Digital Twins Workshops Descriptions

Researchers at the University of Tennessee at Chattanooga (UTC) and Tennessee Technological University (TTU) are hosting a pair of Workforce Development Workshops that will convene thought leaders in multiple areas—including but not limited to engineering education, software engineering, HPC, uncertainty quantification, control systems, cybersecurity, machine learning, and cyber-physical systems/Internet of Things—to strategize educational approaches to digital twin modeling and simulation. Problems at the intersection of these disciplines are critical to achieving scalable, reliable, and cost-effective digital twins of sufficient fidelity for complex systems and production engineering, such as manufacturing and chemical plants [1], airplanes [2], and wind turbines [3].

Background

Digital Twins. Digital twins—integrated virtual representations of physical entities—are a rapidly expanding technology that exemplifies a critical skill area in production engineering. Digital twin software systems “facilitate the means to monitor, understand, and optimize the functions of all physical entities, living as well as non-living” [4]. In fact, it is likely that “by 2021, half of large industrial companies will use digital twins” [5]. Expensive machinery, delicate parts, and complex systems can be digitally modeled in real time: paired with predictive analytics and forecast models, data collected by studying digital twins can transform a company’s production capabilities. These systems are arguably as complex in their algorithms, data, and software as the physical systems they model, but they offer an effective way to mitigate risks and improve performance without significant loss of time or money. In specific applications, digital twins can be used to support model-predictive control of systems to improve safety, efficiency, profitability, and performance.

Industry 4.0. This data-driven approach to integrating online information with physical operations is a crucial driver of so-called Industry 4.0 (“the current trend of automation and data exchange in manufacturing technologies” [6]). Recent advances in overlapping fields of science and engineering, such as high-performance computing (HPC), big data, networking, and numerical modeling and simulation, are what have enabled Industry 4.0 and thus the design and application of digital twins. Because of this complexity, digital twin design, implementation, and operation are often taught and learned as separate skill sets. Those separate skill sets are then practiced by individuals from varying backgrounds and with varying levels of expertise. In a production environment, machine operators must, for instance, interface with designers and programmers. Each group has its own understanding of a digital twin system’s purpose and applicability; bridging gaps in knowledge and communication between those groups is paramount to safe, effective, and efficient digital twin operation. Identification of both the skills gap and the future potential jobs needed to fill it has already begun, such as the “Digital Twin Engineer Persona” described by Deloitte [7].

Production engineering in Industry 4.0 in requires digital twins, but digital twin technology cannot mirror the emerging complexity of Industry 4.0 without specialized, multidisciplinary education and workforce development with a strong foundation in software engineering. In other words, digital twins cannot be treated as an afterthought. As industries adopt data- and technology-driven approaches to manufacturing, education must keep pace accordingly: we need knowledge workers who can reliably design, develop, and operate production-ready digital twins at a high level.

Education 4.0. The two 2-day workshops will focus on effective pedagogical and andragogical strategies for the intersection of Industry 4.0 and Education 4.0 via Engineering Education 4.0, using digital twins as the platform to disseminate best practices in higher education.

Education 4.0, like digital twins, is a combination of physical and virtual information. Using virtual reality in the classroom is one example; adding process management to information science curriculum is another [8]. Accordingly, Engineering Education 4.0 encompasses engineering design challenges that result from Industry 4.0 [9], including digitizing manufacturing [10]. The goal of integrating digital twins into Engineering Education 4.0 is to connect theory with case studies—to help students understand the challenges of real production spaces and help employers understand the constraints of education [11]. What's more, well-executed digital twins (created and/or managed by knowledge workers who have been educated in the particular challenges of digital twins and Industry 4.0 via Engineering Education 4.0) can ideally be redeployed in experiential learning and workforce development.

Workshop Goals

The first workshop, to be held at UTC, will elicit knowledge units to be taught at the intersection of the disciplines required to achieve production-ready digital twins. The second workshop, to be held approximately four months later at TTU, will emphasize translation of the engineering methodologies into modules that are suitable for delivery in multiple educational formats, including both face-to-face and distributed environments for graduate and continuing education.

The activities/outcomes/topics of the workshops, emphasizing digital twins workforce development at the intersection of Education 4.0 and Industry 4.0, are therefore expected to include the following:

1. Create a roadmap for digital twin educational infrastructure for workforce development (courses, delivery modes, learning outcomes) via Engineering Education 4.0
2. Identify skill sets and roles for knowledge workers who interact with digital twins in Industry 4.0
3. Identify open and existing areas of research and inquiry needed to implement the educational infrastructure roadmap
4. Propose transformational, cross-cutting training in HPC and systems modeling for engineers already trained in particular domain areas (e.g., vehicles, manufacturing plants, control systems)
5. Compile gaps in underlying disciplinary / educational areas (or uncertainty at the multidisciplinary interfaces of these areas) that limit the productive design, implementation, deployment, and utilization of digital twins for which additional R&D and educational research are needed
6. Recommend strategies for the timely realization of the roadmap, such as funding mechanisms; sustained, organized collaborations of the public and private sectors with academia; and the formalization of sub-disciplines within the space of digital twin technologies

These workshops will result in unique recommendations for effective, innovative, distributed production engineering education in general. Specifically, these recommendations will also lead to convergent research projects at the intersection of educational research and the multidisciplinary areas needed to design, implement, and operate digital twins. Collaborations are expected to emerge between educators and domain experts, yielding outcomes such as the enhanced design of HPC simulation and machine learning software systems that are both responsive to evolving needs of production environments and suitable for use in classroom environments. Ideally, sustainable communities of practice bridging academia, government, and industry will also result.

Workshop 1 will result in a high-level design of a possible educational process that brings together best practices from all sides and takes into account what skills and critical perspectives ideal digital twin experts would possess, whether in design, implementation, or operation (for example, how to know when the simulation is no longer reflecting the physical system appropriately). In other words, we aim to create a "10,000-foot view" of the intersection of software engineering in Industry 4.0 and Engineering Education 4.0. Conveniently, we will parallel Deloitte's report on personas in digital twin manufacturing [7], adding the educational component to address the more complex nexus of Industry/Education 4.0 concerns.

To facilitate cross-disciplinary discussions that remain at a high level, we will encourage participants to use a middle-out design perspective—that is, to examine the interfaces of their respective fields with those of other participants in the digital twin application space. Some sub-disciplines are more mature than others in employing digital twins; however, the workshops will remain vertical-agnostic (production-manufacturing specific) as much as possible. Workshop 1 will focus on iterative discussions of people and processes rather than of technologies. Again, the goal is to prototype a process, not to design a full solution. We're interested in what Industry 4.0 stakeholders have to say about what they would consider to be a mature process model for creating successful digital twin knowledge workers, including known limitations in their current endeavors and how educational infrastructure can support that path to maturity.

STEM education experts will facilitate synthesis of domain experts' perspectives in a purposely designed collaborative learning environment. Each new piece of information will offer the opportunity for recalibration and iteration on the design process, instead of relying on a more rigid top-down development approach.

Workshop 2 will begin with an overview of the results of Workshop 1 and a debrief from the structured period between workshops. Participants will have a chance to reconvene (or convene, if they did not attend the first workshop) with fresh perspective, sharing ideas across disciplines and recalibrating with engineering education experts. This review of past results will also include re-emphasizing broadened participation and bias avoidance.

This second workshop will have a different focus than the first, as we will look to more application-area experts than in the first workshop. Integrating narrower perspectives from verticals will allow discussion to include specifics of engineering complexity, including speed, cost accuracy, material, and other constraints. The result will be a qualitative understanding of the level of fidelity required for digital twins in the representative production spaces. Significantly, these spaces will have varying levels of implementation of digital twins, from true digital twins to digital models to digital shadows [1].

The educational goal of Workshop 2 will be to gather the assembled perspectives into a detailed design of the ideal Education Engineering 4.0 infrastructure for workforce development. Taking into account the products of the Inception workshops (the 100,000-foot roadmap and the concept of the preferred digital twin professional), participants will work to fill identified gaps and develop a corresponding 1,000-foot roadmap. This new, more finely grained roadmap will be used to outline future possibilities for development of the proposed infrastructure.

Finally, Workshop 2 will end with risk assessment: domain experts will review risks to validity, areas of uncertainty, and other possible pain points in digital twins design, development, and operation that should be added to the post-workshop roadmap. This assessment will include reiteration of the kinds of critical decisions Industry 4.0 and digital twins professionals should be able to make independently.

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