International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 297-306 www.ijaem.net ISSN: 2395-5252

Artificial Intelligence and its relation with Computer Aided Manufacturing

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Date of Submission: 25-02-2023 Date of Acceptance: 05-03-2023

ABSTRACT – Artificial intelligence (AI) research papers are essential for developing the subject and influencing the direction of technology. This paper provides the AI application areas, appraise existing approaches, and recommend new research directions. In order to increase the effectiveness and quality of the manufacturing process, artificial intelligence (AI) is rapidly being employed in computer-aided manufacturing (CAM). Process optimization, quality control, and predictive maintenance are a few CAM applications for AI.The creation of algorithms and methodologies that enhance the functionality, precision, and effectiveness of AI models is one of the key contributions of AI research publications.

This paper covers the fundamental ideas behind artificial intelligence and examines how it is now used in the manufacturing industry. The problems with artificial intelligence are also identified and some possible solutions are suggested. We hope that the information offered in this paper might serve as a valuable set of guidelines and references for future work on artificial intelligence in the manufacturing sector.

KeyWords: Artificial intelligence, computer–aided manufacturing(CAM), Computer Numerical Control(CNC), Computer Aided Design(CAD), Aircraft manufacturing, surface roughness prediction.

I. INTRODUCTION

Over the past few years, the manufacturing industry has exploited the use of AI technology, and has taken advantage in particularly knowledge-based systems, throughout the manufacturing lifecycle. These technologies have been motivated by the competitive challenge of improving quality while at the same time decreasing costs and reducing design and production time. Artificial intelligence has several advantages that are desired in manufacturing practice, including learning and adapting ability, parallel distributed computation, robustness, etc[01].

Artificial Intelligence has received a major focus in both academia and the industry recently due to the competitive advantages that it can provide to manufacturing organizations in creating a more efficient and sustainable operation [02]. The manufacturing sector is going through a period of change with production and AI technology progress setting the pace of this transformation [03]. At the same time, more and more emerging AI technologies such as big data analytics, advanced robotics, expert systems for diagnosis, computer vision and pattern matching for outgoing product quality are creating an impact to the manufacturing industry in a major way [04].

AI algorithms may examine a variety of elements through process optimization, including raw material selection, tool path planning, and cutting parameters, to streamline the production process, decrease waste, and increase productivity. By examining the manufactured product's quality and identifying flaws, surface polish, and other quality characteristics, AI may also be utilized for quality control[05]. Machine vision and image processing techniques may be used to do this and guarantee that the result satisfies the necessary quality requirements.

In general, the application of AI in CAM may result in increased productivity, decreased costs, and higher-quality products, making it a technology that is becoming more and more significant in the industrial sector.

II. RESEARCH METHODOLOGY

The methodology of AI in computer-aided manufacturing (CAM) typically entails identifying the issue or challenge of conventional CAM systems, gathering and preprocessing data from various sources, such as sensors and control systems, developing an AI model using a suitable algorithm and training it on the pre-processed data, integrating the AI model with the CAM software or control system, testing and evaluating the AI-based CAM system to determine its efficacy, and finally, implementing the system.

III. OVERVIEW OF AI TECHNOLOGIES

The manufacturing sector may undergoing a radical transformation thanks to artificial intelligence. The potential advantages include enhanced quality, decreased downtime, lower costs, and higher efficiency[06]. This technology is accessible to smaller firms also.

Though they pertain to two different ideas, the terms artificial intelligence and machine learning are occasionally used interchangeably. By using historical data to show you the odds between several choices and which one obviously worked better in the past, it assists us in solving a specific problem[07]. It explains the significance of everything, the chances that specific outcomes will occur, and their likelihood in the future[05].

3.1 Why adopt AI

Making decisions that can be put into action more quickly and correctly than a human can is what artificial intelligence (AI) in manufacturing refers to. This makes a lot of sense for forecasting and for comprehending anomalies or outliers, to name just two applications[08]. Forecasting can add value in some stages of the production process. There is a good probability that you can make forecasts if you have access to enough historical data as well as information about the decisions and processes around the data.

A human analyst may find the data from one machine to be overwhelming, which is where AI might be useful. Additionally, because manufacturing systems are integrated, one measure in one step of the process can affect another step in the same step. How can you know what's happening in another region if you're just focusing on one? AI may offer a remedy. The four categories listed below are where AI has a big financial influence[09].

- Predictive upkeep. By using historical information from maintenance logs, you may forecast how a machine will perform under a future payload and determine whether you'll need to fix it, when, why, and how based on what fixed that problem in the past[10].
- Reliable prediction. Significant cost savings can be achieved by predicting and minimizing failures.
- Increasing output or yield. You may prevent quality passes by anticipating when a machine or process won't meet requirements and taking proactive steps to bring it back into compliance.
- Forecasting of demand and inventory. It is possible to estimate the demand and movement of essential parts with a complete understanding of plant operations and the production data, leading to significant inventory savings[11].

3.2 How might computer-aided design be improved by artificial intelligence?

The number of manual actions needed to create a design has decreased because of CAD. The drafting process has been significantly expedited by this time savings, which also allowed designers to refocus their efforts[12]. Designers create ever-more complicated ideas as a result. Although the fundamentals have been covered, there are still a lot of other barriers that prevent designers, engineers, and architects from rationally enhancing their workflows. Significant bottlenecks include the following[09]:

- In order to create the optimal design for a project's requirements, designers frequently have to manually adjust model parameters.
- Validating designs after each modification might cause the project to be delayed by days or even weeks because changing just one parameter can significantly affect the attributes of a design.
- A project's progress can be slowed down by feedback loops since gathering data to figure out what needs to be changed takes time.

Since they are simply "glorified drawing boards," one could argue that existing CAD systems conduct computer-aided drafting rather than computer-aided design. Because current technology only helps designers with drafting, the opportunities and challenges of CAD have not yet been fully explored or addressed[12].

AI can address these problems as it develops and becomes more thoroughly integrated into CAD by:

- By producing ideas based on specific criteria, it is possible to expedite the drafting and selection of design solutions (such as weight, size, costs, or material).
- Modifying and altering designs automatically if they don't satisfy performance or aesthetic standards.
- Depending on the user's previous behaviors,

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recommending more details to include in the design.
- Adapting current designs to user input, evolving technology, or fresh legal needs.

These processes might be combined into a single solution in future, more sophisticated AI models that would handle the entire design process. AI might free up designers and engineers to concentrate on other, possibly more crucial issues like enhancing the quality, effectiveness, and dependability of their works by handling the labor-intensive tasks.

3.3 What role has AI played in CAD thus far?

AI has already made its way into computer-aided design in one form or an another[17].

"Three most important architectural potentials of the new machine mediation techniques are the expansion of the spatial imagination, and the radical break with a hierarchical design approach, and the introduction of different disciplines into the design process, relating to the design immediately to its final execution."

For instance, a number of software providers have included AI capabilities in their architectural, engineering, and construction solutions. Autodesk provides generative design tools to users in order to assist them optimize their drawing workflows, maybe most prominently. The company's technology accomplishes this by swiftly generating design proposals based on a variety of input factors, including pricing, production processes, materials, or spatial requirements.

Notably, AI in CAD isn't just used for designing and refining designs. Siemens unveiled a new version of its NX CAD software in February 2019 that features a user interface that alters depending on the user and situation. A CAD tool frequently provides the draftsperson or engineer with too many commands. Many people contend that just 10% or less of the available commands are applied in 90% of CAD system operations. When the AI system determines that the engineer would need more commands—commands that might be unknown or infrequently used—a dynamic UI displays them.

The development of CAD datasets for AI training has involved a lot of work, with Sketch Graphs serving as a prime example. Sketch Graphs, which was released in 2020 by academics at Princeton University and Columbia University, has 15 million parametric CAD sketches. The drawings are shown as a geometric constraint graph, where the edges denote the geometric relationships between the primitives (nodes). Sketch Graphs places more emphasis on the relationship structure of its sketch samples than other CAD datasets that stress 3D shape modeling.

IV. DEVELOPMENT OF AI IN CAM

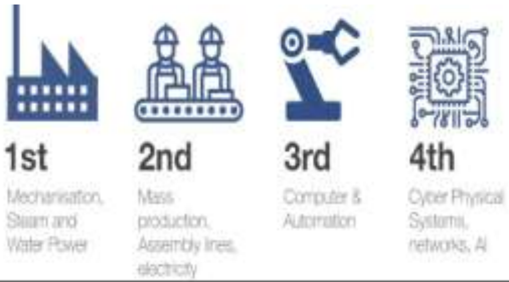

Figure: 01 Revolution In Manufacturing Industry with AI

Efficiency, accuracy, and reliability are important needs in the manufacturing sector. Artificial intelligence (AI) can enhance the technology that manufacturers have embraced, such as computer-aided design (CAD) and computer-aided manufacturing (CAM)[13]. The full potential of these technologies can be realized by incorporating AI into 3D modeling. In CAD, digital designs are created, analyzed, and modified using computers before a product is made. These models are then used by CAM to regulate production procedures and equipment in order to produce final goods that adhere to design criteria. The manufacturing sector has benefited greatly from both innovations, but AI has more potential[14].

To achieve some additional functional requirements specification for AI in CAM, one should imagine to a certain extent the performance of an intelligent distributed computer environment. number of users will exploit, update and extend systems's knowledge[15].

So, The first case is to be preferred, for the knowledge-quanta may be supposed to have primarily local significance[16]. Then , the knowledge should be first handled locally and after that consequently included in an existing knowledge base, or used as a foundation of a new one. then, a local knowledge server should be able to determine the significance of each knowledge-quantum in the local pool local or global and in the latter case, to leave it to the common knowledge server[17]. However, that is enough to show the necessity of a higher level intelligence in the computer environment of CAM[18]. Hence, there is a need for tools for building multi level knowledge hybrid knowledge bases and handling systems and also a variety of knowledge handling structures. Further, the needed knowledge handling tools should be able to work in a distributed computer environment with CAM, i.e. to be compatible with a properly designed system layer and as well as to be compatible on the support layer[19]. Both of the above mentioned requirements are directly connected to the openness, flexibility and transparency of the distributed computer environment, so they produce the questions to be asked when one purchases software expert systems building tools for the creation of AI in CAM[20].

4.1 How AI is improving CAD and CAM processes in modern manufacturing ?

Figure: (02) 3D modeling [21].

- **Increased Productivity:** Higher Productivity AI first and foremost enhances 3D modeling by increasing the effectiveness of the procedure. As many as 15 million CAD designs are used as the basic dataset by certain AI design assistants, which influences their forecasts[08]. With that much knowledge, they can make forecasts that are remarkably accurate. By eliminating the need for users to manually sketch several elements, this increases efficiency during the design process. These AI assistants are also capable of automating design decisions[08]. For instance, AI can automatically apply geometry to new projects by aligning them based on how pieces were applied in previous designs[16]. To guarantee that everything lines up properly, this process would often need slow, careful tweaks, but AI can do it in a matter of seconds. Manufacturers can then accelerate the time to market for new products while they can also concentrate on other activities or produce more[19].

- **AI Is the Future of 3D Modeling:**

The Future of 3D Modeling Is AI 3D modeling with AI is still a relatively new technique. The technology is already expanding across CAD and CAM software systems, despite its youth[22]. The reasons why CAD and CAM technologies are so widely used are their effectiveness, accuracy, and dependability. Each of these advantages can be enhanced by AI, resulting in higher-than-expected results[23].

- **Ongoing Improvements:** Continuous Development AI in 3D modeling can facilitate continuing advancements, just like in other industrial processes[22]. Over time, they'll start to notice trends in their triumphs and failures and propose adjustments to maximize the former and decrease the latter. The design and manufacturing processes can be combined with the use of AI in CAD and CAM, opening the door for operational benefits[05]. Both sides' data will show how the production side can change to better support the designs engineers desire to create. As new elements surface, AI can identify these areas for development and adapt them[08].

V. AN APPLICATION OF AI FOR CAM AND CAD TO INTEGRATE AIRCRAFT MANUFACTURING

A single engineer lacks the expertise needed to incorporate the restrictions and manufacturing characteristics of aircraft into the structural design process. Concurrent Engineering (CE) makes it possible to integrate design and production to allow trades based not just on product performance but also on other difficult to evaluate factors, such production and support[08]. System designers would benefit greatly from a decision support system, or knowledge- based system, that helps guide manufacturing concerns throughout the preliminary design process. To illustrate the KBS's (knowledge Based System) functionality as a design tool, it will be used in an integrated design environment with other tools already available[19].

5.1 KNOWLEDGE-BASED SYSTEM DEVELOPMENT

5.1.1 Problem Domain

The High Speed Civil Test (HSCT) is the unique test case, and the area of study is the integration of design and manufacturing. The focus of this research will be on a significant airframe component, exactly the same one that caused designers the most difficulty in the 1970s.

The KBS's task is to choose the production procedures for the structural parts of the wings. In this area, it is not feasible to pre enumerate all of the potential outcomes and then choose the best one based on the data. that is normally available as a first-level structural analysis. Instead of, a set of workable techniques that satisfy the external restrictions imposed by material specifications, fabrication and assembly issues, and cost considerations.

Regarding product design, a few assumptions have been made.

The **first**, prior to structural modeling and optimization, the materials from which the wing structural components will be made are preselected from a database of potential possibilities. This presumption is made because it is impossible to predict the weight of each structural component accurately without modeling its unique material qualities. **Second,** when utilizing weight-complexity based parametric cost models, calculated weights and dimensions of the structural components will vary dramatically with different materials depending on performance requirements and load conditions. When using commercially available parametric cost models, this factor is often ignored. **Third,** some related to process selection will be abstracted to the functional level. Before precise models of the parts are constructed in CAD systems, the manufacturing procedures in the aerospace manufacturing sector are chosen.

The information about the components that will be known before modeling, after structural analysis and optimization, and before the KBS chooses the processes is shown in **Table 1[19]**.

Product & process parameters	Skin panel	Rib	Spar	Spar cap
before modeling and structural analysis/optimization:				
material & associated properties, constraints, & max. service temp.	✔	✔	✔	✔
grid coordinates	✔	✔	✔	✔
modeled as membrane element		✔	✔	
modeled as rod element				✔
after structural analysis and optimization:				
thickness	✔	✔	✔	
cross sectional area				✔
part weight (mass)	✔	✔	✔	✔
production considerations and decisions:				
manufacturing process	✔	✔	✔	✔
fasteners	✔		✔	✔
stiffener type	✔			

International Journal of Advances in Engineering and Management (IJAEM)
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stiffener material	✔			
solid or honeycomb construction	✔			

Table 1: Wing Component Modeling [19]

In order for the KBS to operate effectively, the knowledge regarding material selection, manufacturing procedures, stiffener types and materials, fasteners, and fundamental part configuration must be represented in a suitable manner. In a KBS, rules are the most typical form of domain knowledge representation. The frames used to define the items that appear within the rules are frequently combined with the rules themselves [24].

5.1.2 Knowledge Base Development

The knowledge and rule bases raise a number of significant difficulties. Several of the data sets required for the knowledge base building are not collocated.

The relevant information must be acquired through a lengthy process of knowledge acquisition. The most suitable format must be used for compiling and coding historical data on material usage and process selection factors as well as current design guidelines and norms. With the use of frames, it is possible to categorize the data that represents technical information[19].

5.2. SYSTEM INTEGRATION WITH EXISTING TOOLS

Knowledge-Based Engineering (KBE) is a subset of KBS and AI technologies that focuses on automating the generation of support information, engineering analysis, and CAD geometry. The system must function inside an integrated design environment in order to be helpful and show its functioning. Without the proper interface automation techniques, the system's intended functionality won't be visible. As **Figure 03** shows the proposed integrated design environment in which the Knowledge-Based Engineering (KBS) will function.

The system executive scripts will be written in the Tk/tcl (toolkit/tool command language) interpretive shell system. To enable the creation of fully complete, fully functional graphical user interfaces, Tk/tcl combines an interpretative language core with windowing applications. The creation and application of parametric, intelligent CAD systems is a special objective of several aerospace industries. Even if the combination of a KBS and a CAD programme is not a next-generation system in and of itself, it is a step in the right direction [19].

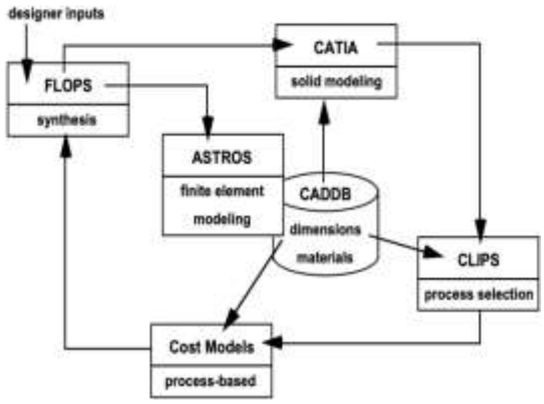

Figure: (03) Integrated Design Environment

As shown in **Figure 03**, the system will be given direct links to CATIA for the purpose of retrieving or storing data regarding the structural elements of the wing. A single function that dynamically accesses all of the internal CATGEO functions will be utilized to access the CATIA resources using Tk/tcl. The Automated STRuctural Optimization System of the USAF and NASA Langley's FLight OPtimization System are two other technologies that are now employed for the product design analyses **(ASTROS)** [19].

5.3 COST MODELING

The stages of the wing product design in this study are decomposed traditionally from the system level to the sub-system level to the part level. Take-off gross weight (TOGW), range, payload, cruise speed, and passenger count are typical examples at the system level. Any decisions made about funding a specific programme will be based on the Life Cycle Cost (LCC) of the intended system, which includes all manufacturing expenses (both recurring and nonrecurring) [19].

VI. AI BASED SURFACE ROUGHNESS PREDICTION

For recently machined objects, there are currently no commercial software tools that assist the accomplishment of preset surface roughness. Machine operators and Computer Aided

Manufacturing (CAM) programmers rely on experience to determine the ideal balance between time and quality optimization[25].

Computer- aided manufacturing programs, which calculate the tool path from input parameters such tool geometry, feed rate, spindle speed, but also part and blank geometries, help manufacturing planning within the Computerized Numerical Control (CNC) milling domain[07]. Professional CNC programmers choose those parameters, but skilled machine operators still need to execute at least one test run to adjust the feed rate in the event of chatter vibrations.[09].

As mentioned, both online and offline chatter avoidance technologies have made significant strides towards optimizing the surface roughness of machined objects. A machine-learning system will be trained using planning, process, and quality data pertaining to features[24].

6.1 Feature based Database Design and Sensor Integration

The data will be compiled into a database in the form of parameter sets and time series, comprising measurements of the surface's roughness, vibration information, cutting depth, feed rate, and spindle speed.

The proposal for integrating the data from the various PLM sources (CAD, CAM, Process, and In- spection) and supplying it to the AI, which is fed by a database categorized by features, is shown in **Figure 04**.

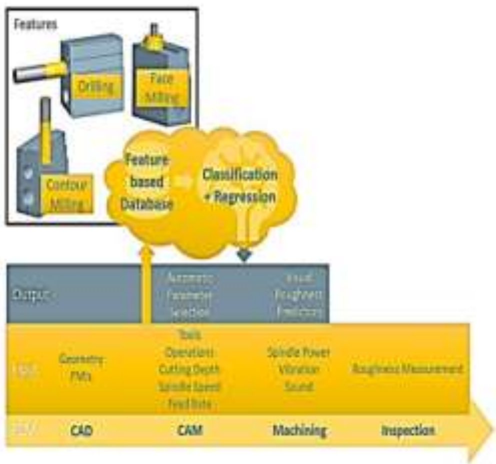

Figure:04

The manufacturing features, which serve as the database's central entities, are displayed at the top. As a core information source for the CAM optimization and the live visualization, which are depicted in the Output layer, the classification and regression model feeds off of the database[25].

6.2 Experimental Data Generation

The defining of the experimental variables, such as feed rate, spindle speed, and cutting depth, is the first stage in the design of experiments. But it's also important to identify the static conditions, such as the component and tool material, geometry, kind of tooling, and tool wear[25]. Simply put, the spindle speed, feed rate, their combination, and the insert radius have a substantial impact while the tool diameter and depth of cut have little to no effect.

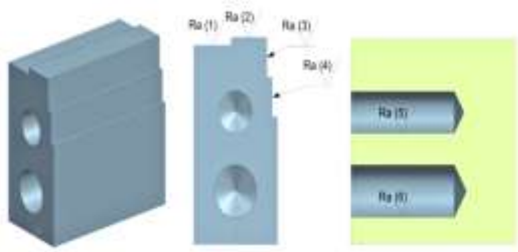

Figure: 05

The Part design demanded roughness values Ra (1) to Ra (6) of three different manufacturing features (face milling, contour milling, and drilling) for two specific geometries per feature.

A part with three distinct production features—drilling, face milling, and contour milling—is shown in **Figure 05**. Each feature, there are two distinct operations included. While the drilling operations have different tool diameters, the milling features have different cutting depths. Before being post-processed into an NC programme, the CAM programme is developed and its cutting parameters automatically adjusted with predetermined offsets and within the required range[09].

The physical parts are categorized for data traceability and readied for identification when the CAM and CNC is programmed, which including tool change, are generated[07]. Finally, the machine learning platform, database connectivity, and data flow must all be well documented and continuously monitored while the machining experiments are being conducted. In this project, a Fanuc 31i numerical control made by Fanuc Austria is combined with a 5-axis milling center manufactured by DMG Mori called the DMU 75 Monoblock[25].

6.3 Data Preparation Analysis and Model Building

A machine learning method with a classification and regression component, like a random forest, is constructed and trained by the collected data sets based on the final data input structure. The experiment execution phase and the simultaneous model development phase will employ an existing data lake structure and machine learning platform.

VII. CONCLUSIONS

Based on the research paper evaluation, "Artificial Intelligence in computer assisted manufacturing," it can be stated that AI has tremendous potential to enhance computer aided manufacturing (CAM) operations. The article gives an overview of the present level of AI in CAM and examines several uses of AI in CAM, such as improving manufacturing processes, quality control, and predictive maintenance.

The report outlines the benefits of adopting AI in CAM, including enhanced productivity, decreased costs, and increased accuracy. The authors do point out that careful planning and implementation are necessary for the integration of AI into CAM as well as that there may be issues with data management and privacy that need to be resolved.

The article contends that through allowing more effective and efficient CAM processes, AI has the potential to revolutionize the manufacturing sector. To fully exploit the advantages of AI in CAM and to address the issues and constraints related to its application, more research and development is necessary.

In conclusion, AI research articles are essential for developing AI, enhancing the functionality of AI models, addressing ethical and societal concerns, and encouraging global partnerships. They are essential in determining how technology will develop and how it will affect society.

ACKNOWLEDGEMENT

We would like to express our special gratitude to our teacher **Dr. Ashok Kumar Madan** who gave us the golden opportunity to do this wonderful Research on the topic **"Artificial Intelligence and its relation with Computer Aided Manufacturing"**, which also helped us to know about so many new things in the manufacturing unit. While making this project he helped and guided us in solving any queries and issues we had.

In addition, we would like to thank the **Department of Mechanical Engineering of Delhi Technological University** for giving us the opportunity to collaborate and work together on this Research project.

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