A simulation selection tool to improve efficient decision-making in data-driven design.

Bachelor thesis
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Main research question: What types of simulations are most beneficial at different stages of a data-driven design process, and how do their applications support decision-making?

As industries strive to address complex challenges with greater efficiency, precision and sustainability, simulations have become indispensable tools in the design process[1]. In the evolving landscape of design engineering, the role of simulations and data-driven decision-making has become increasingly significant[2]. The chair IDPDE is part of the Department of Design, Production & Management in the Faculty of Engineering Technologies. This chair has a working group that is working on the new curriculum for the newly developed study programme for Industrial Design Engineering, particularly the newly developed module 5 on data-driven design. This research is about simulations and how these can be linked to data-driven design. The main research question was derived from the needs of the stakeholders. The following topics were researched: simulations, data-driven design and design processes.

Data-driven design

Data-driven design is a method of making design decisions based on data collected by designers, leading to more effective and user-centred solutions. This helps to minimise assumptions, guesswork and reliance on opinion, resulting in highly relevant and accurate product design decisions. By using data as a tool, designers can better understand end-user needs and improve end-user satisfaction[3].

Design Processes

Industrial Design Engineering can be defined as a systematic series of steps of decision-making aimed at finding an effective solution to the given problem. It consists of activities required to define, conceptualise and finalise the form and function of a product, system or production process that aligns with the customers' desires[4]. The design process is intended to serve as a bridge between the problem statement and the solution.

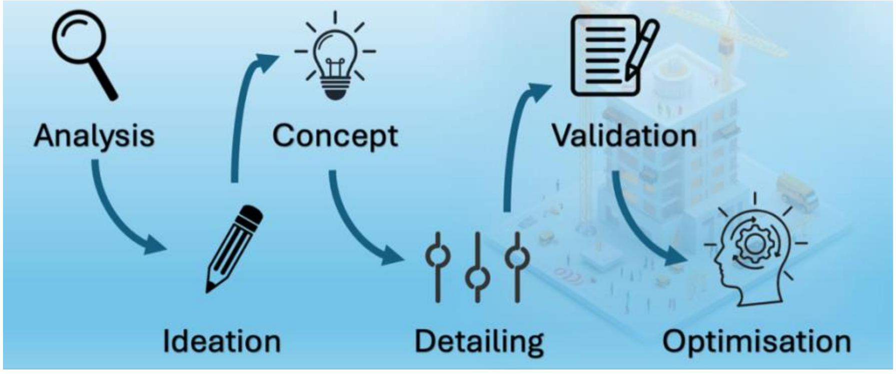

Figure 1: The standardised design process in Industrial Design Engineering.

Simulations

A simulation can be described as the creation of a virtual model of a system or product to study its behaviour and specify certain characteristics under various conditions. This approach helps reduce the time and cost associated with physical prototyping [5, 6]. Simulations can vary in their level of detail and accuracy. Low fidelity simulations provide a basic representation, requiring minimal resources and time. High fidelity simulations are detailed representations, including accurate measurements and material properties, requiring more time and resources [7]. Simulations can be categorised according to their focus. This research includes four main types of simulations that are commonly used across various industries, these also contain subcategories to an extensive amount [8]. Physics-based simulations are used to understand and predict how real-world phenomena affect a design [9]. Manufacturing and process simulation replicate production processes[10, 11, 12]. System-level simulations focus on how subsystems interact within a larger system to provide insight into its performance [13, 14]. Experimental simulations are used to explore and improve designs by testing different configurations and parameters [15, 16, 17].

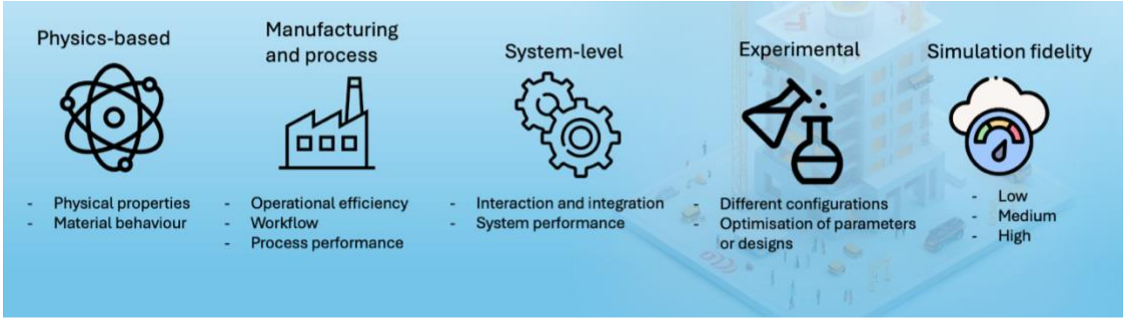

Figure 2: The four main simulation types used in this research.

Problem analysis

There is no clear way to describe which simulations are most useful in which situation or stage of the design process. There is an overabundance of different simulations that can be performed, making an internet search very difficult and inefficient. A solution to this, could be a method to help designers determine when to use which simulation. This could allow designers to learn more about the differences between certain types of simulations more quickly and easily, whilst providing a clear overview to determine different options for simulations in a design process.

Concept development

A list of requirements was stated, followed by a brainstorm of ideas. The most promising ideas were evaluated against each other. The best option was an interactive tool that helps students to select a suitable simulation for their design process by filtering on characteristics.
For the method to be developed a database was established, which was achieved by the collection of as many simulations as is feasible. A comprehensive list of simulations was compiled through extensive research on the internet, yielding 168 simulations that can be executed on various design aspects. Each simulation was reviewed to understand its purpose and functionality, afterwards they were systematically categorised to ensure consistency within the database.

Simulation type	Simulation subtype	Fidelity	Ideal design phase
Physics-based simulations	1. Structural analysis	Low (L)	Analysis phase (A)
	2. Thermal analysis	Medium (M)	Ideation phase (I)
	3. Fluid dynamics	High (H)	Concept phase (C)
	4. Electromagnetic simulations		Detailing phase (D)
	5. Kinematic and dynamic simulations		Validation phase (V)
	6. Biological and medical simulations		Optimization phase (O)
	7. Chemical reaction simulations		
	8. Optical simulations		
	9. Acoustic simulations		
Manufacturing and process simulations	10. Factory layout and logistics simulations		
	11. Robotic path optimization		
	12. Supply chain simulations		
	13. Discrete event simulations		
System-level simulations	14. Agent-based simulations		
	15. System dynamics simulations		
	16. Virtual and Augmented reality simulations		
	17. Digital twin		
	18. Economic and lifecycle simulations		
Experimental simulations	19. Design of Experiment simulations		
	20. Monte Carlo simulations		
	21. Topology simulations		

Figure 3: The categorisation of the 168 simulation was done in this format.

An interactive tool has been developed to help students to make quick decisions about which simulation is appropriate for their design process. The tool's interface has filters for simulation type, subtype, fidelity, ideal design phase, keywords and simulation name. The tool helps the student to quickly find information about the different types of simulations available and when they are ideally used. To ensure that the tool is used correctly, and all the necessary information is available, a guide was developed, which includes user instructions and more elaborate information on each simulation. A user test was carried out which proved that the tool, addition to the guide, is more efficient than an internet search.

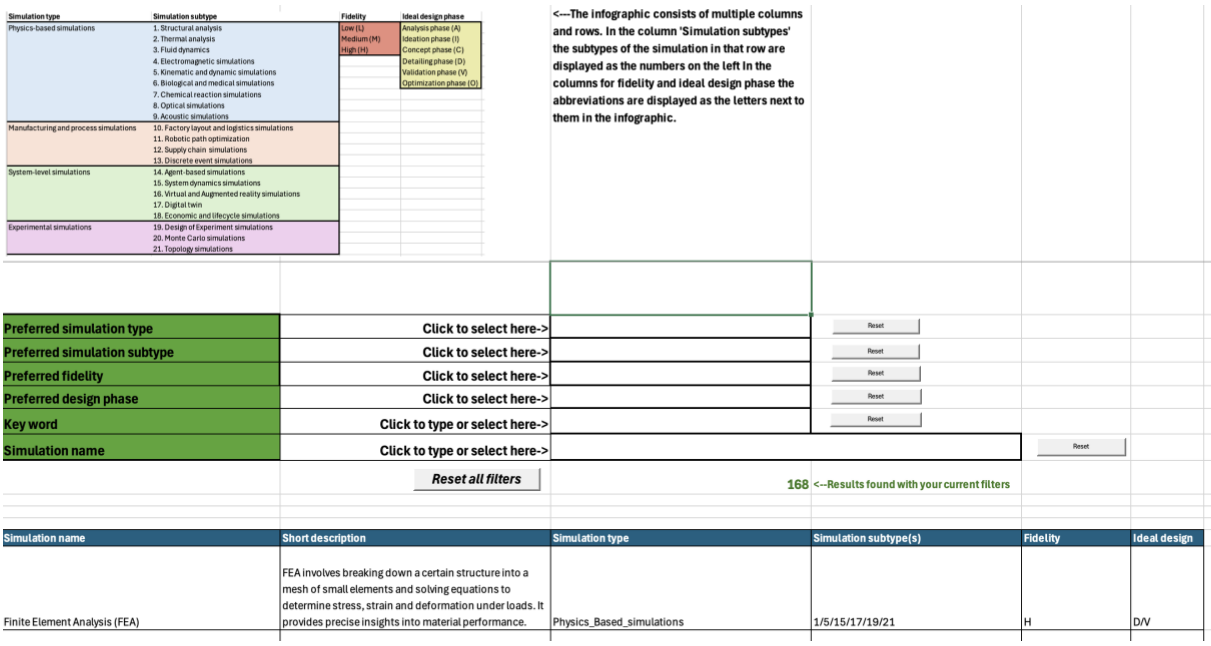

Figure 4: The final interface of the simulation selection tool.

Conclusion

The variety of simulations, each serving a specific purpose within a design process, makes it difficult to determine which type is most beneficial at a particular design stage, as each simulation evaluates different characteristics. Therefore, each simulation can contribute to decision making in a unique way, depending on the objectives of that stage.

The number of simulations available can be considered overwhelming. A tool has been developed to help students to make quick decisions about which simulation is appropriate for their design process. This would streamline the decision-making process by matching simulation choices to the specific needs of each design phase.

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