

Digital Twins for Education and Study of Engineering Sciences

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Abstract: Digital twins, used by education and engineering, are software-models of industrial plants, which are simulated and visualized similar to its industrial originals and synchronized with them. In the paper are shown steps of design of digital twins upon some examples of the master degree program at University of Applied Sciences Darmstadt. It will be described why and how it is possible to use the digital twins. The different stages of the development of software-models, which are equipped with different levels of source code will be shown. The advantages of digital twins for engineering study including the economic considerations will be discussed.

Keywords: Simulation, model-in-the-loop, software-in-the loop, processor-in-the-loop, digital twin

Introduction: The Way to Digital Twins

The practical exercises on the real technological devices are supposed as a necessary part by the study of engineering sciences at universities. To reduce high costs for building their own well-equipped laboratories the universities use hardware-models of industrial processes, which are usually boxes with microcontrollers, located inside. The success of programming has opened a new way of costs reducing, namely: the software-models (Figure 1). But as low are costs for software-models, they cannot replace the real industrial devices.

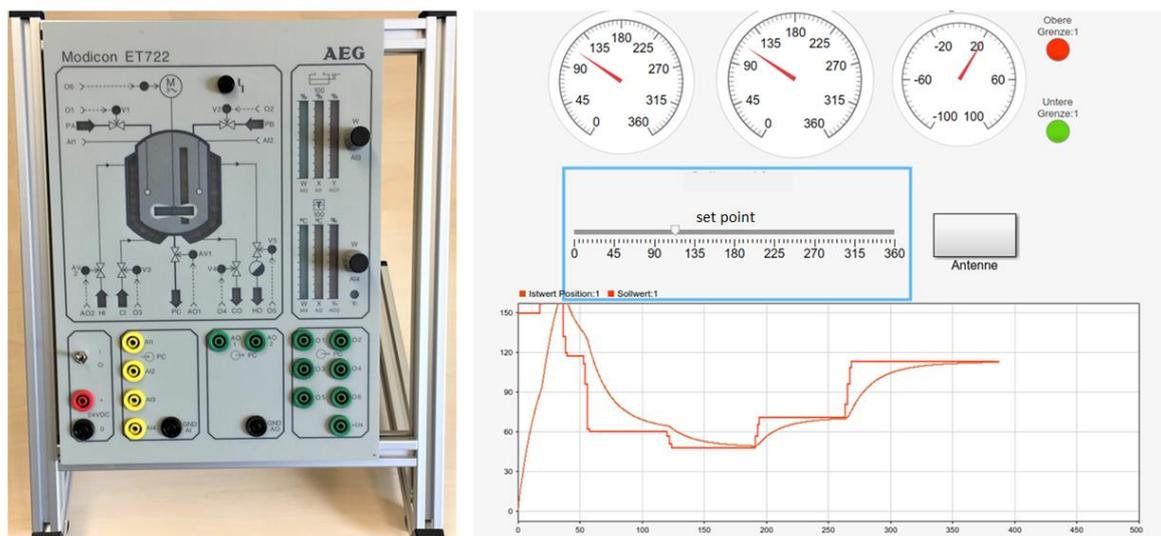


Figure 1. Hardware-model of a Batch-reactor as a Laboratory Device (on the left) and its Software-model

Another way to do practical exercises on the real devices is remote control or so called Web Lab (Henry, 1998; Henry & Zacher, 2010a, 2010b). The global digitalization of information, known as “Industry 4.0” concept, has led in the industry and also by laboratories of engineering study to so called “digital twins” (Piascik et al., 2010). A digital twin is simulated and visualized software-model, which is synchronized with the original system and operates in the real time (Figure 2).

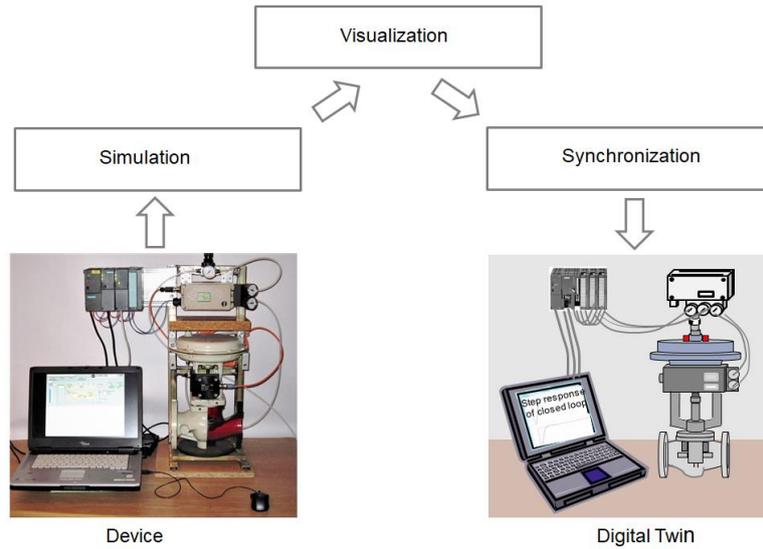


Figure 2. Developments Stages of Digital Twins for Study and Education

From MIL to PIL and HIL

The following options of digital twins are possible (Figure 3):

- Model-in-the-loop (MIL), if software-models of a plant and of a controller interact on only one host PC.
- Software-in-the-loop (SIL), if the controller code is executed together with the software-model of the plant on the same host.
- Processor-in-the-loop (PIL), if software-model of a plant is executed on one host (usually on a PC) and the controller code is implemented on another host (usually on a microcontroller board).

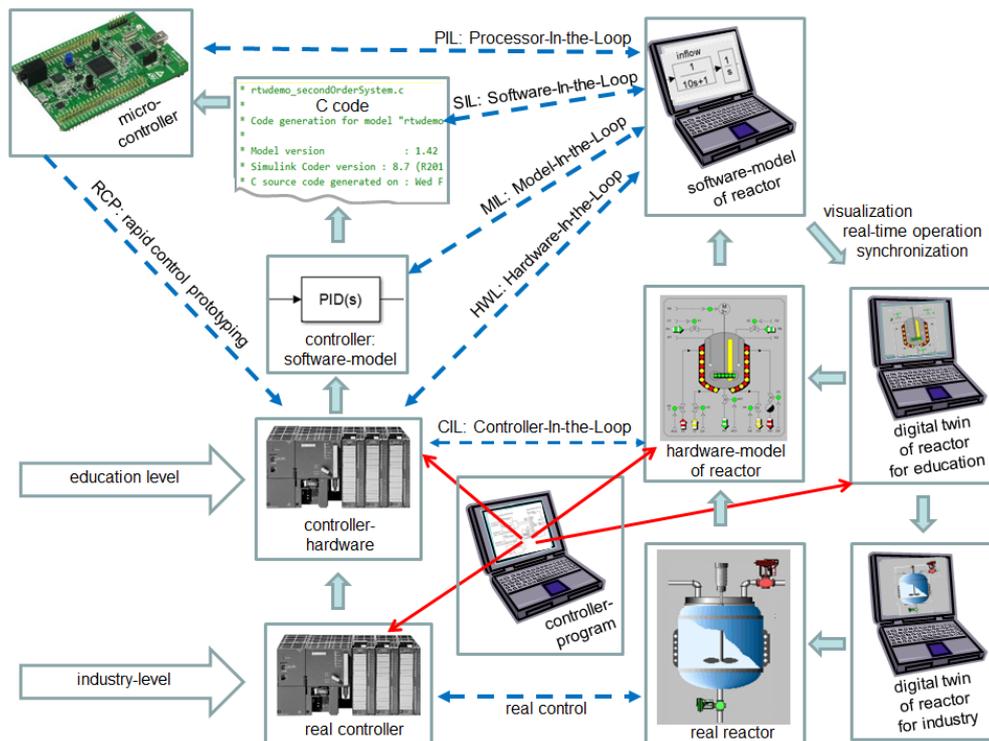


Figure 3. Classification of Hardware- and Software-models

Experiences about Digital Twins by Engineering Study

An example of digital twin and videos can be found in (Szabo, & Gurkasch, 2018) In Figure 4, the digital twin developed in (Lutz & Herbst, 2019) and used in (Czwalina, Gilung, Jeckel, & Heymann, 2019) for practical exercises by university courses such as “Automation” or “PLC” is shown.

The following problems by using the digital twin were found:

- The real-time capability can be lost, if the simulation system does not offer the necessary performance.
- The visualization and animation depends on software platform (MS Windows or MacOS).
- The 90 comparators were necessary to display the level of real device with MATLAB® with LEDs.

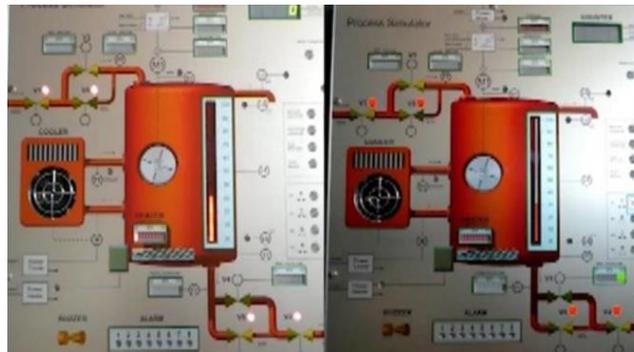


Figure 4. Digital Twin (l.) Simulated and Controlled by [6] with MATLAB ®/Simulink. The Hardware-model OSLO-3 (r.) Controlled with PLC Freelance and Field Controller AC-700 of ABB.

In Figure 5, a digital twin of a mechatronic device, which was designed by project team (Freitag, Alonso Gonzalez, & Buhl, 2020) for learning purposes to be transportable and therefore suitable for demonstration in the classroom, is shown. As a control device was chosen an S7-1215C CPU of SIEMENS. The conveyor was simulated very close to reality, depending on the speeds of the conveyor belt. However, it was observed that considerable resources are required even for this relatively simple simulation task.



Figure 5. Conveyor model (l.) designed by [8] with the CAD SIEMENS NX and its digital twin animated with MCD software (Mechatronics Concept Designer from SIEMENS)

Conclusions

The numerous advantages make digital twins an indispensable tool in today's university world. The benefits of digital twins are:

- Easy preparation for the training or experiments.
- No hardware is required to be installed or tested.
- An unlimited number of people can work with digital twins and apply them.
- The internship with digital twins can be made as comfortable as in classic laboratory rooms.

The disadvantage by creating a digital twin is the design effort, which is only one-off. Also the high costs for CAD-licences belong to a disadvantage. However the whole costs savings by the use of digital twins in an education laboratory consisting of fifteen laboratory places are 26% against fifteen real devices.

References

- Czwalina, D., Gilung, W., Jeckel, T., & Heymann, J. (2019). *PLCopen für digitalen Zwilling des OSLO-3*. Hochschule Darmstadt, FB EIT, Fernmaster Studiengang, 2019. (accessed on the 29.01.2020): https://www.zacher-international.com/C22_Team_Projekt/PLCOpenOSLO/PLCOpenDigiZwi.pdf
- Freitag, E., Alonso Gonzalez, C., & Buhl, J. (2020). *Digitaler Zwilling einer Förderanlage*, Hochschule Darmstadt, FB EIT, Fernmaster Studiengang, 2020. Video (accessed on the 29.01.2020): https://www.zacher-international.com/C22_Team_Projekt/DigiZwi/DigZwi_Foerderstrecke.mp4
- Henry, J. (1998). *Laboratory teaching via the WWW*. – In: ASEE Southeast U.S. Annual Meeting, 1998
- Henry, J., & Zacher, S. (2010a). *Description of the remote UTC-WebLab for engineering education and interactive demonstration with online experiments*. International Conference “Remote Engineering & Virtual Instrumentation“ REV, KTH, Stockholm, Sweden, June 29-July 02, 2010
- Henry, J., & Zacher, S. (2010b): *WebLabs in Control Engineering Education: status and trends*. – In: 7. AALE Angewandte Automatisierung in der Lehre und Forschung, FH Technikum Wien, 10./11. Feb. 2010
- Lutz, M., & Herbst, D. (2019). *Digitaler Zwilling der OSLO-Tafel*, Hochschule Darmstadt, FB EIT, Fernmaster Studiengang, 2019. Video (accessed on the 29.01.2020): https://www.zacher-international.com/C22_Team_Projekt/Digitaler_Zwilling_L_H/DZLH.mp4
- Piascik, R., et al. (2010). *Technology Area 12: Materials, Structures, Mechanical Systems, and Manufacturing Road Map*. 2010, NASA Office of Chief Technologist.
- Szabo, A., & Gurkasch, T. (2018). *Digitaler Zwilling der Simulationstafel ET722*, Seminararbeit DHBW Stuttgart, FB Technik, 2018. Video (accessed on the 20.01.2020): https://www.zacher-international.com/Projekte/DHBW_Stuttgart/ET722_DigZwi/ET722_DigZwi_Sz_Gur.mp4