

# Digital Twinning of Manufacturing Systems based on the Finite State Method

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## Abstract

The Digital Twinning of Manufacturing Systems is continuously gaining in importance concerning the optimization of production processes and requirements for production efficiency improvements. Therefore, the finite state method will be presented in this work as a semi-analytical approach of the Production System Engineering based on Markov Chains. The presented method can efficiently calculate the probability distributions associated with each possible system state defined according to the number of buffers and their capacities. In this study, the finite state method is employed to describe the ship steel hull process as a platform for the implementation of digital twinning technology. The method is employed to rebuild a model of a real ship production process using a combination of serial and splitting lines. The key performance indicators such as the production rate, the work in process, and probabilities of starvation and blockade are calculated and compared to the corresponding results obtained through a simulation approach using the software tool Enterprise Dynamics. The conclusion highlights the advantages and disadvantages of methods employed in the context of Digital Twin Technology.

## Keywords

Digital Twin, Finite State Method, Production System Engineering and Shipyard.

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## Biographies

**Viktor Ložar**, was born in 1983 in Friedrichshafen, Germany, where he completed an elementary school and technical college. In 2011 he got his master's degree in Naval Architecture at the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, where he graduated in 2023 with a PhD on the topic "Development of a simulation model to determine the key performance indicators of shipyard's processing lines". Starting from October 2011 he worked in the shipyard 3. MAJ, Rijeka, as a Hull constructor. After that, he was a Junior Designer at the Brodarski institut d.o.o., a Constructor in the production at VTR Komponente d.o.o, a Tool constructor for stamping tools at Parametrik d.o.o., and a Mechanical Engineer Designer at PIA Automation Croatia d.o.o. Since 2020 he enrolled in the project ANTYARD as an assistant researcher and 2024 he became a teaching assistant at the University of Zagreb. He published several papers and participated in conferences.

**Neven Hadžić**, Associate professor, was born on November 3rd, 1984 in Zagreb where he completed elementary school and classical college. He enrolled in the study of Naval architecture at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, in 2003. In 2008 he started postgraduate study and has completed it in 2013 with the dissertation on ship hydroelasticity. He is employed at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb and was elected to associate professorship in 2019. He actively teaches courses: Ship

production I, Ship production II, and Design of shipyards. He has participated in four international research projects and participates presently as a principal researcher or collaborator in several projects dealing with production system engineering. His main fields of research interests are related to hydroelasticity, dynamic response of ships and offshore structures, offshore renewable energy sources, and analysis and designing of production processes. His previous work resulted in the publication of 6 books and more than 90 scientific and professional papers in international and domestic journals and conference proceedings. He received several awards for his work. Some of the most distinguished are: the Annual Award of The Society of University Teachers, Scholars and Other Scientists - Zagreb (2015), the Annual Award for Young Scientists (2015), and the Annual award Ivan Filipović (2017).

**Tihomir Opetuk**, Associate professor, was born on 07. September 1984 in Zagreb. He finished elementary school in Vukovina and High Aviation technical school Rudolf Perešin in Velika Gorica. He enrolled Faculty of Mechanical Engineering in 2003. He completed an Undergraduate university program in Industrial Engineering and Management module in 2007 with a bachelor thesis on the topic: Implementation of Group Technology in the Process Planning. In 2008 He completed the Graduate university program in the Industrial Engineering and Management module with a diploma thesis on the topic: Model Development for the Time estimation in Machining of Rotational Parts. In 2008 he was awarded Faculty Medal for Academic Achievement. In 2016 he completed Postgraduate doctorate studies in the Industrial Engineering and Management module with a doctoral thesis on the topic: Model of Green Supply Chain Management Implementation. From August 2008 he was employed in the company Končar Distribution and Special Transformers Inc. as a process engineer. For two and a half years he was an assistant director for the construction of a high voltage laboratory, assembly plant, warehouse, and office space. Starting from February 2012 he works at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb, at the Department of Industrial Engineering. He is the author or co-author of a chapter in the book, 18 scientific papers published in international journals, 26 papers at international conferences, and has participated in the writing of professional papers and projects for the economy.