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Human-Centric Assembly Cell & Line Validation

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Abstract. Further digitalization is in progress for production processes which creates new challenges for both human centric assembly line management and individual assembly operators. By providing an efficient platform and 'virtual assembly line twin' the collaboration between Manufacturing Engineering and Production Operations can be significantly improved providing an efficient platform for assembly validation, ramp-up, operator guidance and virtual try-outs of improvements and changes to the assembly line. The main target is to provide a further strengthened platform for Human Centric Experiential Discovery and Validation, providing a rich virtual twin of the assembly environment, thus enabling efficient and reliable decision making by the key stakeholders involved in the manufacturing engineering, ramp-up and production operation processes, while providing digital continuity with upstream and downstream workflows for efficient integration within the customer processes. This session highlights most valuable IC.IDO (I See I Do) themes supporting the virtual validation of human centric processes in the production line, supporting our customers to increase productivity while ensuring worker health and safety, minimizing waste (Muda) and human error throughout the product lifecycle fulfilled with some proven customer examples. The session will also highlight customer requirements from innovation perspective to improve future workflows to generate a higher level of working efficiency.

Keywords. Human Centric, Virtual Assembly, Operator 4.0, Process Validation, Virtual Reality

1. Introduction

While significant focus in context of Industry 4.0 is on extensive automation and digitalization of the production environment, this is not necessarily true for all assembly processes which remain human-centric in practice. As new technology transforms many aspects of the assembly process including future employment rates and job profiles; there is common agreement that most tasks in general assembly will stay human-centric for any foreseeable future. Production flexibility required by novel and transformative new products can result in processes for which humans are still superior to machines [1]. At the same time there will be new challenges in introducing new processes, tools and human-machine interactions that needs to be efficiently validated from a human-centric perspective, requiring efficient ramp-up and knowledge transfer to the final production environment and human operators.

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2. Customer challenges for human centric assembly process validations

What does a Program Manager do when faced with a start of production pulled ahead by four months for the product to launch ahead of competition and a design and validation budget slashed at the 11th hour to match the competitor's offer or if your customer reduces their aerospace program lead-time by 18 months from 5 years to 42 months [2]?

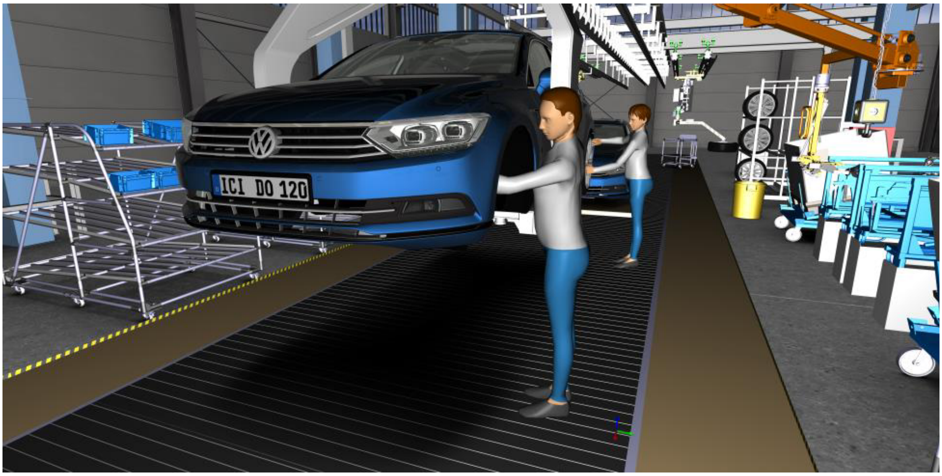

Figure 1. Experience assembly process with Digital Human Models. Model data is Courtesy of Volkswagen.

There is neither time nor resources available to work according to standard processes anymore: activities must be rushed, reduced and/or bypassed and key design decisions considered "good enough", making risk mitigation pivotal.

2.1. Keeping up with market disruptions

Every day, new disruptive companies emerge and challenge the established organizations with compelling products, lower structural costs, more nimble processes, and a simpler approach. Smart, dynamic entrepreneurs devise clever strategies leveraging new technologies and new mentalities to overrun the slower, historical processes of larger corporations. Existing companies must align to the new market conditions or dwindle. To cut costs and hope to reduce lead times, Program Managers can no longer afford to design iteratively based on physical prototype trial and error. Design, validation, and manufacturing teams must be involved from the start, to reach a common understanding of the design without constructing a prototype. They must understand and experience the product before it exists. This is as true for manufacture and assembly on the factory floor as it is for the engineering design of the product.

2.2. Recognizing the interactions of people with proposed products and processes

Conducting an experiential process validation, an immersed engineer might conclude that a virtual build or service task as performed in fully physical context is "feasible" to complete, but that the process is sub-optimal for comfort or ease, in the space provided with the proposed tools.

In contrast to a deterministic simulation that might compute that a motion path is plausible for the installation of a component, a human operator will observe that, without super-human powers, they might not be able to see the workspace clearly enough to complete the task. Computer animations to illustrate a proposed process can take hours to prepare, requiring specialized skills to manipulate a digital human model like puppeteering and could still fall short of proving the validity of the procedure. Working in a Virtual Reality (VR)-enabled Virtual Build (Figure 1), an engineer can, within seconds, evaluate, perform, and optimize an assembly sequence and tooling manipulation intuitively, just like they would in a pilot production facility.

First-person exploration only gets you so far because the circumstances are unique to the individual. Production will likely be distributed to different locales and performed by the local population, for localized product variants, in a unique production environment. Adding the ability to record and playback object animations, extends that singular experience over the potential a range of localizations in real-time. Capturing the assembly experience of other individuals in VR not only reaches the value of physical pilot assembly lines, it can reflect plausible production conditions that would take years of production to observe, mitigate, improve, and resolve.

3. Enhancing productivity and processes for the factory of the future

Sequences coupled with advance anthropometric digital human models, allows virtual build users to apply their first-person actions to “manikins” reflecting any number of regionalities, gender, and proportions. It becomes easy to explore, in the virtual environment, building a new product, and directly arrive at objective analytics for a diverse range of potential workers. Thereby it is possible, for example, to learn that, a 95% European male who performed an assembly action with ease could assign that same action to a 5% Asian female manikin and discover that she would find the same task uncomfortable or even unfeasible.

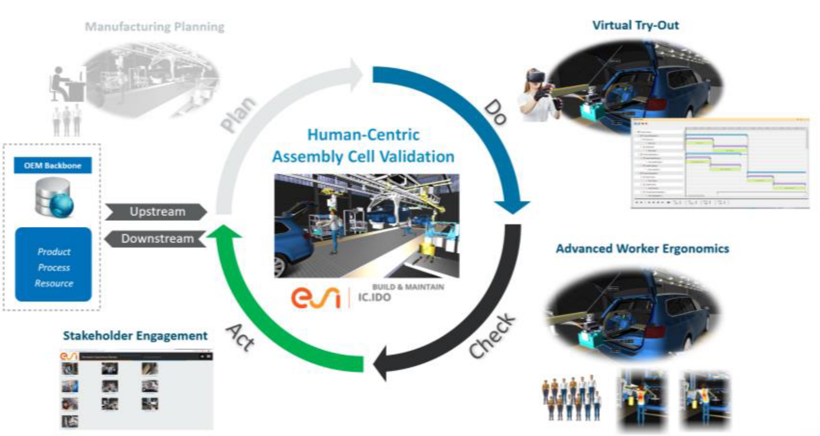

Figure 2. Digitally guided assembly process with Digital Human Models. Model data is Courtesy of Volkswagen.

3.1. Augmented Reality and Virtual Reality

Assembly sequences are also required for creation of documentation and deployment of work instructions. Recent technology advances in the factory of the future point to a range of digitally guided assembly processes (Figure 2). Augmented Reality (AR) is one hot topic in this area, wherein digital model data can be overlaid with the real product to indicate the required sequence of operations. AR technology is lauded for its ability to enhance spatial understanding of complex tasks and communicate in 3D object visual overlays, like “holograms”, what would take mountains of words and static illustrations to convey.

It does not, however, invalidate the need to prove and validate assembly processes and sequences; it instead increases the stakes that an expensive deployment of digital work instructions exposes production risks if the AR process is not feasible. In a Virtual Reality environment, one can validate assembly sequences using purely digital data. The findings from Virtual Builds can then be captured and exported as the basis for Augmented Reality digital guided assembly operations. It is not a question of VR versus AR, but instead that Virtual Reality can be used to validate what will eventually be deployed on Augmented Reality, before the physical products are ready.

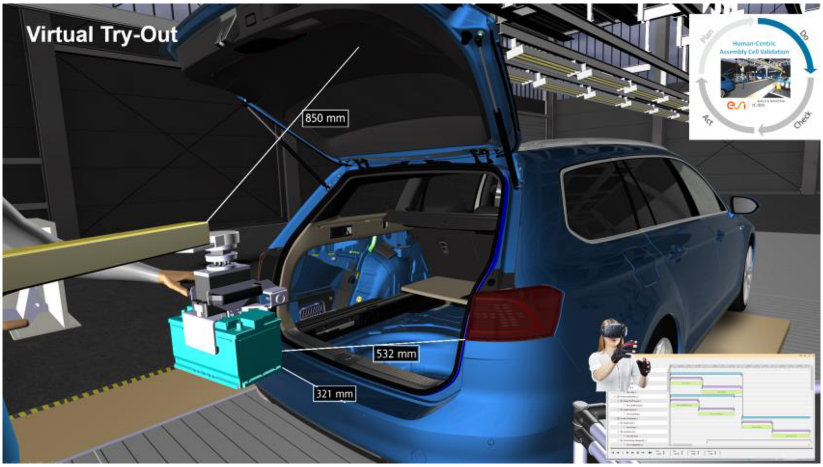

Figure 3. Human centric assembly cell validation. Model data is Courtesy of Volkswagen.

3.2. Validating the production process across multi-disciplinary teams

Bringing in more competencies for a product evaluation is always beneficial. That is why modern design methodologies usually call for a “multi-disciplinary approach” or simultaneous engineering in design reviews and risk assessments. Additional sets of eyes spot more risks, alternative perspectives identify more trade-offs, different minds find more solutions. Where a test engineer might confirm that a button is too hard to press, an ergo-nomics engineer might point out that it is too small and not easily accessible, a safety engineer might note that it reduces accidental actuation, and a sales manager might wonder why there is even a button to begin with. The more interaction, the richer the analysis and the more potential to confirm solutions or to identify problems, then as a group explore design opportunities. The design team can then rework the product, or the affected procedure, with confidence that all parties are aware and on board with the improved solution.

The ability to experience and interact with products, before they are ever physically manufactured—on screen, with a head-mounted display, on a power wall or in a Cave, as an individual engineer, as a group, with a supplier or with a customer team, across a global enterprise—is invaluable. The discussions engaging team members and other stakeholders in an interactive quest for issues and improvements so early in the program, before tools are even kicked-off, inevitably lead to a stronger confidence in the design and manufacturability of the product from all involved, and ultimately from the whole company.

4. IC.IDO for human-centric assembly cell and line validation

With IC.IDO [3], ESI [4] offers a solution for Human-Centric Assembly Process Validation. This immersive virtual workspace (Figure 3) enables multi-disciplinary evaluations, discussions, and resolutions to the challenges that new products and processes bring to the factory of the future. It allows individuals or teams, together or from remote sites, to experience and interact with digital designs, so that engineering teams can identify necessary improvements and engineer corrections before construction starts on tooling for the manufacturing plants.

ESI IC.IDO solution helps product and manufacturing engineering managers address challenges brought by shorter product lifecycles, globalization and new technology trends, to better manage the risk of missed production targets (delivery, cost, quality, safety); through real-time, rich-context, virtual (VR enabled) validation of human-centric production processes, facilitating early identification of issues and improvements while reducing reliance on traditional off-line simulation, costly physical trials, or limited expert opinions.

The goal is to provide a further strengthened platform for Human Centric Experiential Discovery and Validation, providing a rich virtual twin of the assembly environment, thus enabling efficient and reliable decision making by the key stakeholders. No matter if they are involved in the manufacturing engineering, assembly ramp-up, or production operation processes, a Collaborative Virtual Workspace expands digital continuity with upstream and downstream workflows for efficient integration within the customer processes.

Core focus also includes the progression toward 'Operator 4.0' [5] providing a human centric perspective on Industry 4.0. Focus is two-fold, on one hand side enabling virtual validation of new production technology in context of the worker of the future 'Operator 4.0', e.g. including increased automation of the assembly line, while also enabling VR and AR enabled workflows into new buying centers within Production and Service Operations to support efficient operator ramp-up through virtual try-outs, training and operator guidance.

5. Existing customer reference examples [6]

Fiat Chrysler Automobiles (FCA) [7] has production units in 40 countries and commercial presence in 150 countries. The group is home to brands like Alfa Romeo, Chrysler, Dodge, Fiat, Jeep, Lancia, Ram, SRT, Maserati, and Mopar (parts and services). As part of FCA's ambitious MFG2020 initiative, an Industry 4.0 project, FCA Latin America (LATAM) considered how to further improve the engineering and validation of assembly operations for the new Fiat Argo car model, seeking to further reduce costs and delays.

Figure 4. Human centric assembly cell validation at FCA. Model data is Courtesy of FCA.

For this action, they turned to ESI's Virtual Reality solution, ESI IC.IDO. The 'Fiat Argo' was the current program for FCA LATAM and had a strong focus on interior assembly and trim. It was the first time that FCA LATAM applied IC.IDO throughout an entire project, including in the validation of vehicle assembly. The Virtual Reality solution was used to identify risks in the product design before construction of a physical prototype.

All of FCA engineering groups – manufacturing, production, and ergonomic health & safety (EHS) – were involved in the action (Figure 4), which enabled them to reach an optimized solution for all areas reviewed. 18 months had been considered an acceptable ROI for this kind of Industry 4.0 technology investment. But in fact, the project reached full ROI after only eight months and FCA was able to successfully assemble the new vehicle as planned. ESI IC.IDO brought agility, reduced time and enhanced workplaces.

IC.IDO enabled FCA LATAM to experience the real process conditions of assembly and assure the conformity of the product by considering all the interferences in the virtual phase of development. IC.IDO enabled FCA LATAM to evaluate different process scenarios and design variants for the program, including the validation of the manipulator arms for passenger compartment assembly.

By evaluating the planned processes in advance, FCA LATAM was able to implement a corrective action plans to develop a new work cell device and validate assembly procedures to optimize and validate the proposed assembly process. It was crucial, prior to the following phases of the program, to assure the products were safe and feasible to assemble.

Today, FCA LATAM has IC.IDO installations at the Automotive Industrial Center of FIAT Betim and at Jeep Goiana, which allows them to use the tool across the entire range of FIAT's brands.

6. Scientific outlook and next generation HC assembly process validation

ESI is part of an ITEA 3 [8] driven project consortium called MOSIM [9] (**Mo**dular **Si**mulation of Human **M**otions) (Figure 5). In the project ESI has a role as system integrator and industrial partner (Figure 6). MOSIM is an open modular framework for efficient and interactive simulation and analysis of realistic human motions for professional applications. The IC.IDO solution from ESI is one of the proposed target engines who wants to use the project outcome for later industrial use mainly to enhance the current capabilities within the human centric assembly validation area.

The impact of present engineering practices on the people who produce, use, and maintain products is often left unquantified until late in the product lifecycle; in some cases, too late to address in the immediate product design or even the next generation. The idea of MOSIM need to increase comprehension of current engineering and manufacturing paradigm the integration of products and processes on the people who build, use, and maintain products throughout their lifecycle. There is no holistic solution on the market which takes care of human factors during assembly including realistic human simulation capabilities on board. ESI's intention is to use these projects results for improving human centric manufacturing/manual assembly evaluations.

Figure 5. MOSIM consortium partners.

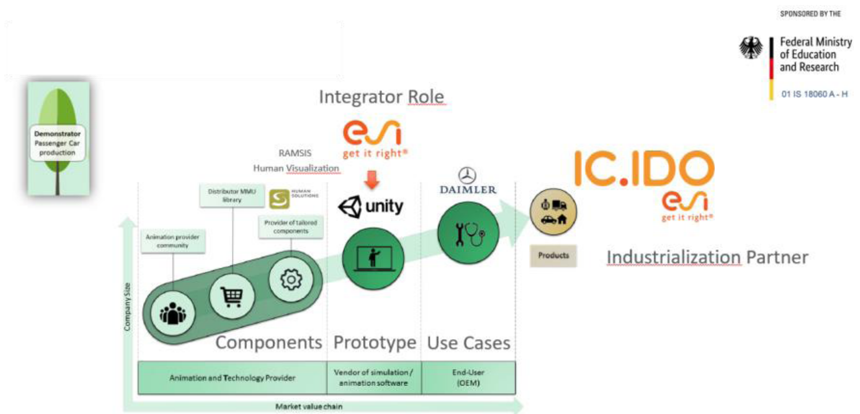

Figure 6. ESI main project role in the MOSIM consortium.

ESI expects a huge paradigm shift and implications for automotive production (Figure 7):

- From the viewpoint of an assembly station, nearly each **product** can be considered **unique**
- Associated **assembly tasks** may vary within each cycle
- Rising **complexity** and **efforts** for production planning departments
- Simultaneously, **changed paradigms**, are leading to a **decreasing prediction** quality of planning methods

Figure 7. Paradigm shift for simulating human motions in future.

ESI expects also a huge reduction of needed time effort compared to curren industrial practise (based on DMU related human task simulation).

The generation of a rich repertoire of realistic human motions in complex and possibly highly collision afflicted environments is not sufficiently addressed by commercial tools. Complex process workflows with an exhaustive number of possible manual task sequences can only be partly addressed today, since process variants must be modelled by hand. As manual modelling is inevitably linked with high additional effort, the potential cost reduction is significant. In order to introduce approaches and software solutions, which are capable to automatically simulating a rich repertoire of realistic human motions, MOSIM aims to develop and implement a generic concept which is inspired by the Functional Mock-up Interface (FMI) standard [10].

MOSIM transfers the idea of co-simulating models from different simulation environments to the field of human simulation by means of introducing the Motion Model Units (MMU). To achieve the mentioned goals, three main approaches, each incorporating various technical contributions which clearly go beyond the state of technology, will be explored within MOSIM.

The main ideas behind MOSIM are:

- Concept and Implementation of an extensive **library** consisting of **MMUs** encapsulating various human motions regardless of the respective use-case.
- Development of tailored approaches, enabling **autonomous generation** of plausible **MMU sequences** and context-dependent decision-making using recent AI methods.
- Unifying both approaches, a **co-simulator** will be implemented, generating natural and continuous human motions by **sequencing** and **executing** the obtained set of **MMUs** using generic transition models.

The main expected outcomes for the MOSIM outcomes are for ESI:

- Extension of IC.IDO assembly process validation module
- Validation of assembly sequence plan's out of workers perspective (people, tools, resources)
- Integration of MOSIM platform into IC.IDO "target engine" to simulate human centric assembly processes (automized)
- Integration of ergonomic analysis (e.g. RULA [12] and others [13]) using RAMSIS kernel (by Human Solutions GmbH [11]) and MOSIM MMUs in IC.IDO.

ESI wants to push the MOSIM concept [14] forward from an industrial perspective to relevant industry pillars like automotive, aerospace or heavy industry for example even though to define an industry standard within the consortium.

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