedersen, "Is it Possible to Manage and Plan Co-Modal Freight Transport Without a Centralised System?," Int. J. Appl. Logist., vol. 3, no. 2, 2012.
[5] J. O. Strandhagen et al., "Logistics 4.0 and emerging sustainable business models," Adv. Manuf., vol. 5, no. 359, 2017.
[6] Y. Patil, "6 key IoT Implementation Challenges for Enterprises to consid-er." [Online]. Available: https://www.saviantconsulting.com/blog/iot-implementation-challenges-enterprises.aspx. [Accessed: 20-Jan-2001].
[7] M. W. I. Ek and P. Frykblom, "Hur kan staten främja användandet av digitaliseringens möjligheter i näringslivet?," Östersund, 2018.
[8] H. Bosson and J. Ingmarsson, "Digitalisering av svensk industri-kartläggning av svenska styrkor och utmaninger," 2016.
[9] F. Tao, J. Cheng, Q. Qi, M. Zhang, H. Zhang, and F. Sui, "Digital twin-driven product design, manufacturing and service with big data," Int. J. Adv. Manuf. Technol., vol. 94, no. 9–12, pp. 3563–3576, 2018.
[10] M. Crnjac, I. Veža, and N. Banduka, "From concept to the introduction of industry 4.0," Int. J. Ind. Eng. Manag., vol. 8, no. 1, pp. 21–30, 2017.
[11] Hauge, Jannicke Baalsrud, Y. Zafarzadeh, Masoud, Jeong, Y. Li, and M. Khilji, Wajid Ali, Wiktorsson, "Digital and Physical Testbed for Production Logistics Operations," in The Path to Digital Transformation and Innovation of Production Management Systems, Cham: Springer International Publishing, 2020, pp. 625–633.
[12] A. K. F. Yao, M. Ahmad, B. Ahmad, R. Harrison, and A. W. Colombo, "Optimizing the Scheduling of Autonomous Guided Vehicle in a Manufacturing Process," in IEEE 16th International Conference on Industrial Informatics (INDIN), 2018, pp. 264–269.
[13] M. W. Grieves and J. Vickers, "Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems," in Transdisciplinary Perspectives on Complex Systems, Springer International Publishing, 2017.
[14] D. Glaessgen, E. and Stargel, "" The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles," in "53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 2012.
[15] E. J. Tuegel, "The Airframe Digital Twin: Some Challenges to Realization," in AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 2012.
[16] M. P. Reifsnider K, "Multiphysics stimulated simulation digital twin methods for fleet management.," in In: 54th AIAA/ASME/ASCE/ AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013, p. 1578.
[17] S. M, C. M, and Doyle R et al, "DRAFT modeling, simu- lation, information technology & processing roadmap.," 2010.
[18] S. Boschert and R. Rosen, Digital twin the simulation aspect. Basel: Springer International Publishing, 2016.
[19] Y. Chen, "'Integrated and Intelligent Manufacturing: Perspectives and Enablers.,'" Engineering, vol. 3, no. 5, pp. 88–595, 2017.
[20] N. Schleich, B., L. Anwer, Mathieu, and S. Wartzack., "'Shaping the Digital Twin for Design and Production Engineering.' –," CIRP Ann. Manuf. Technol., vol. 66, no. 1, pp. 141–144, 2017.
[21] R. Stark, C. Fresemann, and K. Lindow, "Development and operation of Digital Twins for technical systems and services," CIRP Ann. - Manuf. Technol., vol. 68, no. 1, pp. 129–132, 2019.

[22] Y. Lu, C. Liu, K. I. K. Wang, H. Huang, and X. Xu, "Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues," Robot. Comput. Integr. Manuf., vol. 61, no. August 2019, p. 101837, 2020.
[23] P. W. Kritzinger, M. Karner, G. Traar, J. Henjes, and W. Sihn, "Digital Twin in manufacturing: A categorical literature review and classification," IFAC-PapersOnLine, vol. 51, no. 11, pp. 1016–1022, 2018.
[24] F. Tao and M. Zhang., "Digital Twin Shop-Floor: A New Shop-Floor Paradigm Towards Smart Manufacturing.","," IEEE Access, vol. 5, pp. 20418–2042, 2017.
[25] F. Tao, Q. Qi, A. Liu, and A. Kusiak, "Data-driven smart manufacturing," J. Manuf. Syst., vol. 48, no. January, pp. 157–169, 2018.
[26] B. Brenner and V. Hummel, "'Digital twin as enabler for an innovative digital shopfloor management system' in the ESB logistics Learning Factory at Reutlingen University," Procedia Manuf., vol. 9, pp. 198–205, 2017.
[27] A. Stefan, I. A. Stanescu, and J. Hauge, "Approaches to Reengineering Digital Games," in ASME. International Design Engineering Technical Conferences and Computers and Infor-mation in Engineering Conference, 2016.
[28] J. Baalsrud Hauge, "An educational framework for supporting the implementation of the Intelligent Cargo con-cept," Int. J. Adv. Logist., vol. 5, no. 2, pp. 86–100, 2016.
[29] V.-F. F. und -betrieb, Simulation von Logistik-, Materialfluss- und Produktionssystemen. 2014.
[30] K. N. P. Nokelainen, T. Nevalainen, Mind or Machine? Opportunities and Limits of Automation.The Impact of Digitalization in the Workplace. Cham, Switzerland: Springer, 2018.
[31] J. David, A. Lobov, and M. Lanz, "Leveraging Digital Twins for Assisted Learning of Flexible Manufacturing Systems," in IEEE 16th International Conference on Industrial Informatics (INDIN), 2018, pp. 529–535.
[32] D. Jones, C. Snider, A. Nassehi, J. Yon, and B. Hicks, "Characterising the Digital Twin: A systematic literature review.," CIRP J. Manuf. Sci. Technol., 2020.
[33] E. Negri, L. Fumagalli, and M. Macchi, "A Review of the Roles of Digital Twin in CPS-based Production Systems.," Procedia Manuf., vol. 11, pp. 939–948, 2017.
[34] A. Fuller, Z. Fan, C. Day, and C. Barlo, "Digital Twin: Enabling Technologies, Challenges and Open Research," IEEE Access, vol. 8, pp. 108952–108971, 2020.
[35] M. Holler, F. Uebernickel, and W. Brenner, "Digital Twin Concepts in Manufacturing Industries-A Literature Review and Avenues for Further Research," in Proceedings of 18th International Conference on Industrial Engineering (IJIE). 18th International Conference on Industrial Engineering (IJIE, 2016.
[36] D. Dutta and I. Bose, "Managing a Big Data project : The case of Ramco Cements Limited," Intern. J. Prod. Econ., vol. 165, pp. 293–306, 2015.
[37] P. Lim, Kendrik Yan Hong; Zheng and C.-H. Chen, "A state-of-the-art survey of Digital Twin: techniques, engineering product lifecycle management and business innovation perspectives.," Jorunal Intell. Manuf., vol. 65, no. 1, 2019.
[38] E. Barricelli, Barbara Rita; Casiraghi and D. Fogli, "Barricelli, Barbara Rita; Casiraghi, Elena; Fogli, Daniela (2019): A Survey on Digital Twin: Definitions, Characteristics, Applications, and Design Implications.–167671.," IEEE Access, vol. 7, p. 167653–167671., 2019.
[39] H. Park, A. Easwaran, and S. Andalam, "Challenges in Digital Twin Development for Cyber-Physical Production Systems.," in Cyber Physical Systems. Model-Based Design, Bd, Roger Chamberlain, W. Taha, and M. Törngren, Eds. Cham, Switzerland: Springer International Publishing, 2019, pp. 28–48.
[40] N. Enders, Martin Robert; Hoßbach, "Dimensions of Digital Twin Applications - A Literature Review.," in In: AMCIS 2019 Proceedings. THE AMERICAS CONFERENCE ON INFORMATION SYSTEMS - AMCIS., 2019.
[41] R. B. Roy, D. Mishra, S. K. . Pal, S. Chakravarty, Tapas; Panda, and M. G. et al. Chandra, "Digital twin: current scenario and a case study on a manufacturing process.," Int J Adv Manuf Technol, vol. 107, no. 9–10, pp. 3691–3714, 2020.
[42] T. Y. . Melesse and S. Di Pasquale, Valentina; Riemma, "Digital Twin Models in Industrial Operations: A Systematic Literature Review," Procedia Manuf., vol. 42, pp. 267–272, 2020.
[43] A. Orozco-Romero, C. Y. Arias-Portela, and J. A. M. Saucedo, "The Use of Agent-Based Models Boosted by Digital Twins in the Supply Chain: A Literature Review," in Intelligent Computing and Optimization, Bd., Pandian Vasant, I. Zelinka, and G.-W. W. (Hg.):, Eds. Cham: Springer International Publishing (Advances in Intelligent Systems and Computing), 2020, pp. 642–652.
[44] L. E. Kavraki, P. Svestka, J. C. Latombe, and M. H. Overmars, "Probabilistic roadmaps for path planning in high-dimensional configuration spaces," IEEE Trans. Robot. Autom., vol. 12, no. 4, pp. 566–580, 1996.
[45] S. M. LaValle and J. J. J. Kuffner, "Randomized kinodynamic planning," Int. J. Rob. Res., vol. 20, no. 5, pp. 378–400, 2001.
[46] M. Likhachev, "Search-based Planning for Large Dynamic Environments, PhD thesis," Carnegie Mellon University, 2005.
[47] M. Likhachev, G. Gordon, and S. Thrun, "ARA*: Anytime A* with provable bounds on sub-optimality," in Proceedings of the 16th International Conference on Neural Information Processing, 2003.
[48] P. Mårdberg et al., "'A novel tool for optimization and verification of layout and human logistics in digital factories,'" Procedia CIRP, 2018.
[49] R. K. Yin, Case Study Research and Applications: Design and Methods, Sixth., vol. 53, no. 9. 2019.
[50] J. Meredith, "Building operations management theory through case and field research," J. Oper. Manag., vol. Vol.16, no. 4, p. pp.441-454, 1998.
[51] C. Zhuang, J. Liu, and H. Xiong, "Digital twin-based smart production management and control framework for the complex product assembly shop-floor," Int. J. Adv. Manuf. Technol., vol. 96, no. 1–4, pp. 1149–1163, 2018.
[52] HC Pfohl, Produktionslogistik. Berlin: Heidelberg: Springer Berlin Heidelberg, 2018.
[53] J. M. Baalsrud Hauge, A. Engström, I. A. Stefan, and J. Strömgren, "Bridging educational and working environments through pervasive approaches," in 3rd International Joint Conference on Serious Games, JCSG 2017, Springer Verlag , 2017, p. 296-307, 2017, pp. 296–307.
[54] V. Toivonen, M. Lanz, H. Nylund, and H. Nieminen, "The FMS Training Center - a versatile learning environment for engineering education"," Procedia Manuf., vol. Vol. 23, p. 135–140., 2018.
[55] B. Bajic, N. Suzic, N. Simeunovic, S. M. A, and A. Rikalovic, "Real-time Data Analytics Edge Computing Application for Industry 4.0: The Mahalanobis-Taguchi Approach," Int. J. Ind. Eng. Manag., vol. 11, no. 3, 2020.
[56] E. Hofmann and M. Rüsch, "Industry 4.0 and the current status as well as future prospects on logistics," Comput. Ind., vol. 89, pp. 23–34, 2017.