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THE MAIN PROBLEMS IN THE DESIGN OF AUTOMATIC SYSTEMS AND THEIR SOLUTIONS

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Annotation
Computer-aided design (CAD) is the use of computer-based software to aid in design modeling, design analysis, design review, and design documentation. Nevertheless, the benefits of CAD can be elevated in combination with artificial intelligence (AI), extended reality, and manufacturing. AI can create an intelligent graphics interface and change tedious design processes into sophisticated ones. The primary aim of this review is to present an overview of current state-of-the-art CAD and its applications, as well as to forecast its future prospects. The article is written using a systematic review of journal papers with a focus on a wide spectrum of potentially relevant researches on CAD. The benefits of incorporating AI into the CAD systems, the use of CAD in extended reality and 3D printing, and finally a brief discussion of issues that are pushing CAD to new levels are all discussed.

Keywords: CAM, CAD, Artificial intelligence (AI), Extended reality, Virtual reality, 3D printing

ОСНОВНЫЕ ПРОБЛЕМЫ ПРОЕКТИРОВАНИЯ АВТОМАТИЧЕСКИХ СИСТЕМ И ПУТИ ИХ РЕШЕНИЯ

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Аннотация
Компьютерное проектирование (САПР) — это использование компьютерного программного обеспечения для помощи в моделировании конструкции, анализе конструкции, обзоре конструкции и проектной документации. Тем не менее преимущества САПР можно увеличить в сочетании с искусственным интеллектом (ИИ), расширенной реальностью и производством. ИИ может

создать интеллектуальный графический интерфейс и превратить утомительные процессы проектирования в сложные. Основная цель этого обзора — представить обзор современного состояния САПР и его приложений, а также спрогнозировать его будущие перспективы. Статья написана с использованием систематического обзора журнальных статей с акцентом на широкий спектр потенциально актуальных исследований в области САПР. Обсуждаются преимущества включения ИИ в системы САПР, использование САПР в расширенной реальности и 3D-печати и, наконец, краткое обсуждение проблем, которые выводят САПР на новый уровень.

Ключевые слова: CAM, CAD, искусственный интеллект (ИИ), расширенная реальность, виртуальная реальность, 3D-печать.

AVTOMATIK SISTEMALARNI LOYIHALASHDAGI ASOSIY MUAMMOLAR VA ULARNING YECHIMLARI

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Anotatsiya
Kompyuter yordamida loyihalash (CAD) - bu dizaynni modellashtirish, dizayn tahlili, dizaynni ko'rib chiqish va dizayn hujjatlarida yordam berish uchun kompyuter dasturidan foydalanish. Biroq, SAPRning afzalliklarini sun'iy intellekt (SI), kengaytirilgan haqiqat va ishlab chiqarish bilan birlashganda oshirish mumkin. SI aqlli grafik interfeyslarni yaratishi va zerikarli dizayn jarayonlarini murakkab jarayonlarga aylantirishi mumkin. Ushbu sharhning asosiy maqsadi SAPRning hozirgi holati va uning ilovalari haqida umumiy ma'lumot berish, shuningdek, uning kelajakdagi istiqbollarini bashorat qilishdir. Maqola CAD sohasidagi potentsial tegishli tadqiqotlarning keng doirasiga e'tibor qaratgan holda jurnal maqolalarini tizimli ko'rib chiqishdan foydalangan holda yozilgan. SAPR tizimlariga sun'iy intellektni qo'shishning afzalliklari, to'ldirilgan reallik va 3D nashr qilishda CADdan foydalanish va nihoyat, CADni keyingi bosqichga olib chiqadigan muammolar haqida qisqacha muhokama qilinadi.

Kalit so'zlar: CAM, CAD, sun'iy intellekt (SI), kengaytirilgan reallik, virtual reallik, 3D nashr qilish.

Introduction

Modern mechanical engineering should develop in the direction of production automation with the widespread use of computers and robots, the introduction of flexible technologies that make it possible to quickly and efficiently rebuild technological processes for the manufacture of new products. Automation of technology design and production process control is one of the main ways to intensify production, increase its efficiency and product quality.

An important place is occupied by complex computerized systems for the design and manufacture of products. The use of electronic computer networks provides distance learning in the preparation of mechanical engineers.

Thus, this topic is of interest due to the fact that the trend of the modern stage of design automation is the creation of complex systems, including design, process design and manufacture of products. The designed technological process must promptly respond to changes in the production situations of the product manufacturing process.

With the help of digital technology, technological advancement is bringing the world to a new level. Numerous technological advancements, software and hardware capabilities, and workflows are all happening at rapid pace. Platform evolutions such as cloud technology and the effect of the Internet of Things (IoT) are presently driving the adoption of a universal access system to provide fast and effective innovation, flexible resource, advanced online security and scalability. According to author's, computer-aided design (CAD) technology is continuously evolving to keep up with the changing environment. AI based simulations offer a better solution with less effort in spite of the internal parameters of the system under work. For example, in a simulation, meshing is the most time-consuming and error-prone task. Most meshing tools disregard the parametric information and merely mesh the model's border representation. As a result, each time a parametric modification is implemented, the model is essentially re-meshed from the initial concept, which occurs several times during the design process. Moreover, the size of mesh is also another factor while meshing. Abbasi et al. Discovered the impact of mesh size in conventional friction stir welding (CFSW) and underwater friction stir welding (UWFSW) in their examination of thermal and mechanical characteristics of Al6061-T6 utilizing a three-dimensional computational finite element technique. Deform-3D software was used to simplify a high amount of mesh distortion during friction stir welding due to strong plastic deformation processes. In general, getting the perfect meshing takes a long time. However, with the latest developments like SimSolid, it is now possible to get simulations right away. SimSolid enables quick design iterations since it generates

simulations without meshing. This reduces the time required to perform simulations by eliminating the requirement to employ local mesh control in more strained places. It is capable of doing same analyses as other commonly used finite element analysis (FEA) tools. ANSYS Discovery live tool can produce simulation results in real-time. As fast as you can rotate the model, one can edit the geometries and see stress results. Instant CAD tool can perform simulations on the part being analyzed, and can give simulation results instantaneously. This can increase productivity through waste reductions. According to studies, CAD can be used to its full potential to increase productivity and work quality by integrating with emerging modern technologies.

In general, creating an intelligent design environment necessitates the development of numerous software with computational and analysis features. In this paper, the future of CAD with AI, extended reality, and 3D printing is reviewed. The main objective of this review is to evaluate the importance of integrating AI into CAD systems and investigating the application of CAD in extended reality and 3D printing technology, and its future prospects.

Tasks of this article:

1. Disclose basic information about CAD / CAM systems
2. Consider examples of CAD / CAM systems
3. Identify the prospects for the development of CAD / CAM systems

Basic information about CAD / CAM systems

CAD systems (Computer Aided Design) - computer-assisted design; CAM systems (Computer Aided Manufacturing) - production with centralized control from a computer; CAD / CAM systems - computer-aided design and manufacture of parts using a computer; CAE systems (Computer Aided Engineering) - complex design (including drawing of parts and assemblies), technological preparation of production and manufacture of parts using a computer. At the same time, CAE systems include high-quality provision of the designer with the necessary information technology tools and are assumed as components of the CAD and CAM subsystems.

Thus, computer-aided design is design under the control of a computer-aided design system - CAD. But what is CAD?

According to the ideas adopted in our country, CAD is an organizational and technical system that performs computer-aided design, a set of design automation tools interconnected with departments of the design organization. The necessary

components of CAD are methodological, linguistic, mathematical, graphic, informational, technical, organizational support.

Methodological support provides documentation on the composition and rules for the operation of CAD. Linguistic support reflects the level of those linguistic means with the help of which information is transformed in the system. Mathematical software determines those design methods and algorithms, on which, in fact, the entire CAD superstructure is built. Computer graphics in CAD performs the functions of formalizing images of designed structures, interpreting design results, obtaining hard copies of drawings and layouts. Information support is used to timely transfer the attributes of information about a given design process using flexible manipulation of information on magnetic media. Hardware is a set of CAD hardware, the layout of which determines its purpose. Organizational support regulates the relationship between designers and a set of design automation tools.

All of these components interact in CAD according to certain principles and are the basis on which computer-aided design is based.

CAD/CAM systems in the CCI

So, in literal translation, the term CAD / CAM means computer-aided design and manufacturing. Computer-aided design generally refers to the development of a product design project based on three-dimensional geometric modeling of parts and assembly units, followed by automated generation of a set of drawing and design documentation. A system that performs computer-aided design is called a CAD system.

If a CAD system during design solves only the task of automating the receipt of a set of drawing and design documentation, then it is classified as a 2D system. A CAD system in which design is performed on the basis of three-dimensional models belongs to the class of 3D systems. Next, we will talk about 3D systems.

Computerized manufacturing is understood as the automated formation, based on the existing geometric model of the product, of control programs for the manufacture of product parts on CNC equipment. A system that solves this problem is called a CAM system. Some CAM systems have limited modeling capabilities, but typically the part models on which the machining process is based are "received" from the CAD system through consistent interfaces.

The construction of a spatial geometric model of the designed product is the central task of computer design. It is this model that is used in the CAD / CAM system for further solving the problems of generating drawing and design documentation, designing technological equipment, developing control programs for CNC machines

(Fig. 1). In addition, this model is transferred to CAE systems and used there for engineering studies. According to a computer model, with the help of methods and means of rapid prototyping, a physical sample of the product can be obtained.

Future Prospects of CAD

Artificial intelligence (AI) application in CAD

Previously, the term 'artificial intelligence' is used to describe machine's ability to mimic human intelligence through learning and reasoning during complex problem solving. Many AI researchers have recently challenged this approach, characterizing AI in terms of rationality, which does not limit how intelligence may be characterized. Intelligent machines reason and make decisions independently and without error in accordance with their design or pre-set program. In recent years, companies have been able to establish an efficient and effective intelligent CAD environment by incorporating AI into their systems. Incorporating AI into the CAD system will reduce the lead time dramatically and creates knowledge-based design environment. In hospitals, AI-based CAD is being utilized in a clinical practice alongside a picture archiving and communication system (PACS) to improve workflow. For green manufacturing and sustainable development, the integration of AI with a variety of technologies is currently in great demand.

The necessity for integrating AI into design was recognized early in the CAD development process. According to their report, intelligent design system research fields include small scale intelligent design systems, wide areas intelligent design systems (through coupling), intelligent computation and analysis, and intelligent graphics interface. An intelligent graphics interface equips existing CAD systems with many tools that can improve the accuracy and precision of designs, hence increasing productivity and work quality. However, building an intelligent design system has remained a hot research study until now.

Fig. 1 indicates how conventional CAD can be converted into intelligent CAD systems. The process of merging CAD with AI is called model-based reasoning (MBR). By using the quantitative and qualitative analysis, it predicts the interaction that could exist between different parts of the design.

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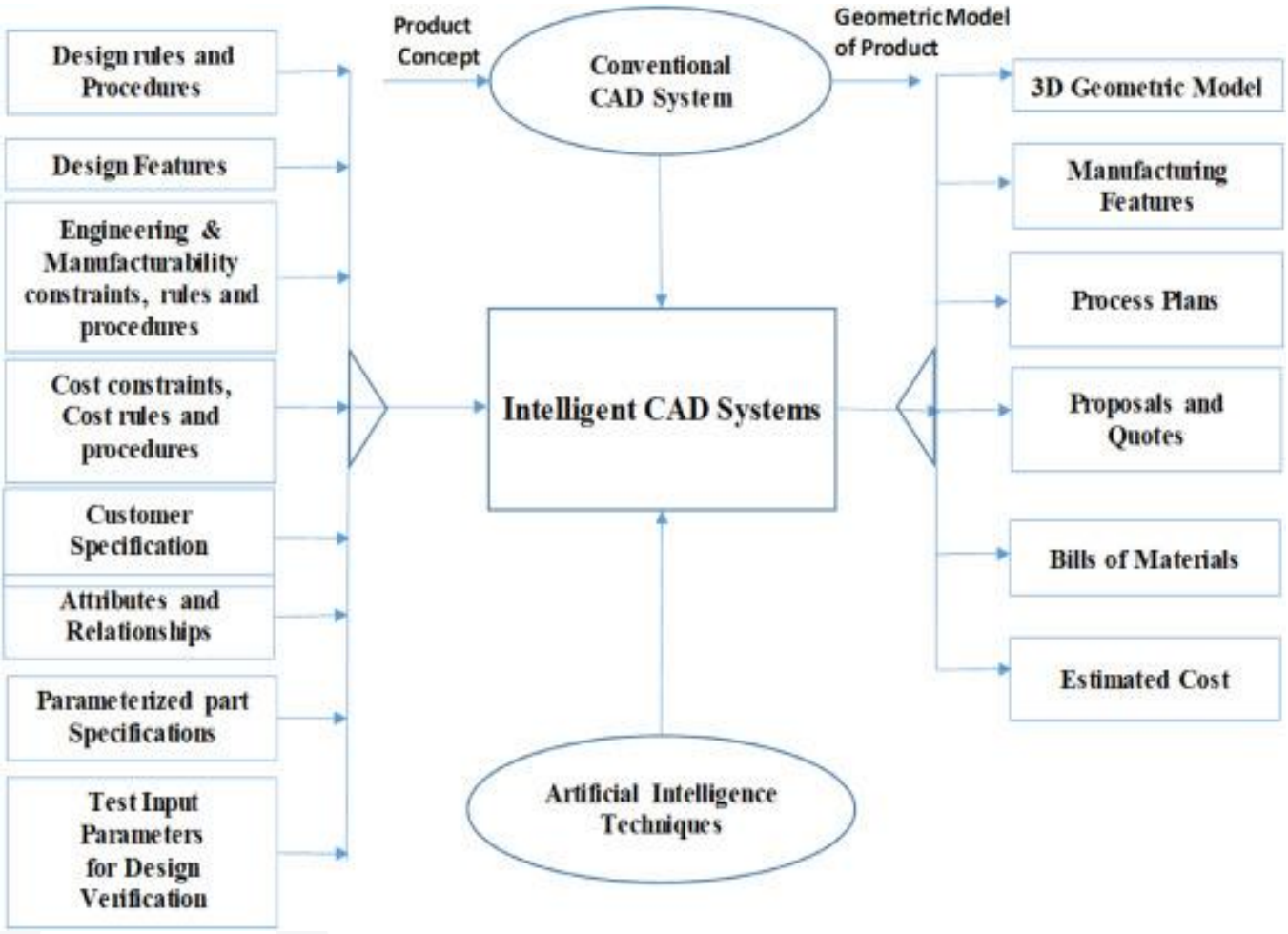

Fig. 1. CAD into intelligent CAD.

Features of MBR:

–The product parts should be stored in a hierarchical manner in order to know their relationship

–It is the designing experts who provide the knowledge-based reasoning and decision-making procedure

–The reasoning and the methodology define the rules for links of product parts

–The cumulative analysis of the qualitative and quantitative simulation defines the efficiency of the product analyzed

–Easy installation procedure in the database

SOLIDWORKS xDesign

Dassault Systemes Company, owner of SOLIDWORKS software, is one of the leading companies that have integrated AI into its design product. The company introduced xDesign that use AI as a tool to draw and extrude in engineering design works. In SOLIWORKS xDesign, operators can deploy different solutions to their design challenges instantaneously through cloud collaboration that are generated by AI tool.

First, the operator creates the model and defines the constraints. Then after, SOLIDWORKS xDesign will generate the part instantaneously through AI integrated to its system based on the constraints defined by the user.

NETVIBES One Part is another AI driven design software introduced by Dassault Systemes Company. The tool provides an intuitive application to reuse already existing parts to safe time. In NETVIBES One Part, operators can get 2D/3D related parts by just a few clicks.

Artificial intelligence (AI) denoiser

Artificial intelligence Denoiser is AI tool created by NVIDIA and use AI and machine learning to provide instantaneous interactive feedback to users for better decision [40]. It uses GPU-accelerated AI to create visually noiseless image at ultra-fast speed. At present, AI Denoiser is the fastest and easiest image visual rendering tool existing to date.

Generative design

Generative design is another AI user developed by AUTODESK. Generative design will lift AI to change tedious design processes into a sophisticated ones. The method is done by changing the parameters randomly with-in already defined boundary to generate a set of distinctive designs based on a built-in parametric CAD system. Fig. 2 shows different alternatives of 3D CAD model for ceiling lamp using generative design by considering space filling and non-collapsing criteria.

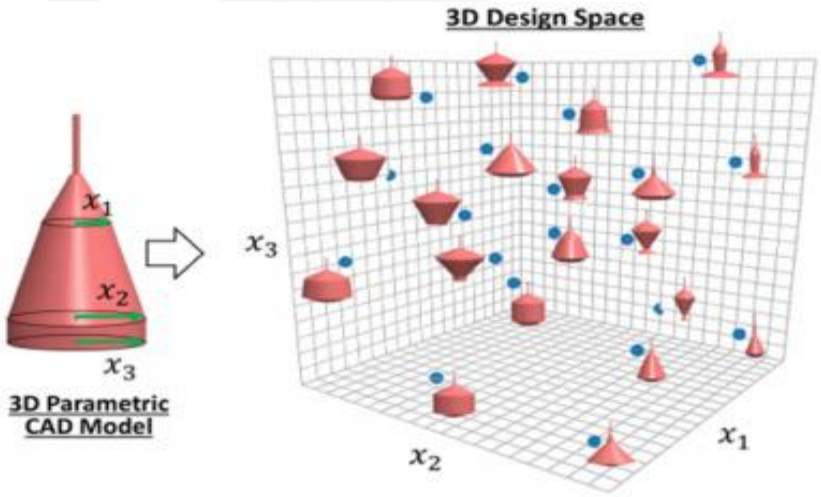

Fig. 2. Design alternatives for a 3D ceiling lamp CAD model

CAD application in extended reality (VR, AR and MR)

Since the advent of CAD systems, it was made possible to see three dimensions of the product before its manufactured. At present day, CAD models are being used beyond 3D modeling. Simulating effects and work scheduling is being done with CAD. Kinematic relationship that helps to verify functionality and collision avoidance can be done in CAD software. However, there is still a gap in that CAD applications do not provide immersive visualization and interactive simulations, such as that seen in extended realities (Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)). There are many intricate pro-cuts in the real world that require detailed conceptualization before being made. It's tough to mimic real 3D world with traditional CAD technologies. However, in extended reality technology, the model created in CAD software is loaded into VR, AR, and MR platforms for immersive simulation and detailed conceptualization.

VR allows students to have a better understanding of the subject matter, especially when a visual representation of the real process is required. In the health sector, virtual reality technology is being used to support procedural training, diagnosis, and to give virtual therapy in times of emergency. In the aviation industry, VR is frequently used for a range of applications, including cabin design and pilot training.

Discussion

In the beginning, the CAD system was used to aid the drawing work only rather than for the product manufacturing. This made the system to move slower in the areas of engineering in general and in the manufacturing field in particular. However, having seen the quality and the productivity improvement behind CAD systems application, industries like aerospace worked hard on its development. Over time, the technological and economic pressure made the pattern of the industries to change. At the present time, the design stage has become the most crucial part of the manufacturing as it affects quality, cost and overall profitability. The breakthrough comes to happen with a development in the computing system; the visual displays, monitor control processes, on-line, real time reservation systems like in the airline, massive data banks and sensors in the industries. Parallel developments in graphics software have also aided the need for the use of CAD system through interactive workstation creation.

According to this review, in combination with AI, extended reality, and manufacturing, the benefits of CAD can be elevated. CAD integration with AI transports design to a new level. CAD integrated AI can analyze a single model against so many factors as per AI program. In general, incorporating AI into CAD provides

easier designing process, stores knowledge, makes changes without human intervention, reduce design lead time, delivers ergonomic engineering, and etc. CAD with VR, AR, and MR concept provides a detailed understanding of the design through interactive and immersive simulation. The benefits of VR, AR, and MR systems are, that they provide the possibility to train machine conductors without the real machine, can enhance teaching-learning system, reduce wastes, share interactive virtual automated machine and provide the opportunity to present working automated machines to customers before building them. The direct link between CAD and manufacturing, as shown in 3D printing, is critical because it offers significant benefits over traditional manufacturing. CAD is a crucial component of 3D printing. A 3D printer will be unable to manufacture a prototype or product without the instructions contained in a CAD file. The CAD file instructs the 3D printer on how much material to deposit and where it should be placed. Using advantage afforded by CAD file, 3D printing technology now has the ability to print at the micro/nanoscale parts, complex forms and can significantly reduce manufacturing costs.

In general, the following three statements summarize the issues that are pushing CAD to new heights. In today's digital environment, unless the CAD systems are infused with AI systems, they will be unable to develop several diverse products based on a single object input. Without the aid of AI, they cannot produce hundreds or thousands of CAD models in a reasonable amount of time, and they won't have the capability to compare and contrast different sections of the design in real-time in order to determine their differences. It is becoming more common to immerse in simulations during product testing in order to determine the product's efficiency and efficacy prior to manufacturing. Accordingly, existing CAD software has to allow users to interact with the simulation results while the simulation is running. Simulations must now be edited in real time. In the manufacturing industry, even if design is one of the most important activities, it will be very difficult to meet the designed product specification fully and stay in the market unless it is directly tied to or integrated with manufacturing. Very complex objects can only be best manufactured through direct integration of design and manufacturing as in 3D printing.

Conclusion

The review concluded that the desire for a wide variety of products based on a single item input, interactive simulation, and direct design-to-manufacturing integration is driving CAD forward. From authors' perspective, the aim to integrate AI into CAD is to create an intelligent design environment in the design and manufacturing areas by developing different software that has computational and analysis features. AI

provides an intuitive application to reuse already existing parts. In extended reality and 3D printing, the need for CAD system is to design and develop 3D model of an object. The intention of extended reality technology is to provide an accurate image and share a detailed understanding through immersion and interaction as the simulation goes on. In manufacturing, using design freedom afforded by CAD tools, 3D printing technology has begun to demonstrate great possible applications and potential benefits in the aerospace, automotive, biomedical, energy, and etc. fields. 3D printing offers a cost-effective and time-efficient ability to make small quantity, custom designed products with complex geometries. The review has also depicted that, although AI-integrated CAD has numerous advantages over traditional CAD, it still requires significant work to gain much more acceptance from industrial and academia organizations. In order to widen the applications of AI-integrated CAD systems, research and development in terms of designs, novel process modeling, optimization, and control are required.

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