Artificial Intelligence and Machine Learning for Manufacturing

NAFEMS

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Event Abstracts

20-21 September 2023

Online

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Preliminary Agenda

We have the following confirmed presentations so far, with more currently being peer reviewed by our committee.

Day 1 - Wednesday 20 September

11:00
Welcome & Introduction
Mahmood Tabaddor - NAFEMS Americas Steering Committee Member

11:15
Driven Analytics for Assembly Process Discovery and Benchmarking at Volkswagen AG
Christine Rese - Volkswagen AG

11:45
AI and Machine Learning Enabling Manufacturing Process and Supply Chain Transformation
Larry Sweet - Advanced Robotics for Manufacturing (ARM) Institute

Break: 30 Minutes

12:45
AI, Machine Learning and Deep Learning in Nuclear Manufacturing for ITER components
Maria Ortiz De Zuniga - F4E (Fusion for Energy)

Case Studies 1 (Parallel Presentations; Stages 1-2)

1:15
Physics-Based vs. Data-Driven Methods to Accelerate Battery Test Cycles
Dr Richard Ahlfeld, Monolith AI (Stage 1)

1:15
Three Practical AI Use Cases for Manufacturing Processes
Remi Duquette, Maya HTT (Stage 2)

1:45
Brief Preview of Day 1
Mahmood Tabaddor - NAFEMS Americas Steering Committee Member

Day 2 - Thursday 21 September

10:55
Brief Welcome
Mahmood Tabaddor - NAFEMS Americas Steering Committee Member (Stage 1)

11:00
Multilayered Large Language Models Strategies for Generating Time Series Simulation Data
Jon Chun, Kenyon College – Co-Founder, AI for the Humanities Curriculum and AI Digital Collaboratory

Case Studies 2 (Parallel Presentations; Stages 1-2)

11:30
Hybrid Digital Twin for Monitoring and Tuning Gas Treatment Unit
Laurent Chec & Bruno Trebucq, Datadvance SAS & Bruno Trebucq, CGI France (Stage 1)

Deep Learning for Manufacturing: an Application to the Rheology Process
Pierre Baqué (Stage 2) - Neural Concepts

Main Program; Stage 1

12:00
Scientific Machine Learning in Industrial and Manufacturing Pipelines
Marta D'Elia - Pasteur Labs

Break: 30 Minutes

Case Studies 3 (Parallel Presentations; Stages 1-2)

1:00
Building Digital Twins at Scale
Sandeep Urankar - Rescale

1:00
Automatic Defect Classification (ADC) solution using Data-Centric Artificial Intelligence (AI) for outgoing quality inspections in the semiconductor industry
Quinn Killough, Onder Anilturk - Landing AI and NXP (Stage 2)

1:30
Enabling IT/OT Integration using Digital Twins of Business Processes
Hannes Waclawek - Salzburg University of Applied Sciences

2:00
Close
Mahmood Tabaddor - NAFEMS Americas Steering Committee Member

Presenter Name: Christine Rese

Presenter Company: Volkswagen AG

Presentation Title: Driven Analytics for Assembly Process Discovery and Benchmarking at Volkswagen AG

Abstract: In automotive manufacturing networks, vehicles are made up of mostly similar parts. Nevertheless, the assembly processes for these parts are often designed in a highly heterogeneous manner across different plants. This heterogeneity is mainly caused by the complexity of the existing plants, different manufacturing processes, complexity and variability of the products and the resulting mix of it during the combination in one specific assembly line. Due to those circumstances nearly no assembly line is the same in production networks. This makes identifying best practices for assembly processes a challenging task which requires a lot of manual effort. To address these issues, we have developed a data-driven approach for benchmarking and optimizing assembly processes. Our approach uses data mining techniques to identify similar assembly processes with a focus on built-in parts and areas for improvement in different assembly processes. The data-driven approach ensures process design consistency across manufacturing locations as well as the reuse and optimization of existing process knowledge within the product development process and series phase.

Presenter Name: Dr. Larry Sweet

Presenter Company: Advanced Robotics for Manufacturing (ARM) Institute

Presentation Title: AI and Machine Learning Enabling Manufacturing Process and Supply Chain Transformation

Abstract: AI and Machine Learning (ML) are accelerating gains in advanced manufacturing, enabling levels of productivity accessible to the diverse eco-system of large to small-sized manufacturers. Combined with advanced robotics, “point of need” manufacturing has the potential to transform the entire logistics supply chain, reduce the size and of vast inventories, and prioritize transportation and skill field technicians for critical items that cannot be manufactured in the field. Advanced robotic manufacturing will provide capabilities for on-site production, repair, refurbishment of parts and consumables, and inspect for defects to capture potential failures before they occur. This presentation highlights two current ARM ((Advanced Robotics for Manufacturing) Institute collaborative team projects with high impact potential using advanced AI and ML as critical enablers.

Ohio State University is leading a team including CapSen Robotics, and Yaskawa to produce heat treated and forged parts with superior strength and durability for replacement of critical structural components, eliminating manufacturing and supply chain lead-times from distant production sites and inventory storage. The robotic process uses incremental steps to 3D scan, heat treat, forge, using computer models to guide each repetition from raw material to final shape. AI-based in-process adaptability adjusts for manufacturing variations associated with low volume, high mix production. This allows the system to learn and improve its process planning, plan tasks and algorithms for generating gripping, path, and process plans. Using lessons learned from feasibility tests at end user site, work is underway to shorten end-to-end cycle times.

GKN Aerospace, Gray Matter Robotics, University of Washington, and EWI are developing uniform work robotic sanding with intra-stage inspection, overcoming limitations in existing systems that have irregular material removal, deep scratches, rework, and unacceptable optical distortion. Uniform work is controlled by robot velocity, spindle RPM, pad pressure distribution, overlap strategy, and lap optimization. Advanced optics measure fine detail scratches in transparent surfaces. Machine Learning using artificial neural networks is critical at each process step, automatically labeling thousands of images across the surface as Good, Marginal, or Bad, for workpieces that are representative of end user production geometries and materials.

Presenter Name: Maria Ortiz De Zuniga

Presenter Company: Fusion for Energy

Presentation Title: AI, Machine Learning and Deep Learning in Nuclear Manufacturing for ITER components

Abstract: Artificial Intelligence (AI) has been applied to many different fields, whereas in others it is still to be explored. In general, this is the case of the nuclear manufacturing and, specifically, the case related to welding success rate prediction and the analysis of outputs from the phased-array ultrasonic (PAUT) nondestructive testing (NDT).The aim of this work is the development and analysis of AI tools for welding success rate prediction and the posterior output processing of PAUT applied to welding defects detection in the ITER Vacuum Vessel manufacturing. Thanks to its complexity, the manufacturing of this large equipment-based on the French nuclear design and manufacturing code (RCC-MR)-has generated a large amount of data. Since the Vacuum Vessel is the first confinement barrier of the nuclear fusion installation, ensuring the quality of its welds is a serious challenge. Each of the five European sectors has approximately one kilometer of welding to be performed. Any defect in these welds results in a large disruption on a quality schedule and on a mechanical level, which has to be recovered, within feasibility limits. The first tool, based on the Random Forest Regression method, is able to predict the success rate of electron beam welding (EBW) and of Tungsten Inter Gas (TIG) welding, with up to 100% accuracy.

Once the weld is performed, the Vacuum Vessel double-wall nature results in un-inspectable welds during the last stages of the segment manufacturing on the full weld depth or from both sides through conventional non-destructive testing methods, such as radiographic examination as accepted by the RCC-MR; resulting in the need to qualify a more advanced ND technique, such as PAUT. PAUT data processing and interpretation has to be carried out by a human expert and requires up to one week per weld on average, due to the coarse grain material of austenitic stainless steel used in the Vacuum Vessel-316LN-IG-and the complexity of the qualified PAUT procedures. This process is long and costly, affecting performance and requiring a large number of resources noting that the cost of training alone to develop a suitably qualified NDE personnel who can do UT examination can be considerable. The second tool tackles the processing operation of the PAUT output. PAUT output can be generated in two formats: an A-scan and an S-scan (similar to a scan in the medical field). Due to the complexity of the task and large amount of data, Deep Learning was promptly identified as the correct AI subset to use for this development. On one hand, a convolutional neural network CNN) has been chosen to analyze data through its perceptron's and process data as an image, similar to the processing of images performed in the human visual cortex. On the other hand, a long short-term memory (LSTM) model was selected to process the same data in a two-dimensional wave representation. Due to the sensitive nature of the information provided and the large consequences of false positives or false negatives, a conservative approach was chosen for the final output. This double gate approach not only increases the accuracy of the result but also increases the human confidence in this tool. This development shows that AI is an appropriate tool to process PAUT data, allowing prompter data availability and giving an additional information set in order for projects to take informed decisions. The subjective interpretation and human error factors can be decreased through this automation, as is the large time required to process each PAUT

Presenter Name: Dr. Richard Ahlfeld

Presenter Company: Monolith AI

Presentation Title: Physics-Based vs. Data-Driven Methods to Accelerate Battery Test Cycles

Abstract: Dr. Richard Ahlfeld, CEO of Monolith, will cover the topic of Machine Learning to maximise the value of engineering tests. With a primary focus on a battery test case study, Dr. Ahlfeld will demonstrate the differences between physics-based and data-driven models, where physics-based approaches fall short and how Machine Learning can complement those. Validating complex, nonlinear systems is hard. And testing every possible scenario on a test bench or in a simulation is not feasible. Over-testing confirms what's already known, while under-testing risks failing certification or missing issues. Physics based models used in engineering tests rely on complex mathematical equations to simulate and predict system behaviour. While these models have been valuable, they often struggle to capture the full complexity and intricacies of real-world systems. Dr. Ahlfeld will discuss the limitations of physics-based models in dealing with uncertainties, non-linearities, and the intractability of the physics that is being investigated. Optimising multiple design parameters through time-consuming experiments poses challenges in various scientific and engineering fields. For instance, in the battery test study, maximising battery lifetime requires extensive experimentation that can take months to years, with each experiment lasting several hours. To address this, Monolith developed an early-prediction model (Next Test Recommender). The Next Test Recommender provides engineers with active recommendations for the exact best test conditions to choose from for the next batch of tests and ranks the most impactful new tests to carry out, based on an analysis of previously collected data. This approach significantly reduces the time and number of experiments required, substantially reducing traditional exhaustive search methods that would take over 500 days to just 16 days (equivalent to 384 hours).

Presenter Name: Remi Duquette

Presenter Company: Maya HTT

Presentation Title: Three Practical AI Use Cases for Manufacturing Processes

Abstract: Manufacturing companies face the challenge of turning their AI investments into tangible returns and ensuring long-term adoption.

If you think your data-rich and ready for an industrial AI project? Come take a closer look!
We will present three (3) successful industrial AI use cases running 24/7/365 for the benefit of our manufacturing clients. Machine learning and deep learning and now generative AI has evolved a lot over the past few years. We will cover the biggest barrier to adoption (no, it is not the tech). We will also review the data engineering best practices that need to be implemented to ensure continuous quality and productivity improvements with AI tech. Find out about practical manufacturing use cases with interesting and measurable benefits. Get answers to the following questions:

- Is my data of good enough quality to take advantage of AI algorithms?
- Do I have enough data to take advantage of AI algorithms? If not, what are alternative solutions to get started?
- What equipment should I add to my production to apply AI technologies?
- What examples of quality improvement in manufacturing production seem to benefit from AI tech?
- What examples of productivity improvement in manufacturing production seem to benefit from AI tech?

What examples of maintenance improvement in manufacturing production and industrial operations seem to benefit from AI tech?

Presenter Name: Jon Chun

Presenter Company: Kenyon College – Co-Founder, AI for the Humanities Curriculum and AI Digital Collaboratory

Presentation Title: Multilayered Large Language Models strategies for generating time series simulation data

Abstract: In the rapidly changing AI landscape, Large Language Models (LLMs) like OpenAI's GPT4 initially may appear tangential to simulation technologies. However, with a closer look, the potential of LLMs becomes clear, presenting exciting opportunities for NAFEMS members. This presentation will deliver a hands-on exploration of leveraging OpenAI's GPT4 and associated LLM frameworks to generate synthetic and enrich existing time series datasets, all within the context of physical simulations for anomaly detection—a key area of interest in the manufacturing industry.

We'll use popular open training datasets used to train predictive maintenance models as both a ground truth reference and a source for augmentation. This will include both normal and abnormal time series for vibration, temperature, pressure and current/voltage measurements. We'll use the ground truth reference time series datasets to evaluate both normal and abnormal time series generated and augmented using the best LLM strategy identified. Our performance metrics will be based on two statistical profiles tailored to two types of time series abnormalities: (a) a global regime/distribution shift type like those found in asset price trading bands, and (b) more localized feature anomalies that often predict impending failures.

We review an incremental progression of GPT4 utilization, illuminating its potential while addressing the inherent limitations. We'll begin with basic GPT models, explore various prompt engineering strategies, then delve into Python Code Interpreter extension and OpenAI tool use via Langchain. We'll explicitly address issues around hallucination, stale training data and innumeracy of LLM. The culmination will dive into OpenAI's 0613 model updates, which introduce a new API function object specification that dramatically enhances the reliability of programmatically interfacing with GPT3.5 and GPT4 models.

The presentation will wrap with a comparative analysis of LLM data synthesis and augmentation techniques against traditional approaches, including both open source and commercial offerings like Gretel.ai. Listeners will be equipped with a practical and up to date understanding of the latest state-of-the-art GPT4 LLM and how to better utilize such generative LLM AI models for their generating or augmenting data for simulation or fine-tuning other AI models. We will close with an update on the recent and anticipated AI advancements, enabling you to better align future LLM applications to particular physical simulations.

Presenter Name: Laurent Chec and Bruno Trebucq

Presenter Company: Datadvance SAS and CGI France

Presentation Title: Hybrid Digital Twin for monitoring and tuning gas treatment unit

Abstract: The proposed paper focuses on an innovative solution to integrate machine learning and artificial intelligence capabilities into a digital twin strategy for monitoring a continuous production asset.

This innovative solution is the result of a collaboration between CGI and Datadvance within ***CGI's Global Innovation Centre*** (Toulouse, France), which aims to help industrial players around the world realise the benefits of Industry 4.0 and its enabling technologies, including the Internet of Things (IoT), augmented reality and digital twins.
In the concept of Industry 4.0 and cyber-physical systems, digital twins are based on predictive models and the valorisation of operational data. They provide the key information to monitor and operate physical assets to maximise efficiency.

However, 'predictive models' can be of very different origin and quality, and there is usually no single model required to build the right digital twin. The challenge is then to build, combine and deploy all these models at scale into an appropriate hybrid Digital Twin.

The proposed process allows real-time interaction with a gas production unit. The aim of monitoring such a unit is to detect anomalies, optimise production, reduce energy consumption, and control maintenance.

The predictive model replaces the simulation model for rapid recommendations, typically for control optimisation. It speeds up the generation of results when latency is critical, while maintaining sufficient accuracy.

We will show how the hybrid digital twin is assembled and how it interacts with the physical asset, from data collection and streaming with the IoT, to the feedback loop and operator support with the dashboard.

This project illustrates different scenarios ranging from simple asset monitoring to more complex asset tuning and optimisation under changing operating conditions.

Presenter Name: Pierre Baqué

Presenter Company: Neural Concept

Presentation Title: Deep Learning for Manufacturing: an application to the rheology process

Abstract: To tackle new challenges, engineers need radically new capabilities, including more effective ways to harness our computational resources.

Because of their historical origin, simulation tools are not well adapted to design optimization in fast-paced production and design environments. It is extremely hard for design teams to leverage insights provided by advanced simulations and by the specialised teams who develop them. Deep Learning technologies can be used to integrate knowledge from simulation and design optimization tools in the workflow of the design engineers, instead of delegating this task to separate expert teams.

In this talk, we explain how recent algorithms based on Geometric Deep Learning, allow shortcutting any simulation chain through a predictive model that outputs post processed simulation results and optimization suggestions, right from the CAD design. These models are being used in engineering companies to simplify processes and to emulate the expertise of simulation engineers in the hands of product or design engineers early in the development process. Thus, the number of iterations between teams are reduced while accelerating the design activities.

In this presentation, we focus on a specific manufacturing application : the rheology process. We will show that the Deep Learning models are used to replace the phase of meshing and solving rheological equations. With inferences based on that model, a classical simulation loop of 4 to 6 days can be shortened to 1 day. In addition, these surrogate models can then be inserted in optimization process to either reduce development time and/or extend the number of optimization iterations to increase performance of the product. The gain in term productivity is up to 30% at iso-perimeter.

Automotive Application Case

An automotive external plastic body part production requires thousands of hours in design, engineering and validations. The mastery of the rheological behavior is a key point for industrial excellence. Calculations are widely used to simulate the material injection in the mold at high pressure and temperature: they determine the part's behavior in term of mechanical constraint and warpage. The results of simulations are used to set-up molds' parameters in production and ensure that all different parts can be assembled together.

For each vehicle's part developed by the company from years, many simulation loops have been performed. A large quantity of results, data, know-how have been produced. The presented innovation intends to implement a model estimator based on that knowledge. It is using deep learning methods through 3D geodesic convolutional neural networks (GCNN) to speed-up simulations loops by capitalization over large databases. Historical data and new simulations are gathered in a usable database: 3D geometries, solvers results, injection parameters. This database is used to train a 3D GCNN that can estimate any new geometry.

A classical loop of simulation is described as follow:

- The design leader produces a 3D shape with respect to a set of constraints and knowhow recommendations.
- The rheology engineer oversees meshing of the 3D surfaces, prepare the solver parameters with materials choice, injection sequences selection, temperatures, pressure, etc.…, and send it to the solver for computation,
- The solver runs the simulation on CPUs for few hours
- The rheology engineer post processes and takes a decision for an optimization action based on the performance targeted
- The design leader integrates the recommendations and produce a new 3D shape
- The loop continues until an acceptable optimal have been found, in a limited amount of hours allocated

Our 3D GCNN models are used to replace the phase of meshing and solving rheological equations. With inferences based on that model, a classical simulation loop of 4 to 6 days can be shortened to 1 day. In addition, these surrogate models can then be inserted in optimization process to either reduce development time and/or extend the number of optimization iterations to increase performance of the product. The gain in term productivity is up to 30% at iso-perimeter.

It is important to precise that under no circumstances this model would replace solvers used to calculate the outputs fields. On the contrary, solver will be valorized as their outcome will be encoded in model and used to capitalize any new simulation of a product.

The interface for the final user is composed by a simple web browser application: the user provides a new 3D geometry plus a preset of injection parameter, and in less than seconds, the estimated 3D field result is obtained.

The project has demonstrated that with only 50 samples, we were able to achieve 82% of accuracy in our results, which was far beyond the expectations. The final users, engineering and development teams are working to enlarge the database and adapt the post-processing steps to add any new simulation result to the database. Once the accuracy of the model will exceed 95% with about 200 simulations in the database, the tool will be ready for use on customers' projects applications.

This innovative method is a precursor. As it has shown good results, it is planned to be deployed and applied to other domains such as crash calculations, static calculations, modal calculations, or thermal simulations. We are also investigating hybrid methods, coupling 3D simulation results with production measurement results.

One can say, the era of 3D ANN based data science has begun!

Presenter Name: Marta D’Elia

Presenter Company: Pasteur Labs

Presentation Title: Scientific Machine Learning in Industrial and Manufacturing Pipelines

Abstract: Scientific machine learning (SciML) has shown great promise in the context of accelerating classical physics solvers and discovering new governing laws for complex physical systems. However, while the SciML activity in foundational research is growing exponentially, it lags in real-world utility, including the reliable and scalable integration into industrial and manufacturing pipelines. SciML algorithms need to advance in maturity and validation, which in the context of traditional and advanced manufacturing settings, requires operating in cyber-physical environments marked by large-scale, three-dimensional, streaming data that is confounded with noise, sparsity, irregularities and other complexities that are common with machines and sensors interacting with the real, physical world.

In this talk, I will highlight some of the current challenges in applying SciML in industrial contexts. By using a practical example, the heat exchanger simulation and design, I will discuss why these are necessary bottlenecks to break through and describe possible strategies.

Special attention will be on the generation of fast and flexible surrogates for heat exchange problems; I will present a comparison of current SciML methods and their improved variants with emphasis on the graph-based Neural Operators we have been building. The talk will conclude describing how to use these operators in the context of industrial design of a heat exchanger and, more in general, manufacturing pipelines, addressing the earlier bottlenecks and alluding to outsized opportunities for advancing manufacturing tools and processes.

Presenter Name: Sandeep Urankar

Presenter Company: Rescale

Presentation Title: Building Digital Twins at Scale

Abstract: Abstract Industry 4.0 is rapidly transforming manufacturing through a convergence of technologies like High-Performance Computing (HPC) and Artificial Intelligence/Machine Learning (AI/ML). These converging technologies unlock new use cases for Digital Twins in digital engineering and manufacturing. Digital twins unlock predictive analytics, allowing manufacturers to accelerate optimal designs, identify defects, improve process efficiency, and reduce capital and operating costs. Digital Twins can be used to generate insights into operational data or simply to speed up the design process. In either case, the foundational need is to develop a machine-learning model or surrogate model. This involves extensive design space exploration, where various parameters within physics-based models are systematically varied. Understanding a system's range of behaviors and limitations is critical for training robust and reliable AI/ML models. The process is computationally intensive and generates large amounts of data, necessitating effective management. In this presentation, we cover 1. How organizations flexibly combine best-in-class digital engineering tools in the cloud Digital Twins. 2. How organizations leverage the latest computational architectures to accelerate R&D breakthroughs. 3. How design exploration can be automated to build effective ML models that generate improved product designs faster

Presenter Name: Quinn Killough, Onder Anilturk

Presenter Company: Landing AI and NXP

Presentation Title: Automatic Defect Classification (ADC) solution using Data-Centric Artificial Intelligence (AI) for outgoing quality inspections in the semiconductor industry

Abstract: Machine vision significantly improves the efficiency, quality and reliability of defect detection & classification and has been applied successfully in many domains. In the semiconductor industry, one way to assure the quality of the processed wafers is to inspect the wafers via inline inspections, and then determine if the defectivity observed is abnormal or accepted via non-yield or quality impacting defects. Reliable classification of the defects when human operators are involved, requires excessive time, expertise and training of the individuals; which increases the cost and time to detect abnormalities on the wafers; along with large variation of correct classification. In this study, we present an automatic defect classification (ADC) application for outgoing quality inspections. In outgoing inspections, all of the defects were manually classified to reject or accept the inspected die with the defect classification. Earlier adoption of ADC systems usually emphasizes both accuracy (recall) and purity (precision) as output metric to deploy the system to classify the defects. In our implementation, purity is targeted as the main output metric for classification of clearly defined defects in the training set. This allowed us to deploy automatic defect classification of defects with high purity and benefit from its automatic classification earlier in the adoption process with immediate impact on workload reduction, while working on less pure defect classes.

Presenter Name: Hannes Waclawek

Presenter Company: Salzburg University with Kempten University

Presentation Title: Enabling IT/OT Integration using Digital Twins of Business Processes

Abstract: The Salzburg University of Applied Sciences together with the Kempten University of Applied Sciences runs a geographically distributed testbed for use in agent-based AI research and education. It consists of a range of components of different manufacturers and platforms constituting a game-based industrial production setting centered around the pick-and-place use case of playing the game of Nine Men's Morris. Humans or AI agents can place production orders in the form of game moves which are then turned into game board states at two geographically distributed robot cells: One located in Salzburg and one located in Kempten. The use of different kinds of robots, PLCs, HMIs along with modern AI methods and communication between geographically distributed facilities brings along with it the need for an approach to seamlessly integrate IT and OT equipment. In this talk, we identify core principles that are suitable for solving this problem and argue how these principles can be used to develop the concept of Industrial Business Process Twins (IBPT). We then evaluate the result with respect to the different views of the RAMI 4.0 model and take a look at possible future additions.