The importance of structural or physical design to meet the compliance of artificial intelligence

Muslim Aleroev[1*], *Maryana* Georgieva[2], and *Vladislav* Sokolov[3]

[1]Kadyrov Chechen State University, Grozny, Russia
[2] Kabardino-Balkarian State University, Nalchik, Russia
[3]Siberian Federal University, 79, Svobodny Prospect, Krasnoyarsk, 660049, Russian Federation

Abstract. Artificial intelligence (AI) has become a transformative force across various industries, but its effectiveness heavily relies on its integration with other technologies. This paper explores the critical role of structural and physical design in maximizing the potential of AI, with a particular focus on mechanical engineering applications. The study examines how the design of components and systems must be carefully considered to ensure optimal AI functionality and data collection. By investigating the synergy between AI and mechanical engineering, the research highlights the importance of compliance between design elements and AI capabilities. The paper discusses various applications of AI in mechanical engineering, including automation, design optimization, and manufacturing processes. Ultimately, this work emphasizes the necessity of a holistic approach to design that considers AI integration from the outset, enabling more efficient and effective technological solutions.

1 Introduction

The late development of artificial intelligence changed the world we know to a state where its transformation is defined by its improvement. Its leaps are greater at each stage, and its influence and application are numerous. One of the main advantages this technology provides is the automation and autonomy of different processes. Its influence on various fields is vast, and its integration and embedment are irreversible. Most industries are heavily dependent on artificial intelligence and related technologies. It is important to note that this technology by itself is only a combination of complex algorithms that work only with other technologies depending on the application.

An algorithm is a great representation of neurons in our brain, and they function as data analysis and data output. Therefore, this technology needs a structure and other combinations of technologies to function as intended. For instance, a robotic arm is built with certain degrees of freedom, which will be controlled and navigated by artificial intelligence. For artificial intelligence to function, it must accumulate data from the environment using different sensors. Hence, the placement of sensors and the design of the structure must be built in a way that maximizes possible data collection [1, 2, 3].

* Corresponding author: muslim-1892@mail.ru

Therefore, the following work will look into the necessity of design compliance for sensor placement to maximize data accumulation. The importance of other technologies when using artificial intelligence will also be covered in this work, with an emphasis on mechanical engineering.

2 Materials and methods

Mechanical engineering is greatly utilizing artificial intelligence in various areas to automate some of the possible processes. The first advantage this technology provides to mechanical engineering is the ability to analyze complex tasks. It offers new methods for engineering tools such as SolidWorks, Abaqus, ANSYS, and other similar tools for complex simulations. It eases the usability of tools, making them personalized to the user's experience. These tools are more intuitive and user-friendly. The technology is capable of automating most of the functions in these engineering tools. For instance, before the occurrence of advanced algorithms, some tasks were manual to a degree that it would take days and weeks for results to be received. Sensitivity analysis for a structure would take many iterative steps before completion. With artificial intelligence, this step can be automated, and the technology, depending on given boundary conditions, performs the iterations by itself and provides results at the end of the process. Other comparable tasks can be similarly completed [4, 5].

The other revolutionary approach this technology provides is generative design. For instance, there is a solid structure of a handle made out of heavy metal that needs to be installed on a door. However, this structure is too heavy for a handle and too strong for such a task. In addition, its design is not ergonomic or conventional. Generative design will look through the given boundary conditions and analyze the structure to provide a new, unconventional design that includes many advantages compared to the initial structure. It will, first of all, select an appropriate material if given such a task. Then the structure will be optimized by cutting out unnecessary material use, while still performing its best within the given boundary conditions. This approach allows users or scientists to shorten the time required to create a new design and analyze it. It provides unconventional and strong constructions with less material use [6].

Modeling by prompts is a new reality in the present. A common or traditional method of building a structure in virtual reality involves manually performing almost every step necessary to complete a model. However, new engineering tools have built-ins that are capable of translating words into geometry. Of course, this method is yet to be improved, but solid results can be achieved with the right input of prompts [7].

Due to its precision, the technology can increase the quality of the end product, making engineering tools more precise. In manufacturing, engineering tools can be navigated precisely to avoid defects and errors in processes. Of course, there are many other applications of this technology in the field of engineering, but the presented applications provide a necessary image to understand its usefulness.

3 Results and discussion

The importance of compliance of the design to a certain aspect can provide the maximization of important sides of the structure. Thus, the design must be created with the other aspects in mind. Three ways of modeling any structure will be described further. The first way is ignoring everything except design. In this case, the structure design will be done without complying with anything. Design for the sake of design. The second way that will be described in this work is a narrow focus on a certain aspect. For example, the structure must be built taking into consideration certain elements such as sensors for navigation or temperature. The last one that will be covered is the way where all aspects are considered when modeling the structure.

3.1 First way - design for the sake of design

Design for the sake of design can also be in demand. If the structure is needed to be promoted through expeditions and advertisements, there is no need for it to fully function. In this case, the design can do all the job without extra parameters that work as intended. The second one can be related to a focus on the design ignoring all the parameters. This is similar to the first example, but the design must work in an intended way. In this case, the design will lack functionality. This is perfect for presentations and business meetings. In other words, this can be named a prototype. It functions to a level that shows the promises for future use but can't be applied in real life.

3.2 Second way - focused design

The second one is more focused on a specific parameter or aspect that most of the time ignores the rest. In this case, for instance, the capability to move in the dynamic environment is considered to be the priority. Then the overall focus is shined onto the motion and the structure's overall flexibility. Other parameters like capabilities to grasp, lift, and speed can be ignored. However, other parameters can be included even if they are not necessary. One of the differences from the first and the third way is that this one can be similar to both of them. For instance, when designing, the main aspect might be chosen for the overall design, which easily can be related to the first way. And when designing with the specific parameter in mind, the end result might include more than one parameter, and hence, this can be related to the third way. Also, this type of structure can be used to add more parameters as one is already perfectly working. Therefore, this structure is a great base for moving to the third stage.

3.3 Third way - full compliance

This path is the hardest one compared to the aforementioned two. In this case, all parameters and aspects must be carefully looked into to not miss any detail. When designing the structure with compliance with other components, it becomes complex and sometimes unreachable, as some of the components do not go with each other. Like when pressing one part of hydraulic pressure and the other side moves out. It is impossible to push both inward, and similarly, some components are not compatible. However, throughout different variations, some results can be reached. As a solution, generative design can be used to combine various variables in one structure. It can distribute the given input to a level where all given variables can be at their most possible stage. For example, different variations of sensors must be included in the final structure, and hence, to position them correctly, a few changes need to be done to the structure. However, adding these sensors means making cuts in the structure that result in a loss of structural integrity. Meaning that a novel approach is needed. For the solution, generative design can be applicable here. It can match complex parameters with the use of iterative steps. The proposed solution can provide not one outcome but many, depending again on the input. The results might be all useful and as well a mess. New technologies can tackle this issue, but in reality, the outcomes are always unconventional. They are good as results but not for the appearance. Therefore, hard steps must be taken. In this case, designing with circles of improvement. It is similar to an iterative approach in engineering tools, but in reality. With this approach, the designer is in control of the overall process and the appearance. However, in this process, generative design also can be used to see tendencies and a novel view on the tackling issue.

The importance of having all the necessary parameters in one structure depends on the specifications of the use. Most of the time, there is more than one parameter that needs to be considered. Hence, while designing, all these parameters must be included. The first advantage is that the structure will be multifunctional. It could be used in various applications and easily adopted. It increases precision and end results. It is more robust to unpredictable challenges. There are many advantages to a design that follows given parameters. Nonetheless, there are downsides to it too. The detailed design approaches in structural engineering are given in Figure 1.

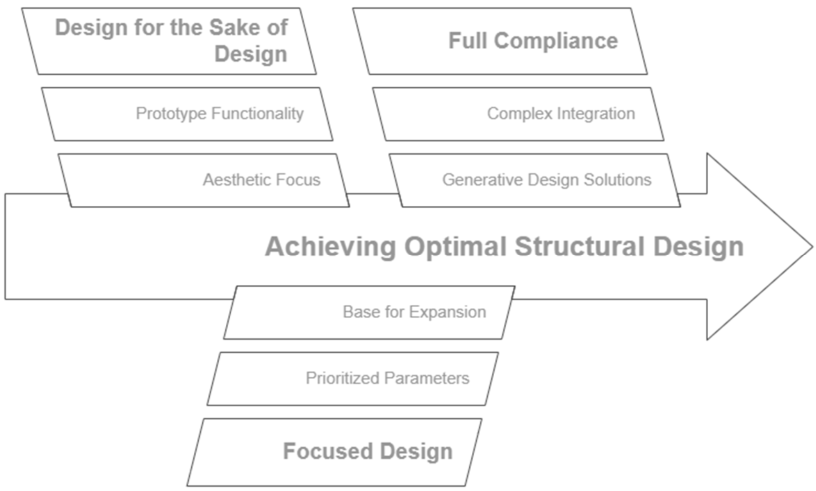

Fig. 1. Design Approaches in Structural Engineering.

Of course, there could be other ways as well for the design of the structure. The work focused on illustrating the importance of including all parameters and aspects for achieving the best possible outcomes from a structure.

4 Conclusion

AI has emerged as a transformative technology with far-reaching implications across various fields, particularly in mechanical engineering. This study has highlighted the critical importance of structural and physical design in maximizing the potential of AI applications. Our analysis reveals that the effectiveness of AI is intrinsically linked to its integration with other technologies and the design of the systems it operates within.

We have explored three distinct approaches to design when incorporating AI:

- Design for aesthetics, which prioritizes form over function;
- Focused design, which emphasizes a specific parameter or aspect;
- Full compliance design, which aims to integrate all relevant parameters and aspects.

It can be concluded that the full compliance approach, while the most challenging, offers the greatest potential for leveraging AI capabilities. This method ensures that structures are multifunctional, adaptable, and robust in the face of unpredictable challenges.

Key applications of AI in mechanical engineering, such as automated sensitivity analysis and generative design, demonstrate the technology's capacity to revolutionize traditional processes. These advancements not only enhance efficiency but also open new avenues for innovation in structural optimization and material usage.

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