International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 1874-1879 www.ijaem.net ISSN: 2395-5252

AI And Its Application in CAD

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Date of Submission: 20-04-2023 Date of Acceptance: 30-04-2023

ABSTRACT— Computer Aided Design (CAD) is on the brink of another revolution with primary drivers in the form of AI and Machine Learning involving the use of Deep Learning (DL). This paper reviews the various real-life applications of AI integrated with CAD like Computer-Aided Teaching, CAD in extended reality, architectural design and aircraft component manufacturing while also discussing the different ideologies and methodologies used for the same. The paper also discusses the prospects of AI integrated with CAD. AI is often integrated within CAD for automated decision -making (ADM), where AI algorithms are implemented for data collection, processing, modelling, and utilization in support of automated decisions. The feedback is evaluated for the improvement of the decision-making process.

Keywords—CAD, AI, DL

I. INTRODUCTION

The major goal of the branch of computer science known as artificial intelligence is to show that a computer system may exhibit intelligence that is strikingly close to human intellect. Learning, prediction, vision, speech recognition, decision-making, translation, social intelligence, motion, and manipulation are just a few examples of what it is capable of learning. In other words, the intelligence displayed by the machines is also referred to as machine intelligence.

In the mid-1980s AI(Artificial Intelligence) was introduced, with this new technology the problem solving abilities of CAD software were enhanced significantly. The purpose of AI is to learn and replicate human problem-solving capabilities. AI software, unlike procedural programming software (such as Fortran, C, C++, or Java), models non-numerical cognitive processes of pattern matching and decision-making [1]. The competence of professionals who can conduct activities involving synthesis, diagnosis, planning, interpretation, and execution of design tasks is captured by AI. As a result, AI software's language is not procedural; rather, it is based on rules that specify how decisions should be made.

Currently, CAD software's main purpose is to automate a design's analytical phases. To ensure that parts and assemblies perform as intended and adhere to design criteria, CAD software is used to construct computer models of the parts, fit them together, and model their performance. Because expert design assessments evaluate whether modifications should be made, the analytical steps of a design process are iterative (design synthesis). Because AI-based solutions incorporate the knowledge and experience of professionals, design synthesis can be carried out without the need for a separate design review and synthesis.

II. HOW CAD AND AI ARE MERGED

MBR (Model-Based Reasoning) is the process through which CAD can be merged with AI. It analyzes qualitatively and quantitively in order to predict the interaction of the design components. MBR is model-based and extracts knowledge from past behavior.

Model-based reasoning tries to solve a problem with a diverse set of approaches and multiple loosely connected techniques. It is mostly applied in the areas of monitoring, control and diagnosis. For diagnostic applications of the model it usually consists of the following elements: (a) replicate and predict the normal behavior of the system, (b) record the relations between internal model components and predicted observations, (c) on detection of an abnormal observation, use the relation between the internal model components and predicted observations to identify contradicting model assumptions, and (d) in the presence of multiple elements, apply a measurement strategy to reduce the number of elements [2].

III. ARTIFICIAL INTELLIGENCE IN CAD

The term “Artificial Intelligence” was used to describe a machines ability to replicate human intelligence through learning and reasoning. Recently, the companies have been able to set up an intelligent CAD environment by incorporating AI into their systems. Integrating AI into the CAD

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system will reduce the lead time significantly and constructs a knowledge-based design environment. In hospitals, AI-based CAD is being implemented in a clinical practice along with a Picture Archiving and Communication System (PACS) to improve workflow [3]. AI integrated with a variety of technology is currently in great demand with respect to green manufacturing and sustainable development. [4].

Fig.1 shows how a traditional CAD system can be converted into an intelligent CAD system. Model-based Reasoning (MBR) is the process of merging AI into an CAD system .By using the quantitative and qualitative analysis, it predicts the interaction that could exist between different parts of the design [5].

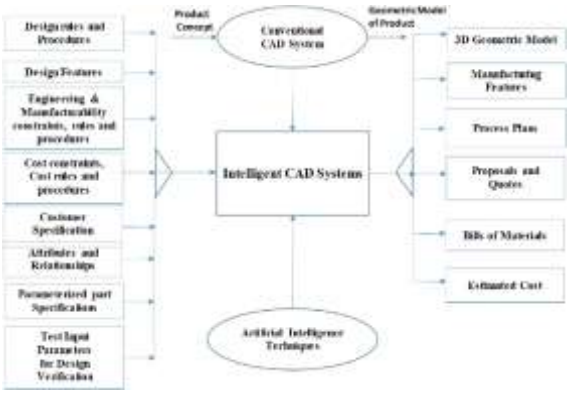

Fig1.-CAD into Intelligent CAD [6]

Some examples of AI integrated CAD software are-

- SOLIDWORKS-The owners of the software (Dassault Systems Company) introduced xDesign that uses 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. The operator first creates the model and specifies the constraints. After the required specifications are defined, SOLIDWORKS xDesign will generate the part instantly with the help of AI integrated within its system based on the defined constraints. [7].

- NETVIBES One Part- NETVIBES One Part is another example of an AI enabled design software introduced by Dassault Systems Company. The utility offers a simple application for reusing previously used components to save time. Operators can access 2D/3D related components in NETVIBES One Part with just a few clicks. [8].

- Artificial intelligence (AI) denoiser-Artificial intelligence Denoiser is an AI tool developed by NVIDIA that employs AI and machine learning to give users interactive feedback instantly so they can make better decisions. [9]. It creates noise-free images quickly using GPU-accelerated AI. The quickest and simplest picture visual rendering tool currently available is called AI Denoiser. [10].

- Generative Design-It is a space filling generative design technology (GDT) which combines a computer program and CAD for the creation of an innovative and original design.

IV. APPLICATIONS

Currently CAD consists of an array of engineering functions from simple drawings to 3D models. CAD integrated with AI makes the designing part a bit easier as AI takes the lead in integrating the engineering aspects as well as predict and perform tasks with its own intelligence. This is suitable for all designs-new design, innovative design or routine design. Here are some of the applications:

1. AI IN COMPUTER AIDED ART TEACHING

The most important part of the intelligent teaching is to test the learning effect of the learners and give suggestions accordingly in order to realize the intelligence of the learning system. The main functions are-

- Knowledge points are divided according to the teaching content and a database of learning elements is established

- The learning effect is evaluated based on the learning situation and the learning guidance and

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learning suggestions are further given in accordance to the learning effect.

- Different teaching content is chosen for different students and a collection of students response information in time is done, analyzed, and processed and the student's performance is judged off it.

- The intelligent teaching model mainly comprises of Knowledge base, Student Model, Teacher Model, and intelligent interface

Knowledge base comprises of Static and Dynamic Knowledge. Static Knowledge means the professional knowledge, assessment knowledge and teaching goals, process, and strategies. Professional Knowledge is the core of the knowledge base and it describes the teaching content and relationship between them. AI methods are used to convert the above knowledge into one that could be understood by the computers-this is called Knowledge Representation.

Dynamic knowledge is temporary knowledge generated during the operation of the system, which is the precondition for the further operation of the system, including the intermediate data obtained in the inference process, the intermediate result of the problem, and the record of theproblem-solving process. A good knowledge representation method can not only organize domain knowledge reasonably and effectively, but also provide information query for the system, but also help students establish clear conceptual relationships, establish knowledge structures, and improve problem-solving capabilities [11].

The Reasoning Mechanism is divided into 3 parts namely Forward Reasoning, Backward Reasoning and Two-way Reasoning.

Forward Reasoning is data driven as each production has a set of conditions on the left and a set of actions on the right. When the conditions are met, the production is activated and the actions are executed.

Backward Reasoning is goal driven and reverse of the forward reasoning. The basic principle is to set a target state and check whether the data base is currently there.

Two-Way Reasoning is also called mixed reasoning as it combines the strength of forward and backward reasoning as well as overcomes the shortcomings of both.

The inference engine comprises of 3 parts namely scheduler, executor and consistency coordinator. The inference model adopts different strategies in accordance to different knowledge bases. Scheduler oversees the whole reasoning process so that it can proceed in a set manner.

The executor acts on the actions selected by the scheduler and is also responsible for accessing the knowledge from the knowledge base and the information from the global blackboard.
The consistency of results is usually used in reverse reasoning.

2. AIRCRAFT COMPONENT DESIGNING

The application is based mainly on the development of a KBM(Knowledge-Based System) for the determination of manufacturing processes for some selective airframe components. The system enables the engineers to design the strongest yet the lightest wing possible at least cost.

The representation of the knowledge regarding material selection, manufacturing procedures, stiffener types and materials, fasteners and fundamental part configuration must be in a suitable manner in order for the KBS to operate effectively.. Domain knowledge is typically represented in the following ways: a KBS acts as a set of regulations. The frames used to define the items that appear within the rules are frequently combined with the rules themselves.

Knowledge-Based Engineering (KBE) can be considered as a subset of KBS and AI related technologies with its primary focus on the automation of CAD geometry creation, engineering analysis and support information generation. [12].

The system must function inside an integrated design environment in order to be helpful and show its functioning. One of the most crucial elements in building system acceptance and credibility will be system integration. Without the proper interface automation techniques, the system's intended functionality will not be visible. Figure 1 shows the suggested integrated design environment in which the KBS will be operational. Many different existing tools and codes will be implemented within the environment in order to perform the required product and process modelling and design trades. The success of the KBS is closely linked to the integrated design environment and without it the success would be restricted. [13].

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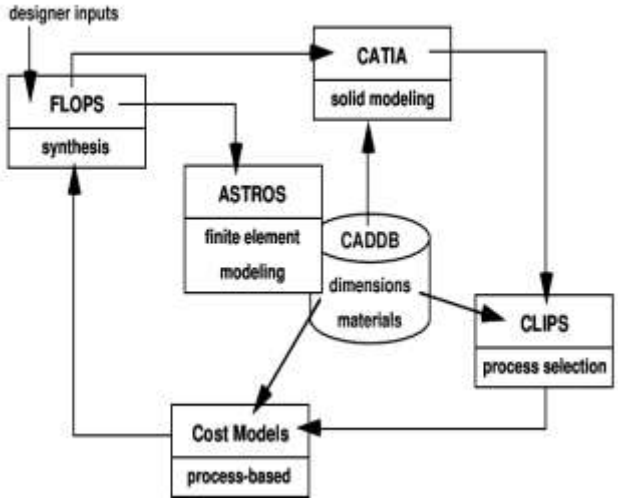

Fig.2-Integrated Design Environment [14]

3.EXTENDED REALITY (VR,AR AND MR)

Virtual Reality(VR) is a type of virtual simulation that enables the users the experience a virtual world of the system generated by a computer stimulation. VR is based on two characteristics- Immersion and Interaction.

Currently, VR is upgraded to use a variety of sensors (eye recognition, voice, gestures, and brain waves) and multi-dimensional information environment interaction, combined with interaction in the real world [15]. VR allows students to have a better understanding of the subject matter, especially when a visual representation of the real process is required [16]. In the health sector, virtual reality technology is being used to support procedural training, diagnosis, and to give virtual therapy in times of emergency [17]. In the health sector, virtual reality technology is being used to support procedural training, diagnosis, and to give virtual therapy in times of emergency [18].

AR also referred to as Augmented Reality. Its main goal is to have some sort of interaction between the virtual world on screen and the real world. Lai et al. (2020) [19], introduced a worker-centered system comprised of multi-modal AR instructions backed by a deep learning network for tool recognition to reduce time and error in an assembly operation. Their research states that the dataset was created using CAD tool models and displayed in a two-dimensional setting without the use of actual tool images.

At the University of Washington, Phillip Dunston and his team have presented the initial concept of AR CAD that can support construction and design [20]. In order to give good intuitive interaction with models created, the report claims that the AR CAD system integrates the AR helper viewer into regular CAD. [20]. The AR CAD system consists of computers for CAD modeling, running and viewing AR and head-mounted display with a camera attached to it.

MR also referred to as Mixed Reality is a step further in the development of VR. It's based on introducing the reality into the virtual world. MR will improve the sense of understanding for better understanding as it utilizes both virtual and real objects. Mixed Reality has 3 main features-

- Combination of virtual and reality
- In virtual 3D
- Real-time operation

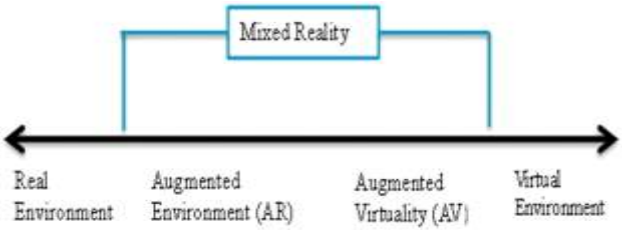

Fig.3-Relationship between VR, AR and MR [21]

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4. AI AIDED ARCHITECTURAL DESIGN

Numerous artificial intelligence approaches are distinguishable in design process varying from low-autonomy to swarm intelligence and neural networks which are capable of achieving high levels of autonomy.

There are 2 main models of AI- Subsymbolic System and Symbolic System. The Subsymbolic systems give their creators a higher level of control since they are created in a form of algorithms whose parameters need to be analyzed strictly in hierarchical way making them less autonomous.

Symbolic System is a set of autonomous design processes that work in a non-hierarchical way. However, this system offers a high freedom of choice in the achieved result having different levels of computation.

Evolutionary Algorithms- They are a set of algorithms inspired by some basic biological phenomenon such as reproduction, mutation, recombination, and selection. Genetic algorithms (Mitchell, 1996) are the most popular variety of multi-criteria optimization techniques in the field of evolutionary computing. Consequently, they are developing the topic that architects, designers, and artists are interested in. Since the middle of the 1990s, the potential applications of evolutionary algorithms in the field of architectural design have been researched as a means of producing answers to issues whose structures could not be easily grasped.

Swarm Intelligence- From a mathematical perspective, it is an emergent behavior that develops from a straightforward set of rules and is created by self-moving entities without the aid of outside coordination. Due to the availability of numerous design software tools based on the boids library, virtual control of swarm behavior and its potential applications became a significant topic in modern generative design.

The development of automated design systems enhanced conceptual thought's potential and involvement in the design process. Soon one can expect digital artificial intelligence aided designer's assistant, which concept can
be based on the existing system, taking a primitive forms nowadays, which learn our behavior and patterns of thinking- recently introduced personal assistants such as Siri or Alex, help us find best possible way to solve our problem or suggest other solutions on their own [22].

V. FUTURE PROSPECT AND CHALLENGES

AI embedded with CAD makes the automation process much easier and more effective for the engineers. As discussed above, AI has already found applications in major sectors and will continue to thrive in the future because of the principle it works upon. AI will play a major role not only in design but also other fields as technology continues to grow. However, designs are based on human's subjective thoughts and emotions which can never be replaced by AI completely no matter how much it goes on to develop.

Although AI is bound to make huge strides in design, it will still require the human thoughts and emotions to produce the best and most effective designs.

VI. CONCLUSION

This paper was successfully able to review different applications of AI integrated with CAD along with their methodologies/principles involved. Additionally, various integrated software was discussed, as well as how AI and CAD are combined. Prospects for AI in design are promising because the field has already started off on the right foot and will only get stronger from here, the only problem being that they can never completely replace human thoughts and emotions.

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