Evolutionary Roadmap: Latest Advancement in Designing Software to enhance designing capabilities

Agam[1]; Bhupesh Kumar[2]

[1,2]Department of Mechanical Engineering Faculty of Engineering Dayalbagh Educational Institute, Agra, U.P., India

Corresponding Author Email: agammanav0025@gmail.com

Abstract— This review paper examines the most recent progressions in computer program plan inside the domains of deigning software especially AutoCAD and Inventor, two prominent software platforms within the fields of designing and building plan. With a focus on enhancing user experience and improving design efficiency, the paper explores the evolution of these programs, highlighting the key developments in their respective capabilities, interface, tools, optimizing workflow productivity, graphics and empowering visionary modeling for complex designing arrangements. Moreover, we examine the suggestions of AI-driven generative plan, which engages engineers and designers to quickly investigate numerous plan cycles, cultivating imagination and development whereas following to strict plan constraints. Additionally, this paper investigates the consistent integration of Artificial Intelligence (AI), Machine Learning (ML) techniques, virtual reality (VR) and expanded reality advances inside the computer program, encouraging immersive plan encounters and real-time visualization of complex 3D models. We evaluate their part in making the strides plan comprehension, diminishing mistakes, and cultivating successful collaboration among the multidisciplinary groups over topographically scattered locations. By fundamentally analyzing these latest advancements, this paper points to supply a comprehensive understanding of the direction of computer program plan in AutoCAD and Inventor, shedding light on the potential future advancements and their transformative affect on the designing and engineering plan scene.

Keywords: Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Design for Additive manufacturing (DAM), Additive manufacturing (AM), Artificial Intelligence (AI).

I. INTRODUCTION

Technological advancement has taken the world to the next level with the help of digital technology. Many advances in technology, software and hardware capabilities, and functionality are happening very quickly. In less than half a century, computer-aided design (CAD) software has evolved into an indispensable tool that supports engineers in completing many important tasks [1]. Computer-aided design (CAD) technology continues to evolve to keep up with the changing environment [2]. AI-based simulations provide better solutions with less effort, even if the internal system fails. A significant part of the success and popularity of CAD is the importance of working with CAD software, which enables CAD to support many engineering projects. It is also recognized that advances in CAD software are important for designing and creating more products. Start with the main goal of improving the accuracy and speed of 2D drawings. CAD software now mostly deals with the development and implementation of 3D geometry. Its foundation has been expanded to consider models that encourage product assembly, problem solving, automated manufacturing support information (such as information costing), design, engineering systems analysis, and interactive communication by encouraging dialogue. To investigate these advancements, this paper presents the results of a study showing the dynamic behaviour of CAD models. The main purpose of this paper is to address the need for further extension in the tools for easy protection of the design. Additionally, in this study, necessary changes in engineering design were identified. Thus, it is expected to contribute to the overall goal of creating better designs using the capabilities of CAD design. This article then concludes the CAD file analysis and then goes on to discuss the analysis process. Finally, the article discusses its implications for the future of CAD software in engineering project management.

I.I. COMPUTER-AIDED DESIGN

One of the main purposes of CAD systems, which started with the production of 2D drawings in the 1960s but today the objective is to define the 3D geometry, correct assembly, model and equipment of physical objects (since the 1980s). That's why CAD is important for engineers to understand how to design finished products (computer-aided manufacturing, CAM) and how well they will perform in CAE when put into use [3]. To understand the features and limitations of the CAD system, it is necessary to understand the nature of the process and the design work of the design engineers who use the system. Therefore, this introduces the basics of CAD models and the basics of geometric representation in CAD systems. Additionally, design work using CAD tools for designers is explained in more detail.

I.II. BASIC MODEL OF CAD SYSTEMS

CAD systems consist of many elements that allow designers to visualize, manipulate, specify, create, and to some extent optimize performance geometries in a software environment. Before delving further into the layer itself, it is important to note that regardless of its resources and functionality, the essence of the CAD system is still the designer [3]. Therefore, the following description of each layer of the process is explained from the design engineer's perspective. Please note that the description may differ from the software developer's perspective.

I.II.I. FRONT-END

Front-end elements represent the single points of contact between engineers and the system, i.e. the human-machine interface (HMI). An important part of the front end is the visualization of 3D geometry, which often makes interaction better due to simple geometry data. In addition to geometry visualization, the front-end also offers geometry manipulation capabilities via the user interface. These depend on the design model included in the system and allow designers to create and manipulate geometry in 3D space. In addition, a wide variety of product models are often described with wooden products. Therefore, the front-end is the intermediary between the design engineer and the back-end software.

I.II.II. BACK-END

The back-end is all the content embedded in the software that processes and provides the information necessary to complete the tasks needed by design engineers. It puts user ideas into action, provides design assistance, performs geometric measurements, and more. However, the main role of the backend is to act as an intermediary between the frontend and the geometry kernel, acting on data collected from the frontend and supported by the embedded geometry kernel. It enables the creation of defined workflows by tracking the design history and the production data required for production.

I.II.III. GEOMETRIC KERNEL

The main product that CAD systems focus on is the digital 3D geometry of the material. The geometry kernel is mainly responsible for the representation of geometry in CAD systems. Here the object geometry is determined mathematically most accurately and also most of the time. To achieve this goal, geometric kernels are based on mathematically different geometric representations, each with advantages and disadvantages. The kernel can also handle basic programming functions such as Boolean operations.

I.II.IV. PROCESSING UNIT

All three of the above layers work together to provide the full functionality of the CAD system. All of this is based on and limited by the operating system and capabilities of the computer or server. Since the geometric kernel is responsible for geometric representation, it is also a limitation in achieving competitive and optimized geometric designs[4].

II. LITERATURE REVIEW

In DAM (Design for Additive Manufacturing) research, general information about design and production processes is analyzed, defined, modeled and made available using data. A library and guide are presented here to help designers use additional materials for manufacturing while taking into account certain constraints. In production, the use of additional equipment is often simultaneously achieved by saving development time and improving product performance. However, the changes in complexity associated with additive manufacturing, particularly the architecture is not often addressed[5][6][7]. In this context, during the research phase, a deficiency was identified in the engineering design tools and business activities required to cope with the increased design associated with additive manufacturing[8].

Although the DAM process itself is described in the literature with step-by-step procedures, the actual design process in the CAD environment for design work is not explained and compared in more detail. In addition to meeting the DAM requirements for CAD through research projects in the database, TU Braunschweig also carried out a project on this topic with AM users in field education and business. In the survey, participants were asked about their attitudes towards using CAD systems, taking into account their level of experience with production processes and accessories. Also, requirements on an ideal CAD workflow suited for DAM were collected. The overall goal is to identify unmet needs in CAD processes and features that are particularly important during DAM. The following key findings from the research highlight the importance of the content of this article:

1. The additive manufacturing information should be available dynamically in the CAD tools that support the design.
2. Given the limited tools available on the market, the users need useful tools to help create geometry, such as special features (such as lattice structures) for specifically designed mesoscopic cell geometry.
3. The CAD systems need to be optimized and targeted to exploit the potential of additive manufacturing.

Later In 2005, Kasik et al. identified ten general challenges that CAD systems must overcome[3]. Some of them are as follows:

1. Geometry Management(Shape Control)
2. Interoperability between CAD and CAE Environments
3. Automatic and meaningful deformation of geometry during design optimization
4. CAD tools do not provide the capabilities of additive manufacturing
5. Production cost

6. Cost savings or feature improvement potential uncertain
7. Credentials and security are unclear and more.

Overall, the deficiencies were identified in all aspects of DAM-related CAD policies. Also the significant evolution of future CAD tools is yet to be seen. Additionally, any construction work required to resolve the additional complexity should also be recorded.

Later in 2018, Fredrik Elgh and Joel Johansson identified the industrial and research needs, as well as changes in product and technology development[9]. A method called simulation-ready CAD modeling was developed as a way to achieve flexibility in finite element analysis (FEA)[10][11]. They examined the existing systems that use CAD models as a multidimensional interactive document. The search is first made by examining the underlying software architecture of the system. Part of the CAD software is then used for modeling directly from the API data. The ability to store information in different systems and their impact on the development process is emphasized.

Computer-aided design/computer-aided manufacturing (CAD-CAM) is currently a growing dental practice. With the use of CAD/CAM systems in the 20th century, different teeth can be created using both dental technology and dental restorations[12]. The body is designed and adapted. The materials used in making prosthetics are increasing rapidly. The first expression was developed by Duret et al. It began to be used in 1971 but was not widely used due to lack of digitization, computer capacity, appropriate and accurate tools and data. Then, from the 1970s to the 1980s, "computer-aided" manufacturing technology was rapidly developed worldwide, including by research institutions in various fields such as business, science, dental CAD-CAM technology, and more[13].

III. EVOLUTION OF DESIGNING PROCESSES

III.I. CONVENTIONAL DESIGN PROCESS

The designer's role in design is to prepare drawings for the customer's approval and guide the design team. With art, it became possible to arrange objects "too large for a single craftsman to do." With the use of art , it was created as a standalone project. The designer has the ability to see the project as a place of constant updates and changes depending on its direction. These are created from a drawing or from layers placed on top of the initial drawing. The process that art creates can be seen as an accelerated version of the development of the process[14].

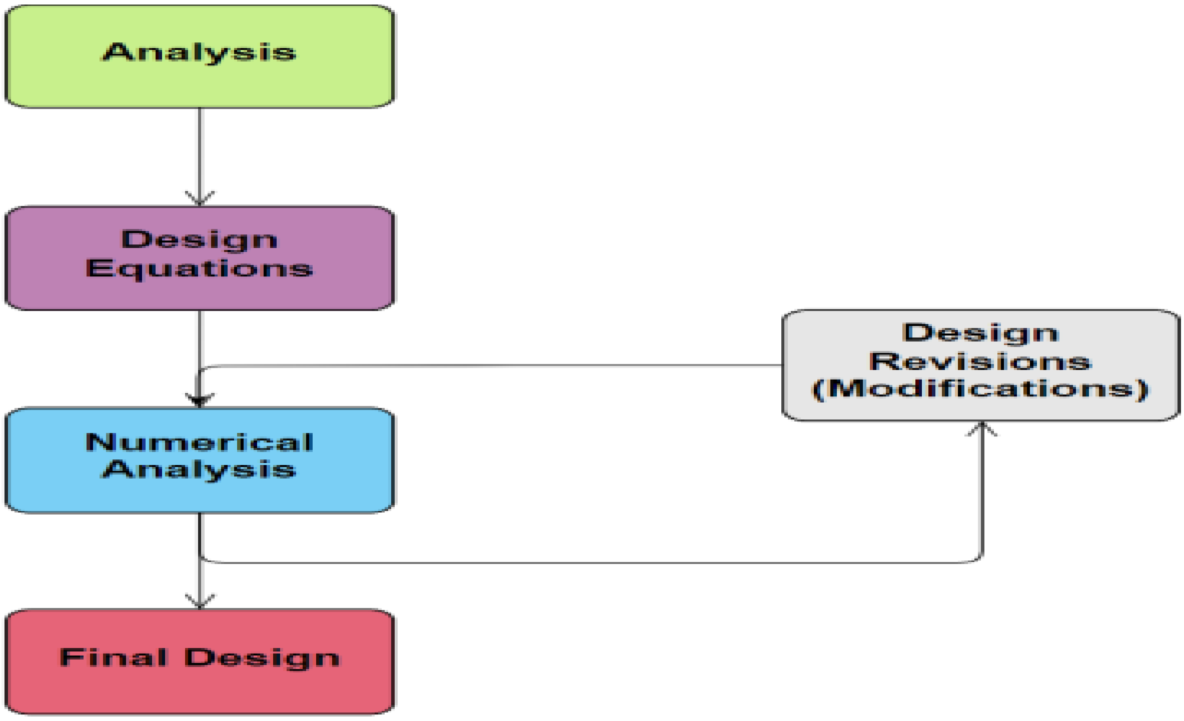

Fig. 1 Conventional Design Process

III.II. NEW DESIGNING PROCESS

The development of new designs is often mentioned in studies aimed at changing the design process, but the main reason for this is the lack of traditional methods, which makes this difficult. This world was made by humans. The main problem that complicates the design process is not only description but also in practice, where designers are forced to use existing knowledge to visualize the future state. In the work of a traditional designer, intuition rather than logic determines. It makes the system unstable. This conflict creates a much more interesting and engaging activity than anyone who has not dealt with it can imagine. Searching for ways to solve this problem led to the creation of research called design science.

With the passage of time, Designers started the use of computers as pens. They began using CAD software to create flat drawings and 3D computer models. This was the time when CAD was evolved. CAD software used as a smart pen allows us to change parts or appearance while still detailing information[14]. The use of CAD software in the next phase of design can be explained as follows:

1. Concept: The project can be effectively initiated by converting drawings into electronic format using drawing equipment or techniques such as scanning and digitization.
2. Design Study: When the project is not decided, you can start creating 2D and 3D drawings, allowing architects to explore designer space.
3. Design Coordination: When design sketches and surveys are completed, the professional designer begins to create hard documentation regarding the design of the project. Currently, collaboration with other disciplines is often needed.
4. Presentation: At this point in the project, the design is accurate enough that the designer can create a 3D model that will give the client an idea of the entire house.

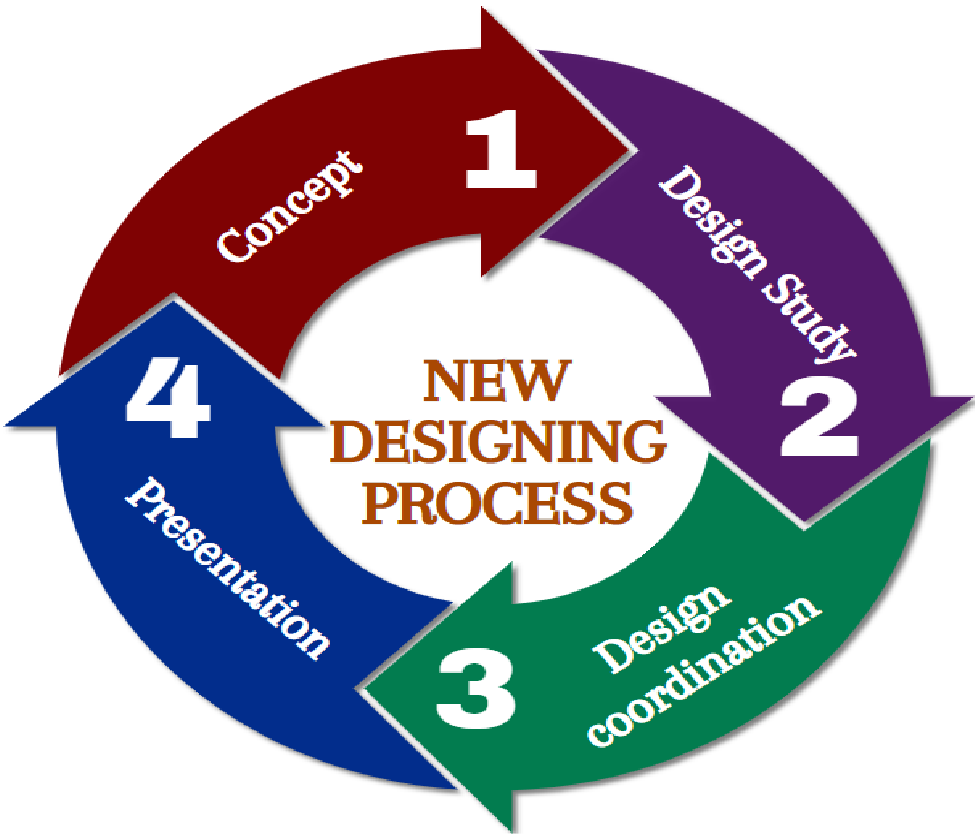

Fig. 2 New Design Process

The advantages of new designing process are:

1. High precision and accuracy to be able to produce electronic products of digital model.

2. Thanks to computer-aided design and implementation, the use of traditional thinking is minimized.

Disadvantages include:

1. The cost of technology is high.

2. The steps from the beginning to the end of this process are very time consuming.

3. Combining beautiful finishes with strong core and frame is a bit difficult[13].

IV. METHODOLOGY

To predict where CAD will evolve over the next few years, it is necessary to first understand the pressures that CAD customers are placing on software vendors or the level of design the customer is asking for. It would be logical to assume that these impacts will lead to continued change and growth in the industry. Patrick E. Connolly carried out a research and found out that major CAD manufacturer had several business concerns:

1. Global competition causing companies to constantly seek to reduce time and costs,
2. The global nature of the business with both customers and clients is about collaborative partners and connectivity needs, better language and information sharing,
3. Product quality issues,
4. Information management issues,
5. Rapid development of the World Wide Web and the Internet / Intranet technologies and
6. Ability to manage larger and more complex data in CAD

Through discussions with many major CAD service providers, the CAD industry's key trends and directions have been divided into four distinct areas:

1. **Interface**: It regards to the “look” and “feel” of the software. Ease of use is becoming an important factor in consumer evaluation and purchasing decisions.
2. **Functionality**: Functionality refers to what the CAD system can do, that is, the tasks it can perform. For most of CAD history, developers have raced to add horizontal functionality (more advanced capabilities) with each subsequent release at the expense of good vertical performance (the ability to do as much as the user wants).
3. **Capacity**: Capacity refers to the ability of a CAD system to handle large amounts of data. In the past, this capability referred to the CAD system's ability to work when dealing with objects with multiple locations. Skill or explanatory ability is now used more to describe complex products.
4. **Management and Communication**: The most exciting areas related to CAD are the World Wide Web, information management, data exchange standards, and collaborative engineering. These can be classified as management and communication. This is probably the fastest growing and most changing area the CAD industry has to deal with.

V. ADVANCEMENTS OF CAD

V.I. INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) IN CAD

The term "Artificial Intelligence" is used to describe the ability of machines to imitate human intelligence through learning and reasoning when solving complex problems. Intelligent machines decide independently and are infallible as they are created. In recent years, companies have managed to create a more efficient and effective CAD environment by integrating artificial intelligence into their systems. Integrating artificial intelligence into CAD systems will reduce delivery times and create a more intuitive design environment[15].

Researchers recognize the need to develop design skills early in the CAD development process. Many studies have prepared the main focuses of intelligent design research. According to their report, research on intelligent design includes small-scale design, general-purpose design, artificial intelligence and analysis, and image integration. He concluded that intelligent graphical interfaces provide existing CAD systems with more tools to increase the accuracy and precision of designs, thereby increasing efficiency and productivity. However, the development of intelligent design is still a research hotspot. Miller et al. (2018) extended the CAD model to include product design and behavior using data previously available in a separate digital twin application. Heikkinen et al. (2018) found seven specific strategies for using CAD models as interactive documents. Panarotto et al. (2020) developed a method for multi-concept CAD modeling based on the combination of modeling and CAD[2].

Figure 3 shows how traditional CAD can be transformed into a smart CAD system. The process of combining CAD with AI is called model-based reasoning (MBR). The Features of MBR are as follows:

1. Elements are stored in a hierarchical manner so that the relationship between them can be understood
2. Information on thinking and decision-making are processed by design professionals
3. Comprehensive review of effective products and various simulations
4. Identification of the effectiveness of product analysis
5. Easy configuration of processes in the database

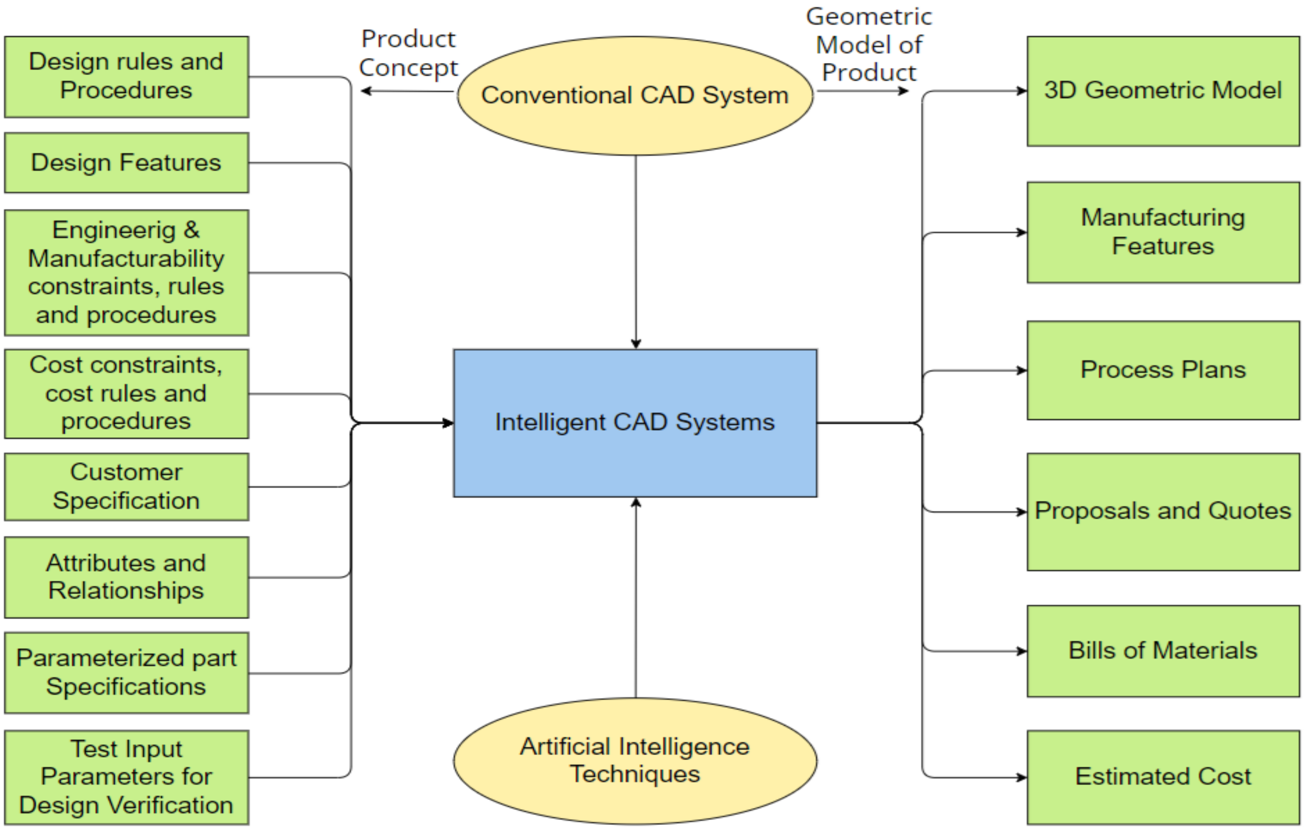

Fig. 3 Intelligent CAD Systems (CAD + AI)

V.II. INTEGRATION OF EXTENDED REALITY IN CAD

Since the advent of CAD systems, people have viewed an object in three dimensions before designing it. Nowadays, CAD models are used instead of 3D models. Simulation effects and planning work are done on CAD. However, there are still differences in CAD applications that cannot provide the optimal and interactive experience, such as Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). With the constant use of technology, models created in CAD software are uploaded to VR, AR and MR platforms for simulation and detailing purposes.

V.II.I. VIRTUAL REALITY

Virtual reality (VR) technology uses computer simulation to create and experience the virtual world of the real system. Users of virtual reality technology are completely immersed in the environment during the simulation. Two characteristics of VR are immersion and interactivity. Now VR is adapted to use multiple sensors (voice recognition, eye recognition, gestures and brain waves) and multi-domain information communication with impact on the world.

V.II.II. AUGMENTED REALITY

Augmented reality (AR) is a computer technology that is part virtual and part realistic. Augmented reality is a real-time calculation that uses the camera's position to combine images taken from the same angle[16]. The goal of AR technology is to allow the virtual world process created on the screen to interact with the real world. According to their report, AR CAD system is an AR assistant integrated into the CAD model to provide a better relationship with the design model.

V.II.III. MIXED REALITY

Mixed reality (MR) is a further development of virtual reality technology[17]. It is a machine created by bringing reality into a virtual environment. Since MR technology includes both virtual and real objects, it will improve perception for a better experience. Mixed reality systems generally have three main features:

1. Combination of virtual and reality
2. Three-dimensional space (3D recording)
3. Urgent employment

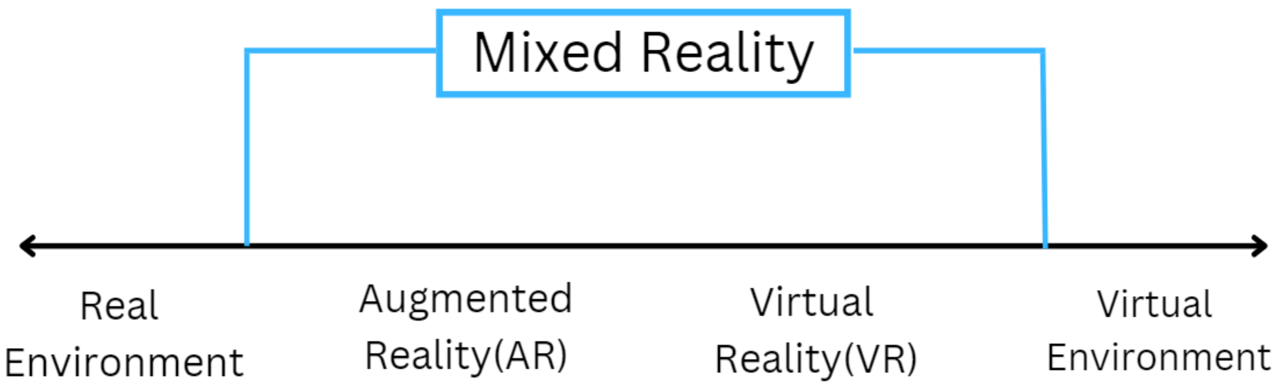

Fig. 4 Relationship between Virtual reality (VR), Augmented reality (AR) and Mixed Reality (MR)

V.II.IV. INTEGRATION OF 3D PRINTING TECHNOLOGY IN CAD

One of the practical uses of CAD is 3D printing. In 3D printing technology, you must first create a 3D product model with appropriate dimensions, then save it as a CAD file in CAD software using the following commands. CAD files contain instructions or rules for controlling a 3D printer. It determines how far the product should be placed and where it should be placed. The saved CAD file will be sent to a 3D printer for processing. 3D printers create parts or objects by adding layer by layer based on what is missing in the CAD file. It is also called additive manufacturing[18]. The use of CAD for the production of three-dimensional objects and models is not available in all cases of 3D printers.

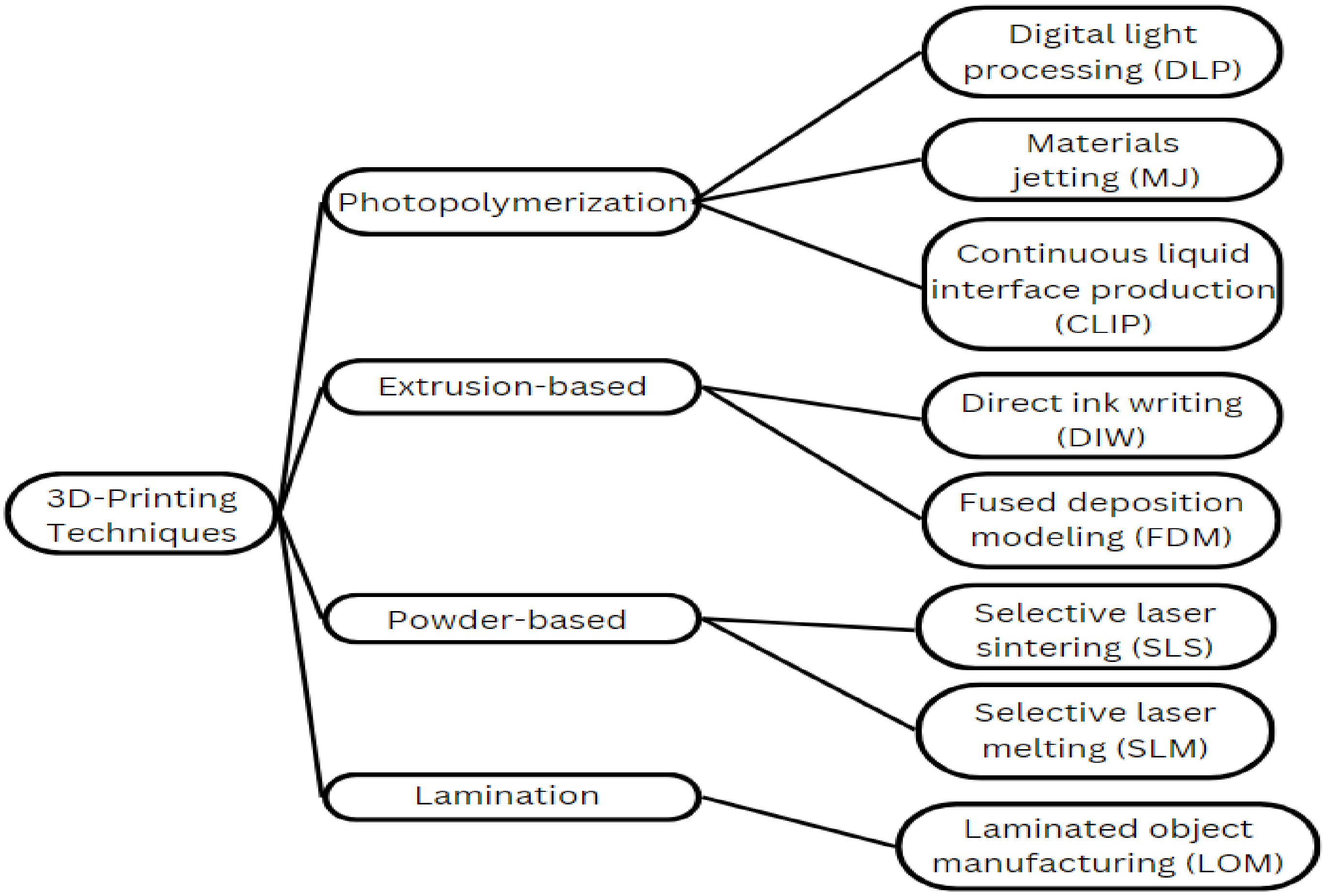

Fig 5 3D Printing Techniques

VI. FUTURE SCOPE OF IMPROVEMENT IN ENGINEERING DESIGN TOOLS AND WORKFLOW

According to the needs of the CAD/CAE environment in the DAM research area, attention can be drawn to the necessary development of future CAD tools and job-creating changes. Some of them are explained in more detail below:

V.I. REPRESENTATION OF GEOMETRY

Today's CAD systems only support certain representation methods, often leading to dead ends and additional effort. However, none of these methods can be considered one of the best methods for producing additional materials in the future[4]. Such resources will unlock new levels of complexity to power the creation of more productive products. Therefore, development should focus on features of future CAD systems that support, modify and provide accurate and precise models and use the correct method to complete the job.

V.II. MANIPULATION OF GEOMETRY

Designers, as humans, are far from the essence and importance of the design process. These stars are still valid for future design practice, even in the context of DAM, where people will be limited in their search for good design. If the geometry manipulation capabilities of CAD tools are not easy enough, design simplification as a shortcut to reduce model effort results in the loss of some of the possibility. That's why it's important to have a design tool that will make creating projects easier. Therefore, the Geometry Operations category focuses on the different methods engineers use when designing virtual models from the front-end system.

V.III. RECOMMENDATIONS FOR DESIGN WORK TO TAKE INTO ACCOUNT DAM'S REQUIREMENTS

The first major difference between design and functional thinking is the more important aspect of the process. Knowing the part design is only possible after precise analysis of the design space. The second difference is the importance of the function of the object before geometric design[4]. The main architecture of the work shown is based on the following three areas: First, Due to the freedom of additive manufacturing (such as integration and joint capacity), additive manufacturing can easily achieve a highly efficient operation compared to traditional manufacturing processes. Second, It should be said that as the number of activities to be carried out in a component increases, the possibility of creating an area of conflict will also increase. Third, Compared with traditional manufacturing technology, AM is generally considered to produce computer-generated optimized geometries that exceed human design capacity, thus improving the use of designs.

VI. DISCUSSION

Originally, CAD systems were used only to assist in drafting rather than manufacturing. This situation has caused the system to progress slowly in the engineering industry in general and in the manufacturing industry in particular. But seeing improvements in performance and productivity after using CAD systems, many industries started worked on it. Now the design phase has become the most important part of production as it affects quality, cost and overall profit. As computer systems evolve, crashes occur. Improving the integration of graphics software also meets the needs of using CAD systems by creating interactive workstations. According to this review, the benefits of CAD can be enhanced when combined with artificial intelligence, realism and manufacturing. The integration of CAD and AI takes design to the next level. Integrating intelligence into CAD can improve the design process, store information, change it without affecting people, reduce production time, provide ergonomic engineering, etc. CAD with VR, AR and MR content provides detailed design information with an interactive and integrated approach[2]. The benefits of VR, AR and MR systems are that they can train machines without real machines, improve teaching, reduce waste and interact with virtual machines.

From this study, we can clearly see that although the research area of DAM has been much studied, the design process still hides challenges that have not been fully resolved. Overall, the need for improvement in the CAD tools presented in this project will not only be beneficial to the DAM environment[4]. Additionally, manufacturing processes such as die casting also lead to design freedom and can benefit from the addition of CAD capabilities to process collaboration in combination with road geometry design. Implications for future research focusing on CAD systems include further investigation of the effects and measures required to meet the DAM requirements outlined in this study. For CAE studies, it is necessary to add detailed information on the subject of design sensitivity for the teaching of each discipline, which is important for the effectiveness of teaching about design studies. Another area that needs further analysis in the context of product development is the underlying process of managing complex needs and trade-offs.

VII. CONCLUSION

The main aim of this project is to solve the need for further development of engineering design tools (CAD/CAE) to deal with complex designs, thus enabling civil engineers to exploit the potential of additive manufacturing. The review concludes that the need for multiple devices as a single input, interactive simulation, and integration directly from design is driving CAD forward. From the author's perspective, the purpose of integrating intelligence into CAD is to create intelligent designs in the design and manufacturing industry through the development of different software that includes calculations and qualification assessment. The review also noted that although AI-integrated CAD has many advantages over traditional CAD, it still needs a lot of work to become more recognized by the business world and educational institutions. Also, It is not enough to create additional CAD resources to demonstrate that these requirements are met. All four major layers of the CAD system (front-end, back-end, kernel, and processing unit) will need further development and refinement. However, it became clear that CAD tools themselves did not need to transition into design and complete the integration but at the same time the design work also had to be modified to meet additional needs and leveraging the design capabilities of additive manufacturing.

REFERENCES

1. T. F. A. Bds and C. A. D. Cam, "ScienceDirect Advancements in CAD / CAM technology : Options for practical implementation," *J. Prosthodont. Res.*, 2016, doi: 10.1016/j.jpor.2016.01.003.
2. B. Regassa Hunde and A. Debebe Woldeyohannes, "Future prospects of computer-aided design (CAD) – A review from the perspective of artificial intelligence (AI), extended reality, and 3D printing," *Results Eng.*, vol. 14, no. May, p. 100478, 2022, doi: 10.1016/j.rineng.2022.100478.
3. D. J. Kasik, W. Buxton, and D. R. Ferguson, "Ten cad challenges," *IEEE Comput. Graph. Appl.*, vol. 25, no. 2, pp. 81–92, 2005, doi: 10.1109/MCG.2005.48.
4. D. Fuchs, R. Bartz, S. Kuschmitz, and T. Vietor, "Necessary advances in computer-aided design to leverage on additive manufacturing design freedom," *Int. J. Interact. Des. Manuf.*, vol. 16, no. 4, pp. 1633–1651, 2022, doi: 10.1007/s12008-022-00888-z.
5. H. O. T. Ware, R. Hai, and C. Sun, *Vat Photopolymerization*, vol. Part F1592. 2023. doi: 10.1007/978-3-031-20752-5_22.
6. M. Kumke, H. Watschke, and T. Vietor, "A new methodological framework for design for additive manufacturing," *Virtual Phys. Prototyp.*, vol. 11, no. 1, pp. 3–19, 2016, doi: 10.1080/17452759.2016.1139377.
7. [7] F. Belkadi, L. M. Vidal, A. Bernard, E. Pei, and E. M. Sanfilippo, "Towards an Unified Additive Manufacturing Product-Process Model for Digital Chain Management Purpose," *Procedia CIRP*, vol. 70, pp. 428–433, 2018, doi: 10.1016/j.procir.2018.03.146.
8. C. Beyer, "Strategic Implications of Current Trends in Additive Manufacturing," *J. Manuf. Sci. Eng. Trans. ASME*, vol. 136, no. 6, 2014, doi: 10.1115/1.4028599.
9. S. Andre, R. Stolt, F. Elgh, J. Johansson, and M. Poorkiany, "Managing fluctuating requirements by platforms defined in the interface between technology and product development," *Adv. Transdiscipl. Eng.*, pp. 424–433, 2014, doi: 10.3233/978-1-61499-440-4-424.
10. J. Johansson, "A Feature and Script Based Integration of CAD and FEA to Support Design of Variant Rich Products," *Comput. Aided. Des. Appl.*, vol. 11, no. 5, pp. 552–559, 2014, doi: 10.1080/16864360.2014.902687.
11. J. Johansson, S. André, and F. Elgh, "Simulation ready CAD-models as a means for knowledge transfer between technology development and product development," *DS 80-6 Proc. 20th Int. Conf. Eng. Des. (ICED 15) Vol 6 Des. Methods Tools - Part 2 Milan, Italy, 27-30.07.15*, no. July 2015, pp. 195–204, 2015, [Online]. Available: https://www.designsociety.org/publication/37842/simulation_ready_cad models_as_a_means_for_knowledge_transfer_between_technology_development_and_product_development "Dental CAD.pdf."
12. M. A. Abdulla, "CAD-CAM Technology : A literature Review," vol. 20, 2020, doi: 10.33899/rden.2020.164542.
13. A. Asanowicz, "Evolution of Computer Aided Design: three generations of CAD," *Proc. Int. Conf. Educ. Res. Comput. Aided Archit. Des. Eur.*, pp. 94–100, 1999, doi: 10.52842/conf.ecaade.1999.094.
14. Y. Xu *et al.*, "Artificial intelligence: A powerful paradigm for scientific research," *Innovation*, vol. 2, no. 4, 2021, doi:

10.1016/j.xinn.2021.100179.
15. M.-B. Ibáñez and C. Delgado-Kloos, “Augmented reality for STEM learning: A systematic review,” *Comput. Educ.*, vol. 123, pp. 109–123, Aug. 2018, doi: 10.1016/j.compedu.2018.05.002.
16. M. Farshid, J. Paschen, T. Eriksson, and J. Kietzmann, “Go boldly!,” *Bus. Horiz.*, vol. 61, no. 5, pp. 657–663, Sep. 2018, doi: 10.1016/j.bushor.2018.05.009.
17. S. Kumar, P. Bhushan, M. Pandey, and S. Bhattacharya, “Additive manufacturing as an emerging technology for fabrication of microelectromechanical systems (MEMS),” *J. Micromanufacturing*, vol. 2, no. 2, pp. 175–197, 2019, doi: 10.1177/2516598419843688.