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SIMULATION OF INDUSTRIAL SYSTEMS FOR NEXT-GENERATION AIRCRAFT MANUFACTURING

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ABSTRACT

Co-design is an important prerequisite for finding the best design solution for both future aircraft and the corresponding industrial systems. This paper discusses the use of simulation in the process of co-defining the optimal industrial system configuration for a future aircraft with a case study determining the logistic system for the aircraft fuselage manufacturing. The scope of the paper includes the industrial performance, the logistics costs and the environmental footprint of the logistic system. To study the large design space, the generation and the execution of the simulation has to be automated in a scalable cloud infrastructure. The simulation is embedded into a complex modeling and analysis environment for defining the system parameters and constraints, the automated (logistics system) scenario generation, the simulation based key performance indicator calculation and the results visualization and comparison.

1 MOTIVATION AND PROBLEM DESCRIPTION

In the development of next-generation aircraft, the co-design (concurrent engineering) of the product and the corresponding industrial system plays an important role in achieving the required aircraft performance and production targets. Airbus' industrial systems are challenged by disruptive aircraft designs, but must also incorporate new available production technologies and materials, as well as the globalization of production away from Europe towards America and Asia. For the Airbus industrial architects, planning the future industrial system including the optimal logistics is a complex decision problem with multiple constraints and conflicting objectives regarding performance, costs, resilience and sustainability.

Modeling and simulation are needed for generating promising design alternatives for the industrial system in reasonable detail and calculating the performance indicators for down-selection of the best solution. Simulation models have to handle uncertainties in industrial system parameters like processing time but also variability in the industrial system topology like production locations or sourcing strategies. The creation of simulation models covering those types of design alternatives is normally time-consuming, costly and application-specific. This limits the number of design alternatives that can be analyzed using simulation. A systems engineering-like approach of separating the definition of scenario configurations, the simulation model creation from those definitions and the model application by industrial architects is needed. The following problems have to be solved: automated generation of promising scenario configurations, the automated generation of simulation models from those scenario configuration data and the deployment in a scalable IT infrastructure to run huge numbers of simulations for analysis of alternative industrial system scenarios. This study investigates the potential of those data-driven simulation models embedded into a scalable, cloud based modeling and analysis environment for the design of industrial systems.

2 CASE STUDY OF THE LOGISTICS SYSTEM FOR THE FUSELAGE MANUFACTURING

The focus of this study is to determine the optimal logistics system configuration for the manufacturing of a future aircraft fuselage. The fuselage is built from multiple large assemblies and components produced by different suppliers in a supply chain distributed across Europe with additional final assembly lines in America and Asia. The aircraft specific large assembly structures require special jigs and transport means to handle the logistics. The distance between potential supplier locations impacts the transport time and may require multimodal transport solutions, e.g., land, air and sea combinations. The defined configurations also include parameters for the target production rates, minimum workshares across the suppliers, multiple final assembly locations, transport means and dual sourcing strategies for selected components. The scope of the analysis of the logistics system includes the costs, the lead time, the achieved production rate and the CO2 emission. The case study used the Anylogic cloud solution for assessing a large number of promising logistics system configurations using data-driven, automatically generated and executed simulation models.

3 SIMULATION APPROACH

The analysis of the industrial system and in particular of the logistics system uses a mixed approach of agent-based and discrete event simulation, implemented in Anylogic. System elements like production nodes, warehouses, logistics links and means and the product are represented by agents while their behavior partially follows the discrete event paradigm. The simulation model supports the parameter uncertainty (e.g. process duration, transport speed) but also topology variability (the structure of the logistics network) defined in input configuration data. It uses dynamic instantiation of a specific simulation model based on input configuration data at startup. It is built from templates for the product (components and assemblies) and processes (production and transportation recipes). In addition, resources (production nodes, transport means, warehouses) create the physical material flow. The system is controlled by messages (product and transport orders) representing the information flow and strategies used.

The simulations run in the Anylogic cloud infrastructure which is embedded in a larger modeling and analysis environment. This environment includes tools for the definition of the logistics system parameters and constraints, the generation of valid logistics system configurations, the simulation of a large number of interesting logistics system configurations and finally the result visualization and comparison. The challenge of the combinatorial explosion of possible scenarios, e.g., for the presented case study ~1E64 valid scenarios exist, is addressed by solver-based approaches and evolutionary algorithms. While the solvers use simplified configurations and constraints for down-selecting promising scenarios (down to <100.000 scenarios), the simulation helps to calculate more realistic scenarios. Those scenarios include ramp-up production output and logistics behavior or disturbances for resilience assessment as requested by the industrial architects.

4 RESULTS AND CONCLUSIONS

The result of the study is an optimal logistics system configuration for the new aircraft fuselage and, more generally speaking, a proof of the benefit of separating discipline modeling and executing the trade studies. The discipline models are pre-developed, parametric models like the presented Anylogic simulation model and can be used in multiple trade studies along the co-design process.

In this study the industrial architect defined the product and production system parameters and constraints. A large set of scenarios were generated and analyzed with the help of the data-driven simulation model running on Anylogic's cloud infrastructure. Compared to manually defined and modeled scenarios (with a small number of parameter variations and a very small number of topology variants) the automated, data driven and cloud based approach supports the detailed analysis of a large number of scenarios by simulation while at the same time reducing the costs for manual modeling.