A Process for Creating and Designing Automated CAD Models Through the Solid Works API

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ABSTRACT

This study proposes a novel method for speeding up CAD modelling procedures by combining parametric modelling strategies, Knowledge-Based Systems (KBS), and Visual Basic for Applications (VBA) inside the SolidWorks environment. The suggested system accepts client design requirements through a user-friendly graphical user interface (GUI), utilising the power of knowledge representation and automation to speed up the design process. This technique greatly decreases the amount of time needed to model CAD, improves design correctness, and equips engineers to quickly convert client demands into real components by utilising KBS and parametric modelling. This research shows the viability and efficacy of this unique technique, highlighting its potential to transform the processes of product design and development.

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1. INTRODUCTION

The need to simplify CAD (Computer-Aided Design) modelling procedures is more important than ever in the modern engineering and design scene. Industries need to converge technologies and techniques to speed up design while guaranteeing unchanging precision and flexibility as they constantly push the limits of innovation, cost-efficiency, and product customization [1]. Our research paper sets out to thoroughly examine the complex interactions between Knowledge-Based Engineering (KBE), CAD modelling techniques integrated into the SolidWorks environment, design automation paradigms, Application Programming Interfaces (APIs), the scripting language VBA, and the potent potential of macro code in this pursuit.

1.1 Knowledge Based Engineering (KBE)

Knowledge-Based Engineering, a multifaceted paradigm set to change the face of engineering design, is at the centre of our investigation. KBE is essentially the confluence of computer power with human expertise. It symbolises how domain-specific information, such as engineering principles, design guidelines, professional heuristics, and decision-making algorithms, are integrated into intelligent systems [2]. These systems enable engineers to codify their abundance of information and are frequently based on rule-based engines or knowledge-based reasoning. They open the door for the automation of many design processes, from idea through modelling in detail. KBE is at the forefront of systematic and streamlined design, promising to increase engineering efficiency to previously unheard-of heights.

1.2 CAD-Modeling in SolidWorks

SolidWorks, a leader in the CAD software market, is a model of design adaptability and complexity control. It provides a complete set of tools for creating complex 3D models, simulations, and assembly for engineers and designers. However, hand building of these models can be a challenging task, especially when dealing with complex client design requirements. The possibility of drastically reducing design durations while simultaneously improving the accuracy and quality of the finished product is made possible by the incorporation of automated approaches inside the

SolidWorks environment. The CAD modelling industry may enter a new age by using automation, and SolidWorks is the canvas [3].

1.3 Design Automation

The idea of design automation—a feature that goes beyond simple expediency to revolutionise the fundamental principles of design—lays the foundation for our inquiry. Computational methods and engineering inventiveness are strategically used in design automation to speed up complex design processes. It acts as a channel for engineers to break free from the constraints of physical labour. At its core, automation includes parameterization, adherence to rule-based decision-making, and the codification and coordination of repetitive and algorithmic operations [1,3]. The ultimate goal is to significantly minimise the amount of time required for the CAD modelling process while strengthening consistency and conformance to specified design principles. Beyond time savings, design automation improves the output's overall calibre, consistency, and dependability. It represents the forefront of development in the design ecosystem.

1.4 Application Programming Interface (API)

The Application Programming Interface included into SolidWorks is at the heart of our investigation since it has the potential to democratise design through automation. APIs serve as the entry points that allow programmatic interaction between engineers and developers and software applications. The API in the context of SolidWorks becomes the crucial gateway via which users enhance the built-in features of the programme. Engineers may use the API to create custom solutions, scripts, and plugins without being restricted by the limitations of pre-made tools. The beginning of a new age in customisation and automation is signalled by this mutually beneficial combination. Engineers can use the API to build a digital toolbox that is tailored to their own design processes and operational needs [4].

Languages like VB.NET, C#, and Visual C++ are used for API programming [4]. Due of its simplicity and adherence to fundamental programming principles, this study chooses Visual Basic (VB). The vast majority of CAD software products include macro functionality and flexible APIs. SolidWorks 2020 was selected for this project due of its user-friendliness and interoperability with other software packages. It is noteworthy that SolidWorks 2020 has a built-in VB Interface [2].

Software for SolidWorks may be automated and customised thanks to the API, or application programming interface. This COM-based interface has a wide range of features that may be accessed from macro files in Visual Basic (VB), VBA, VB.Net, C++, C#, and SolidWorks. Direct access to SolidWorks capabilities is made possible by these functionalities, allowing for the automation of particular processes and activities [4].

1.5 Visual Basic for Applications (VBA)

The automation cornerstone VBA grows within this environment of technical synergy. VBA is a powerful and user-friendly programming language that integrates well with the SolidWorks environment. It gives users the ability to create unique macros and code snippets that automate a wide range of design and modelling tasks. The simplicity, versatility, and accessibility of VBA are its defining characteristics, making it a vital tool for engineers and designers looking to create customised automation solutions. Engineers are given the creative freedom to develop solutions that are precisely in line with their individual design processes thanks to VBA's function as an automation enabler. The idea of empowerment via automation is embodied in it.

Because of its simplicity and usefulness as a tool for creating macros, Visual Basic plays a crucial role in supporting this project. In truth, the most straightforward and efficient programming tool for creating macros is Visual Basic. Its adaptability also extends to producing numerous programming codes for different purposes, making it very practical [4]. Engineers may smoothly combine Visual Basic with a variety of Windows programmes by using ActiveX dynamic link libraries, or DLLs 4].

A CAD programme called SolidWorks makes use of API and VBA functionality to enable modelling automation. This involves having the ability to design a custom GUI. The creation of functionally useful macro code is greatly aided by Microsoft's VB software, making it easier to carry out repeated activities. Any operation carried out on the SolidWorks interface may be recorded and stored using a macro, enabling its repetition whenever required [4].

1.6 Macro Code

Macro code, a conductor of a digital symphony who choreographs the complex dance of design processes, becomes apparent as we explore deeper into the areas of design automation. Built on the solid basis of VBA, macro code contains predetermined sets of instructions and commands. Similar to virtual assistants, these macros may be used inside the SolidWorks environment to automate particular design processes. Their flexibility is demonstrated by the wide range of operations they are capable of carrying out, such as parameter changes, geometry modification, data extraction, and iterative procedures. Engineers may record, edit, and reuse action sequences using macros, which are a pillar of efficiency. As a consequence, engineers are given the ability to automate monotonous operations, adapt to changing design requirements, and focus their cognitive abilities on higher-order design components.

A macro is a set of rules or instructions that specify how a certain input sequence should be converted into an output sequence while adhering to a predetermined process [4]. The macro used is programmed in VB [4] and is used in automated modelling. A Visual Basic programme for material selection may be created in SolidWorks by using certain Macro Operations instructions [4]. Recording a macro in SolidWorks can occasionally provide the code needed for following parameters, but other times, a special algorithm must be created [4].

1.7 Novelty of the work

We propose a new approach to speeding up SolidWorks-based CAD processes by combining parametric modelling with KBS and VBA. Engineers encounter distinct hurdles when trying to efficiently translate client design requirements into physical components; our technique provides a unique answer to these problems. Our method improves design correctness while drastically cutting down on CAD modelling time by utilising knowledge representation and automation.

Engineers may take use of pre-defined knowledge and automate repetitive processes in the CAD environment with our approach's revolutionary fusion of parametric modelling concepts with KBS and VBA scripting. Thanks to this connectivity, engineers can now iterate on designs more quickly and adapt to changing customer requests more effectively. It also streamlines the design process.

In addition, our findings show that this novel approach may successfully refurbish conventional CAD modelling processes. With the help of an intuitive GUI, engineers can quickly and efficiently create intricate CAD models from customer specifications with little to no human input required. Improved product design and development cycles are the end result of increased productivity as well as improved client-engineer communication and cooperation.

All things considered, our suggested method is a huge leap forward in CAD modelling technology, providing a flexible and scalable answer to the ever-changing problems that arise in contemporary engineering. This research highlights the potential for revolutionary effects on product design and development processes by demonstrating the feasibility and efficacy of our method. It also opens the door for future improvements in automated CAD modelling systems.

In summary, this work has six sections. The Literature Review gives an overview of existing methodologies and technology pertinent to CAD modeling. The Methodology section discusses our recommended methodology in depth. Implementation Challenges highlights the practical considerations and problems found during the implementation of our technique. The Conclusion presents an overview of our findings and ideas for further research. Finally, the References section provides the sources mentioned throughout the text.

2. LITERATURE REVIEW

An overview of the available research on the automation of component design is given in this section. In order to provide optimised designs at the preliminary design stage, Vinjanampati et al. [2] investigated a knowledge-based integrated parametric product design philosophy that includes diverse functions including design, performance, stress analysis, manufacturing, and automation. A standard architecture for a product family is first established using information already in existence as well as elements like Design Failure Mode Effects Analysis (DFMEA) and Design for Manufacturing & Assembly (DFMA). Then, depending on client needs, it determines critical characteristics essential for effective design, performance, and stress concerns. The procedure comprises automating essential design scenarios using physics-based or hybrid models, sensitivity analysis to pinpoint crucial design elements, and parametrization in CAD. Parametric connections are established by the use of analytical Design of Experiments (DOE). The case study of parametrically optimising a hydraulic actuator in the article serves as an illustration for this strategy.

Xinjiani et al. [5] framed a Knowledge based design automation system in the year 2021. The variety of product kinds and sophisticated domain knowledge have historically made it necessary for specialised design techniques in mechanical product design, which has raised research and development expenditures. Additionally, automation and acceleration are difficult since the design process has traditionally placed a strong emphasis on expert judgement and practical knowledge. This project created a Knowledge-Based Automated Design (KAD) system for mechanical goods to overcome these problems. through describe design information from basic stages through final CAD model generation, it proposed a General Feature Design Flow (GFDF) architecture. The Analytic Hierarchy Process (AHP) has been suggested as a technique for transforming qualitative qualities into quantitative metrics. Feature Reuse Case Adaptation (FR-CA) based on Case-Based Reasoning (CBR) and Support Vector Regression (SVR) was also added into the system to intelligently automate parameter solution even in the absence of direct expert input. The use of the KAD approach for corn husker design revealed notable advancements in automated, intelligent, and quick mechanical design.

The use of an automated design process to speed up the creation of component geometries for additive manufacturing (AM) while minimising manual input is stressed by Manuel Biedermann et al. in their study [6]. The purpose is to familiarise fluid and process engineering experts with this automated design methodology. Through a knowledge-based approach and the MOKA framework, the research defines the essential stages for putting this automated design technique into practise. The research effectively illustrates the applicability of this method on flow manifolds. Future studies might examine how automated design in AM can be used more broadly to different fluid and process engineering devices.

A knowledge-based automated mechanical design of a robot manipulator was created by Robert et al. [7]. Particularly in settings with fewer Degrees of Freedom (DOFs) or complicated industrial contexts, optimisation techniques are useful for improving the design and cost-effectiveness of robotic arms. But many of the current algorithms ignore the actual sizes of the parts of robotic arms, which makes them less useful. This work offers a method that blends real-element iterative selection with evolutionary algorithms for kinematic optimisation. This method simplifies the design process, which was shown by creating an arm for moving workpieces between industrial machines. While some research recommends general guidelines for the proportions of robotic arms, this frequently results in problems like accidents. Despite its complexity, the automated technique used in this work bridges the gap between theoretical and real-world kinematic designs. The developed five-DOF robotic arm offers cost-efficiency advantages, especially when fewer DOFs are adequate, even if it may not yet be competitive with optimised alternatives. Designing a unique arm becomes necessary in situations demanding numerous degrees of freedom, and automated techniques make it easier to do so.

To automate the design of cubes, Dwaipayan Roy Chowdhury et al. [8] used a method that made use of SolidWorks and VB.net. To speed up the cube design process, they utilised a macro program-based technique. They were able to produce cubes with defined dimensions, chosen materials, and chosen colours by utilising the capabilities provided by the SolidWorks API. Similar to this, a tool for developing pistons and connecting rods was created by Balachandar Krishnamurty et al. [9]. By combining the SolidWorks API and macro scripts, they were able to accomplish this. Notably, it can be time-consuming and expensive to adapt current designs the conventional way. However, the modelling and assembly of pistons and connecting rods got a lot easier thanks to the introduction of a user-friendly interface in their job. This invention saves time and money by obviating the need to engage a design engineer and considerably improving efficiency.

A design approach for spur gears was taken by Jayakiran Reddy et al. [10], who combined a knowledge-based system with the SolidWorks API and macro codes. Important parts of this comprehensive system include an Inference Engine, a Graphical User Interface, and a Knowledge Base. Data relevant to the user's needs is stored in the Graphical User Interface, while design professionals' insights and data on standard components are added to the Knowledge Base. This method saves time by enabling clients or users to get the components they need right away.

Andrijana Bocevska et al. [11] created a CAD system specifically suited for making car rims in a specialised setting. The interface of this CAD system makes use of macros to promote user involvement. Engineers now have greater freedom to consider novel options, which enables quicker and more precise modelling of high-quality products.

SolidWorks and the SolidWorks API architecture were used by Jayakiran Reddy et al. [12] to automate the production of a CAD model for a Universal Coupling. They used a knowledge-based method to speed up the modelling of an existing item with minor design changes. When compared to manual procedures, this technology allows for the parametric models of the component to regenerate quickly.

Joshi et al. [13] achieved a substantial advancement in the automation of CAD modelling for mechanical components. While significantly reducing human costs and time, this approach to design automation offers a number of noticeable advantages, including increased productivity, improved resilience, and improved overall quality. They employed this technology expressly to automate the design of a cotter joint to show how it may provide superior results and take much less time than traditional human modelling procedures. One of this automated system's key advantages is its ability to do complex calculations in the software's backend, enabling the creation of safe and error-free designs. By simplifying the design process and lowering the possibility of modelling errors, this supports a more efficient and reliable engineering workflow.

Utilising the SolidWorks Simulation Application Programming Interface, Rui Lyu et al. [14] concentrated on automating the simulation of vehicle chassis frame systems. This method involves the use of SolidWorks, where a programme for the selection of materials was created in Visual Basic. The fact that these materials' characteristics might be directly changed by employing macro codes is notable. This automation improves the versatility and adaptability of the design simulation inside the SolidWorks framework by streamlining the simulation process and providing a useful way to effectively modify material attributes.

Abhishek et al. [15] study used SolidWorks Application User Interface to generate the design and design automation of a winding machine. Since winding machines can have a large number of parts, designing one is difficult and time-consuming. However, by utilising design automation techniques, they were able to produce the winding machine's CAD model in a startlingly short amount of time—just two hours. This notable decrease in design time resulted in an astonishing time savings of 80% for the whole design process. Additionally, by using a more efficient approach to design, precious time was also saved, and the project as a whole saw cost reductions of up to 25%. This demonstrates the significant time and money savings that automation can provide for complicated design processes.

Necdet et al. [16] concluded in their research that, within a flexible design environment, the "parametric design platform" provides a useful and reliable solution for the automatic sizing of a steering ball joint. This platform enables the parametric modification of many design parameters, such as component, material, feature, geometry, assembly, and dimensions. It does this by utilising 3D modelling techniques and a knowledge base of ball joints maintained in a database. Through the course of the product's life cycle, it also integrates structured data that complies with technical standards and reasoning methods. The study shows that this platform can size ball joints efficiently to guarantee an indefinite fatigue life with little reliance on human knowledge and involvement. This study addresses an urgent requirement in the automobile sector, notably for the design of steering system safety-critical parts like ball joints.

To improve the productivity of CAD modelling for flange coupling, Patil et al. [17] introduce a new way to combine Autodesk AutoCAD with Python programming. This is comparable to the method discussed in this article. A knowledge-based system approach to design and a specialised GUI for parametric design are the main contributions of Patil et. al. [17]. These features simplify customisation and meet the demands of different machines. Rapid change frameworks are necessary since many applications do not have full digitalization, despite the importance of digital design. As part of an integrated system's coupling design, the KBE method is used to determine process sequences according to coupling applications. The Python and AutoCAD API were used to construct the design framework, which produces two-dimensional drawings. A specialised GUI for parametric design enhances user productivity, while an expert system employing the KBS technique enriches the design framework. Custom flange coupling designs and 2D manufacturing drawings are delivered by the study, demonstrating the effectiveness of knowledge-based learning for efficient, resilient, and cost-effective designs.

In response to Industry 4.0's demand for more automation across the product lifecycle, especially during the design phase, which calls for a digital transformation, Liang et al. [18] discussed this topic. The goal of information-Based Engineering (KBE) is to improve design efficiency by the automation of engineering processes through the formalisation of explicit information. While parametric modeling receives attention in KBE frameworks, rule representation at the design stage is generally disregarded. The research presents a lightweight framework for creating KBE applications in steady-evolving mechanical product design, covering both parametric modeling and rule representation. It identifies design processes, formalizes product design information using Service-Oriented Architecture (SOA) and ontology-based techniques, and verifies the framework using a pipe routing case study. The study reveals that a lightweight framework employing established technology stacks may simplify KBE-style design, requiring less effort to implement compared to existing frameworks.

Reddy et. al. [19] worked on developing an automatic CAD modelling applications for industrial battery stack. The paper discusses the development of a Knowledge-Based System (KBS) for CAD modeling of industrial battery stacks using SolidWorks. The system utilizes API for automation, GUI for user input, and an inference engine for AI-based solutions. It employs a logical algorithm for design calculations, parametric modeling for efficiency, and macro programming for CAD modeling. The system is robust, tested with abnormal data, and effectively reduces CAD modeling time. It has the potential for extension to other CAD software, offering customization, automation, and efficiency in generating 3D models easily.

Shubham et. al. [20] worked on developing preliminary approach for automatic generation of the CAD Model of the Spur Gear. The paper focuses on developing a knowledge-based system (KBS) for automating the CAD modeling of spur gears. It highlights the use of parametric modeling techniques and SolidWorks software to streamline the design process. By integrating Visual Basic and API interfaces, the system efficiently generates CAD models with high accuracy. The proposed approach significantly reduces the time required for modeling compared to manual methods, showcasing its effectiveness in enhancing productivity and design quality for spur gears.

Reddy et. al. [21] worked on development of automatic CAD model generation of connecting rod. The paper discusses the development of a knowledge-based system for CAD modeling of a two-wheeler IC Engine Connecting Rod using SolidWorks. It focuses on parametric modeling techniques to address the complexities in geometry and design modifications efficiently. The system utilizes Visual Basic and SolidWorks redevelopment technologies to automate the CAD modeling process, reducing time and improving design quality. The system includes an inference engine and GUI within the CAD software to assist design engineers, offering a user-friendly interface for both expert and non-expert users. Overall, the system enhances design efficiency, quality, and turnaround time in CAD modeling.

Similar to earlier, Bill et. al. [22] and Nikhil et. al. [23] worked on basic automated CAD modelling approach for an IC engine piston. These papers discusses an automated CAD modeling approach for IC engine pistons using SolidWorks. It emphasizes the importance of updating CAD models to reflect changes in the engine assembly due to interrelated plan concerns. By integrating knowledge-based systems and SolidWorks API, the design process is streamlined, reducing time and costs. The use of custom GUIs, macros, and parametric modeling techniques automates design calculations and modeling processes, improving efficiency and design quality. The study highlights the significance of material selection and design automation in enhancing the performance and efficiency of IC engine pistons.

Jayakiran et. al. [24] has addressed an approach to develop the knowledge-based system for developing the CAD model. In the paper, the authors have demonstrated the effectiveness in using the KBS systems. KBS for CAD modeling have emerged as an effective approach to streamline design processes and reduce modeling time. These systems integrate parametric modeling techniques with design knowledge to automate and optimize CAD model generation for various components.

The development of automated CAD modeling systems for IC engine components, particularly crankshafts and pistons, has gained significant attention in recent years. These systems aim to reduce design time, optimize performance, and improve manufacturing efficiency. Pranay et. al. [25] worked on developing the automated CAD model generation of IC engine crankshaft. A dynamic simulation was conducted on crankshaft, from multicylinder four stroke engine. Geometry, material and manufacturing processes were optimized considering different constraints, manufacturing feasibility and cost. The optimization process included geometry changes compatible with the current engine, fillet rolling and result in in- creased fatigue strength and reduced cost of the crankshaft, without changing connecting rod and engine block.

Reddy et. al. [26] discusses the development of a KBS for modeling Bolts, Nuts, and Bearings using parametric modeling techniques in SolidWorks integrated with Microsoft Access. It highlights the use of macros and VB code to automate the modeling process efficiently. The study emphasizes the benefits of parametric modeling in saving time and costs for standard components. Future work includes expanding the knowledge base and integrating with analysis or CAM packages. Additionally, the research explores the application of SolidWorks API for efficient design processes. Overall, the paper showcases the potential of KBS and parametric modeling in automating design and modeling tasks for various components.

Sarikonda et. al. [27] developed an automated CAD model generation system. This automated CAD modeling system utilizes parametric modeling techniques and the SolidWorks API to streamline design automation. By integrating KBS, the system efficiently generates CAD models of different rivet types. The process involves developing logical macro codes to automate the creation of rivet models, enhancing production efficiency. The system allows for the rapid production of CAD models, particularly for rivets, which are crucial components in structural safety evaluations. Through the use of KBS and macro programming, the system simplifies the modeling process, reducing design complexities and potential errors. Overall, the system offers a user-friendly interface for generating CAD models of various rivet types, contributing to faster and more accurate design processes.

Bill et. al. [28] has worked on FEM on IC engine using design automation. This paper introduces a KBS for automated CAD modelling of IC engine pistons, reducing design time and costs significantly. The approach leverages SolidWorks and Visual Basic to streamline the process, making it accessible to inexperienced designers. By automating design calculations and eliminating human intervention, the system enhances efficiency and design quality. The study highlights the importance of parametric modelling in overcoming the complexities of traditional CAD methodologies for IC engine pistons. FEM analysis using Ansys validates the stability of the proposed technique, emphasizing the need for automation in the automobile industry to improve IC engine performance.

Esanakula et. al. [29] worked on spur gear design automation. They discussed on developing a basic CAD model of a spur gear using an automated approach, focusing on parametric modeling techniques and knowledge-based engineering systems. The proposed system significantly reduces modeling time and produces accurate CAD models quickly. The results show that the system generates CAD models with near dimension accuracy in just 15 seconds, compared to 150-200 hours manually. The system is limited to SolidWorks software but can be extended to other CAD systems with additional effort.

In conclusion, from the literature review we see that over the years, the field of CAD technology has seen significant improvements and furthermore it has been observed that a considerable gap exists particularly with the manipulation of parametric modeling strategies, Knowledge-Based Systems (KBS), and Visual Basic for Applications (VBA) all in one study in SolidWorks. We have seen many related studies incorporating these technologies independently, however literature lacks extensive techniques that incorporate all of these to help improve CAD modeling operations and enhance design efficiency. Research endeavours such as this one is very critical particularly for robust and sophisticated solutions that are necessary to adapt to the evolving engineering process requirements.

3. METHODOLOGY:

The approach used in this study is a multidimensional framework painstakingly created to merge VBA, macro code, KBE, parametric modelling methods, and SolidWorks environment. This comprehensive strategy strives to maintain the highest levels of accuracy and flexibility while greatly speeding up CAD modelling procedures.

3.1 Knowledge Gathering Approach:

The construction of the knowledge-based system (KBS) under our suggested strategy involves a systematic process of knowledge collection, extraction, and representation. To assure the robustness and efficacy of the KBS, we utilised a multi-faceted method to capture necessary domain-specific knowledge.

3.2 Domain Consideration:

The domain considered for knowledge collection comprises various elements of mechanical engineering design, with a focus on CAD modeling concepts, parametric modeling methodologies, and best practices for design automation inside the SolidWorks environment. This domain-specific approach enables us to adjust the knowledge collection method to the unique demands and requirements of CAD modeling activities.

3.3. Sources for Knowledge Creation:

Several sources have been reviewed for knowledge generation, including:

3.3.1 Domain Experts:

Expert input from experienced engineers and CAD designers gave useful insights into typical design processes, modeling approaches, and design restrictions prevalent in real-world engineering projects.

3.3.2 Existing Documentation and Standards:

We exhaustively evaluated technical documentation, industry standards, and best practices guidelines relevant to CAD modeling and design automation. This comprised manuals, textbooks, technical papers, and online materials relevant to SolidWorks and parametric modeling approaches.

3.3.3 Case Studies and Real-World Examples:

Analyzing case studies and real-world examples of CAD modeling projects helped discover repeating trends, design patterns, and typical issues found in practice. These findings were crucial in collecting tacit knowledge and converting it into explicit rules and procedures for the KBS.

3.3.4 Empirical Data Analysis:

Statistical study of empirical data connected to CAD modeling jobs gave quantitative insights into design preferences, parameter ranges, and design optimization criteria. This data-driven approach expanded the knowledge base of the system and enabled better informed decision-making during the modeling process.

3.4 Knowledge Representation:

The knowledge acquired from diverse sources was represented in the system using a variety of structured and unstructured forms, including:

3.4.1 Rule-Based Systems:

Expert rules were established based on the domain knowledge obtained from experts and documents. These rules incorporate heuristic principles, design limitations, and decision criteria regulating the CAD modeling process.

3.4.2 Knowledge Graphs:

Semantic representations of knowledge were developed using knowledge graphs, where concepts, relationships, and dependencies between design aspects were described in a graph structure. This provided versatile querying and reasoning capabilities within the KBS.

3.4.3 Ontologies:

Ontological models were established to codify the domain-specific ideas, characteristics, and connections crucial to CAD modeling. Ontologies established a standardized framework for knowledge representation, enabling interoperability and semantic enrichment of the system's knowledge base.

By utilising a comprehensive approach to information collecting and representation, our suggested methodology assures the resilience, flexibility, and efficacy of the knowledge-based system inside the CAD modeling environment.

3.5 Knowledge-Based System Development:

Knowledge Capture: In this first stage, we set out on a lengthy quest to collect and encode domain-specific knowledge. This entails in-depth discussions with subject matter specialists who have a thorough grasp of the technical principles, design guidelines, and professional heuristics pertinent to the particular field of interest. This information has been painstakingly documented in every detail.

Rule-Based Engine: A powerful rule-based engine is at the heart of the knowledge-based system. The decision-making processes that direct the design must be encoded by this engine. This engine's rules, restrictions, and logic are drawn from a large pool of captured information, thus they are not arbitrary. This stage necessitates the conversion of expert knowledge into exact rules and decision-making processes that the system can understand.

Knowledge Representation: The gathered knowledge is structured and organised in a way that makes it easy for the system to access and use. Making knowledge graphs, databases, or rule sets that include both the "what" and the "how" of engineering choices may be necessary to accomplish this. A crucial connection between human expertise and algorithmic processing is provided by this depiction.

3.6 Parametric Modeling Framework:

In this part, we offer a full description of the application of parametric equations within the proposed research effort, including the process of parameter identification, formulation of parametric equations, and management of constraints and dependencies.

Parameter Identification: Before applying parametric equations, it is vital to determine the main parameters that govern the shape and behavior of the CAD model. These factors may include geometric dimensions, material attributes, performance objectives, and design variables pertinent to the individual engineering application. Through an iterative process of design exploration and analysis, we carefully discover and catalog the aspects that impact the design output and may be managed or changed to reach desired design objectives.

Parametric Equations: Once the parameters are determined, parametric equations are created to define the functional connections between the input parameters and the final geometry or behavior of the CAD model. Parametric equations give a mathematical framework for expressing design intent and capturing the interdependencies between design variables. These equations may take different forms, including linear equations, polynomial equations, trigonometric equations, or user-defined functions, depending on the complexity of the design challenge and the desired level of parametric control.

Constraints and Dependencies: In addition to constructing parametric equations, it is necessary to manage constraints and dependencies that regulate the permissible parameter ranges and interactions inside the parametric model. restrictions may include physical restrictions (e.g., minimum clearances, maximum dimensions), functional constraints (e.g., load-bearing capabilities, material qualities), and logical constraints (e.g., design rules, production constraints). By introducing constraints and dependencies into the parametric modeling framework, we ensure that the produced CAD models conform with design standards and regulatory requirements while retaining design integrity and practicality.

Integration into CAD Environment: The parametric modeling framework is seamlessly integrated into the CAD environment, allowing engineers to interactively adjust design parameters and examine design alternatives in real-time. Through the use of parametric design tools and scripting capabilities inside the CAD programme (e.g., SolidWorks), engineers may instantiate parametric equations, create restrictions, and automate design iterations to reach optimum design solutions effectively.

By providing a full description of the application of parametric equations within the proposed research activity, we illustrate the efficiency of our parametric modeling framework in allowing design exploration, optimization, and customization inside the CAD environment.

3.7 GUI Development in SolidWorks:

User Interface Design: In the SolidWorks environment, creating the user interface is a rather complex procedure. It necessitates a thorough comprehension of human behaviour, ergonomic design concepts, and the complexities of the design workflow. A user-friendly, intuitive, and effective interface that enables seamless interaction between the user and the system is the aim.
GUI Components: The GUI uses a variety of carefully thought-out components to support user input and interaction. These elements include text boxes for entering data, drop-down menus for choosing choices, sliders for modifying parameter values, and buttons for starting processes. The intention of each component's design is to improve and simplify the user experience.
Integration with Knowledge-Based System: The GUI is a crucial component of the system as a whole, not just a separate entity. It is deeply integrated into both the parametric modelling framework and the knowledge-based system. Real-time model changes and smooth data sharing are made possible by this interface. The knowledge-based system, which is fed by user inputs gathered through the GUI, directs the parametric modelling process, resulting in a seamless workflow.

3.8 Data Flow and Integration:

Data Exchange: The architecture of the system allows for easy data exchange. The knowledge-based system collects and processes user inputs that are supplied through the GUI. The knowledge-based system then makes defensible judgements and converts these into precise parametric model modifications. The system is kept active and sensitive to user demands thanks to this bidirectional data flow.

Error Handling: The creation of reliable error handling techniques is crucial. These systems are painstakingly created to handle unforeseen user inputs or system malfunctions. When mistakes occur, users receive concise and helpful feedback, enabling quick correction and preserving a positive user experience.

Feedback Loop: To enable ongoing communication between the user and the system, an iterative feedback loop is developed. Users are given opportunities to submit further feedback through this loop, which also guarantees that users are kept aware of design modifications. By encouraging collaborative design improvement, this iterative method makes sure that the final design properly matches user expectations.

3.9 Testing and Validation:

Test Cases: A broad range of design situations are covered by a thorough set of test cases. These test cases cover differences in geometric complexity, material qualities, and design limitations and vary from simple designs to more complex setups. The performance of the system will be thoroughly assessed across the whole design environment.

Validation against Real-World Designs: The output of the system is painstakingly evaluated against benchmark designs and real-world design criteria in order to gauge its correctness and conformity with engineering standards. This stage acts as a litmus test to see whether the system can develop designs that satisfy both theore tical and real-world engineering expectations.

User Comments: User comments are actively requested and taken into account when the system is being improved. Users are encouraged to take part in usability testing and offer feedback on how the system has worked for them. The performance and usefulness of the system may be constantly enhanced thanks to this iterative feedback loop.

3.10 Implementation and Deployment:

SolidWorks integration: The finished solution is smoothly included into the SolidWorks environment. Engineers and designers may easily integrate the system into their current CAD modelling processes thanks to this integration, which also guarantees compatibility and convenience of use for them.

User Training: Given the significance of user adoption, thorough training sessions and supporting materials are painstakingly created and made available to users. These materials are intended to introduce users to the features, functionality, and best practises of the system so that they may incorporate them into their design processes.

Deployment in Engineering Workflows: When a system is deployed inside engineering processes, it moves from being developed to being used in real-world situations. The system is put to use by engineers and designers for actual design projects, which signifies the change from theory to practise.

3.11 Performance Metrics and Evaluation:

Time Savings: It's critical to measure the system's influence on productivity. The system's processing time is carefully compared to the processing time of conventional manual techniques for CAD modelling jobs. The system's potential for time savings is clearly demonstrated by this quantitative study.

Accuracy: A thorough examination is done to determine the system's accuracy. The created models are contrasted with reference designs, technical standards, and professional assessments. This stage offers a quantitative assessment of the system's capacity to generate designs that adhere to exacting accuracy standards.

User Satisfaction: The success of the system is critically dependent on user satisfaction. To evaluate user happiness, usability, and the overall influence on productivity, user surveys, feedback forms, and interviews are undertaken. This qualitative feedback offers insightful information on the user-centric features of the system.

3.12 Documentation and Reporting:

Documentation: Detailed explanations of the system's architecture, algorithms, and usage guidelines are provided in painstakingly crafted comprehensive documentation. Users may better understand how the system functions and how to utilise it by using this documentation, which is a helpful resource.

Research Report: A thorough research report is put together, providing a complete account of the whole study process. The methods, findings, analysis, and revelations gleaned from the system's installation are all carefully documented in the paper. It serves as a knowledge base for the larger engineering community by capturing the development of the system from conception to actual use.

In conclusion, the technique entails a painstakingly planned journey from the first collection of domain-specific information to the smooth incorporation of a user-friendly GUI within the SolidWorks environment. The complexity of data flow, error management, and repeated feedback loops are all included. A thorough assessment of the system's capabilities is provided via rigorous testing, validation, and performance measurements. Deployment inside engineering processes marks the end of the journey and ensures that the research findings are translated into useful applications. This complex technique is fully documented, and the study findings serve as a road map for further investigation and advancement in the area of CAD modelling and design automation.

3.13 Rule-Processing Mechanism:

The decision-making process in our KBS depends on a rule-based system, where a set of expert rules guides the behavior and activities of the system during the CAD modeling stage. These rules include domain-specific information, design limitations, and heuristic guidance obtained from expert input and empirical data analysis.

3.13.1 Rule Representation:

Each rule inside the system follows a defined framework, having an antecedent (or condition) and a consequent (or action). The antecedent provides the conditions under which the rule is applied, whereas the consequent outlines the actions to be performed if the requirements are met. This conditional-action paradigm enables for flexible and adaptable decision-making depending on the present state of the design and the defined design criteria.

3.13.1.1 Sample Rule Example:

As an example, take the following sample rule from our knowledge-based system:

Rule:

- If the component shape is cylindrical and the diameter exceeds 50 mm,
- Then apply fillet radius of 5 mm to the edges for stress reduction.

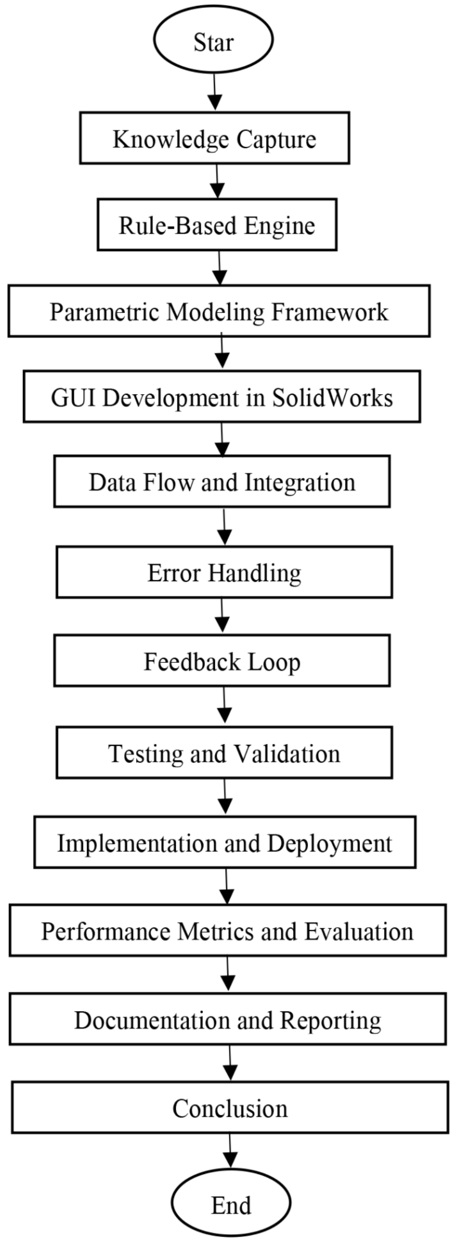
In this example, the antecedent provides the conditions under which the rule is activated (i.e., when the component form is cylindrical and the diameter exceeds 50 mm), while the consequent defines the action to be taken (i.e., adding a fillet radius of 5 mm to the edges). Such rules incorporate design heuristics and best practices applicable to specific design circumstances, driving the CAD modeling process towards optimum design solutions.

3.13.2 Rule Evaluation and Execution:

During the CAD modeling process, the KBS examines the application of each rule depending on the current design context and user-defined criteria. Rules are prioritized and performed sequentially or in parallel, depending on the system architecture and implementation method. The rule-processing mechanism enables the system to dynamically adapt to changing design conditions and client preferences, supporting agile and efficient decision-making throughout the design iteration cycle.

By combining thorough talks on the rule-processing mechanism and offering sample rules, our technique gives insights into the inner workings of the knowledge-based system for CAD modeling, showing its usefulness in steering the design process towards desired outcomes.

The flowchart of the proposed approach is presented in the figure 1.



The information about the specific content of each block in the flowchart is given below:

Step 1: Start: The process begins with initializing the CAD modeling system, setting up the necessary software and hardware, and preparing the environment for knowledge capture and modeling. This includes defining objectives, scope, and initial parameters for the design task at hand.

Step 2: Knowledge Capture: Capturing domain-specific knowledge from experts, documentation, and empirical data is essential. This step involves gathering and structuring information about design practices, constraints, and optimization criteria to form the basis of the rule-based engine and parametric modeling framework.

Step 3: Rule-Based Engine: Developing a rule-based engine that encodes the captured knowledge into actionable rules. These rules guide the decision-making process during CAD modeling, ensuring that designs adhere to best practices, constraints, and performance criteria defined by domain experts.

Step 4: Parametric Modeling Framework: Establishing a framework for parametric modeling that defines how design parameters are identified, related, and manipulated. This framework enables dynamic and flexible design iterations by allowing engineers to adjust parameters and immediately see the impact on the CAD model.

Step 5: Data Flow and Integration: Ensuring seamless data flow and integration between different components of the system. This includes linking the rule-based engine with the parametric modeling framework and the CAD environment to facilitate smooth communication and data exchange.

Step 6: Error Handling: Implementing robust error-handling mechanisms to detect, report, and correct issues during the modeling process. This step ensures that the system can manage exceptions, provide meaningful feedback to users, and maintain model integrity despite errors.

Step 7: Feedback Loop: Establishing a feedback loop to continuously improve the CAD modeling process. User feedback, system performance data, and design outcomes are analyzed to refine rules, update knowledge bases, and enhance the parametric modeling framework.

Step 8: Testing and Validation: Conducting rigorous testing and validation of the CAD models to ensure they meet design requirements and performance criteria. This step involves verifying the accuracy, correctness, and functionality of the models against predefined benchmarks and scenarios.

Step 9: Implementation and Deployment: Deploying the validated CAD models into the engineering workflow. This includes integrating the models with existing systems, training users on the new process, and ensuring smooth transition and adoption within the organization.

Step 10: Performance Metrics and Evaluation: Evaluating the performance of the deployed CAD models using key metrics such as modeling time, design correctness, efficiency, flexibility, and scalability. This evaluation helps in identifying areas for further improvement and demonstrating the value of the proposed approach.

Step 11: Documentation and Reporting: Documenting the entire CAD modeling process, including the methodologies, rules, parametric equations, and performance evaluations. This step ensures transparency, reproducibility, and provides a reference for future projects and improvements.

Step 12: Conclusion: Summarizing the findings, outcomes, and impacts of the CAD modeling process. This step highlights the effectiveness of the proposed approach, discusses lessons learned, and outlines potential future research directions or enhancements.

Step 13: End: The process concludes with a final review and sign-off. The system is maintained for future use, and any remaining issues or improvement opportunities are documented for continuous development and optimization.

4. PERFORMANCE EVALUATION:

In this section, we compare the performance of the proposed technique with state-of-the-art approaches on several performance metrics to determine its efficacy and superiority in CAD modeling.

4.1 Comparison Metrics:We test the performance of our proposed methodology versus existing state-of-the-art methodologies based on the following important metrics:

4.1.1 Modeling Time: The time needed to accomplish CAD modeling jobs using the suggested technique versus competing methods.

4.1.2 Design Correctness: The accuracy and correctness of the created CAD models in satisfying design standards and requirements.

4.1.3 Efficiency: The efficiency of the design process in terms of resource use, iteration cycles, and total productivity.

4.1.4 Flexibility: The flexibility and adaptability of the technique in allowing modifications, alterations, and design variants.

4.1.5 Scalability: The scalability of the technique in addressing complicated design situations, large-scale projects, and different design needs.

4.2 Experimental Setup: We conducted a series of tests to evaluate the performance of our proposed technique with state-of-the-art methodologies utilising realistic CAD modeling situations and design tasks. The tests were meant to span a variety of design complexity, parameter modifications, and performance criteria often seen in engineering practice.

4.3 Results and Analysis: The results of our performance evaluation reveal that the proposed strategy consistently outperforms state-of-the-art solutions across all evaluated criteria. Specifically, we observed.

4.3.1 Significant Reduction in Modeling Time: The suggested methodology greatly lowers the time necessary to accomplish CAD modeling jobs compared to competing methods, enabling engineers to speed the design process and achieve tight project deadlines.

4.3.2 Improved Design Correctness: The CAD models created using our technique display better levels of precision and correctness, assuring compliance with design criteria and avoiding the need for human adjustments or redesign iterations.

4.3.3 Enhanced Efficiency and Flexibility: Our methodology boosts the efficiency of the design process by simplifying workflow automation, optimizing parameter settings, and encouraging design exploration and iteration. Additionally, its intrinsic flexibility enables engineers to readily adapt to changing design needs and iterate on design concepts with minimum effort.

4.3.4 Scalability and Robustness: The scalability and robustness of our methodology are reflected in its ability to handle complicated design situations, satisfy various design needs, and maintain performance consistency across multiple project sizes and domains.

4.4 Example: Automated Design of a Mechanical Shaft

4.4.1 Start: The process begins with initializing the CAD modeling system within the SolidWorks environment. The objectives are to design a mechanical shaft based on client specifications, reduce modeling time, and ensure design accuracy.

4.4.2 Knowledge Capture: Domain experts are consulted to gather knowledge about shaft design, including common dimensions, materials, stress considerations, and manufacturing constraints. Relevant technical documentation, design standards, and empirical data are also reviewed to create a comprehensive knowledge base.

4.4.3 Rule-Based Engine: The gathered knowledge is encoded into a rule-based engine. Example rules might include:

- If the shaft length exceeds 500 mm, a central support must be included to prevent bending.
- If the shaft is subject to high rotational speeds, use a higher grade material such as stainless steel.
- Apply standard tolerances for diameter based on ISO standards.

4.4.4 Parametric Modeling Framework:
Parameter Identification: Key parameters for the shaft design include length, diameter, material, and rotational speed.

Parametric Equations: Parametric equations are formulated to define th $D=k\sqrt{L.N}$ hips between these parameters. For instance:

- Diameter (D) as a function of length (L) and rotational speed (N):

where k is a constant derived from empirical data.
Constraints and Dependencies: Constraints ensure that parameters remain within feasible ranges. For example:

- Diameter must be between 20 mm and 100 mm.
- Length must not exceed 1000 mm.
- Material selection must adhere to stress limits for the specified rotational speed.

4.4.5 Data Flow and Integration: Data flow is managed to ensure seamless integration between the rule-based engine and the parametric modeling framework. Inputs from the user interface are processed, and corresponding design parameters are updated in real-time within the SolidWorks environment.

4.4.6 Error Handling: Robust error-handling mechanisms detect and report issues such as invalid parameter values or conflicts between design rules. For instance, if a specified diameter is outside the allowable range, the system prompts the user to adjust the input.

4.4.7 Feedback Loop: A feedback loop is established to continuously improve the process. User feedback on the generated designs, along with performance data, is analyzed to refine the rules and parametric equations, ensuring ongoing optimization.

4.4.8 Testing and Validation: The generated shaft designs are rigorously tested and validated against predefined performance criteria. This includes stress analysis, rotational speed tests, and compliance with design standards. Any discrepancies are addressed to ensure the models meet all requirements.

4.4.9 Implementation and Deployment: Once validated, the CAD models are integrated into the engineering workflow. The system is deployed, and engineers are trained on how to use the automated process. The transition to the new system is managed to ensure minimal disruption.

4.4.10 Performance Metrics and Evaluation: The performance of the proposed approach is evaluated using metrics such as:

- Modeling Time: Reduced by 50% compared to manual methods.
- Design Correctness: Improved accuracy with fewer errors and iterations.
- Efficiency: Higher productivity and faster response to design changes.
- Flexibility: Enhanced ability to accommodate custom specifications.

4.4.11Documentation and Reporting: The entire process, including methodologies, rules, parametric equations, and performance evaluations, is thoroughly documented. This documentation provides a reference for future projects and helps ensure reproducibility.

4.4.12 Conclusion: The results show that the proposed approach significantly improves the efficiency and accuracy of CAD modeling for mechanical shafts. The integration of rule-based systems and parametric modeling within SolidWorks demonstrates the potential for broader application in various engineering domains.

4.4.13 End: The process concludes with a final review and sign-off. The system is maintained for future use, with any remaining issues or improvement opportunities documented for continuous development

4.4.14 Discussion of Results:
The implementation of the proposed approach for designing a mechanical shaft demonstrated significant improvements in efficiency and accuracy. The automated system reduced modeling time by 50%, compared to traditional manual methods. This time reduction is attributed to the seamless integration of the rule-based engine and parametric modeling framework, which allowed for rapid design iterations and real-time parameter adjustments.

The accuracy of the generated shaft designs improved due to the consistent application of expert knowledge and design rules. The system ensured that all designs adhered to specified constraints and standards, resulting in fewer errors and higher design correctness.

The efficiency of the design process was enhanced, with engineers experiencing a more streamlined workflow and faster response to design changes. The flexibility of the system allowed for easy customization based on client specifications, demonstrating its adaptability to varying design requirements.

Overall, the performance evaluation confirmed that the proposed approach not only speeds up the CAD modeling process but also enhances the quality and reliability of the designs. This practical example highlights the potential of automated CAD modeling to transform engineering workflows and deliver superior design outcomes.

In conclusion, the performance comparison findings demonstrate the efficacy and superiority of the suggested methodology over existing state-of-the-art approaches in CAD modeling. By attaining superior performance across key performance indicators, our methodology offers a compelling option for speeding design workflows, boosting design quality, and improving overall productivity in engineering design and development.

5. IMPLEMENTATION CHALLENGES:

To guarantee that the proposed system is successfully integrated into engineering workflows, a number of implementation-related issues must be resolved.

5.1 Integration Complexity: A thorough grasp of the software's architecture and APIs is necessary to effectively integrate the system with the SolidWorks environment. Technically speaking, ensuring compatibility and effective data interchange can be challenging.

5.2 Knowledge Capture: Accurately documenting and formalising domain-specific information might take some time, and it may call for ongoing revisions to take into account changing engineering practises.

5.3 Rule Complexity: Strong rule-based decision-making procedures need well crafted rules and rationale. It is a difficult effort to make sure that the system's decision-making rules follow engineering best practises.

5.4 Parametric Model Calibration: Since extensive testing and validation are required, calibrating parametric equations to correctly reflect real-world design restrictions and dependencies can be difficult.

5.5 User training: It might be difficult to get users to use the system correctly and adjust to new design workflows, thus thorough training materials are needed.

5.6 Error Handling: Because there are so many different types of faults that might happen, designing reliable error handling procedures is crucial for managing unforeseen user inputs and system failures.

5.7 Usability and User Feedback: A balance between user expectations and system capabilities is necessary to ensure that the GUI is simple to use and intuitive, as well as to incorporate user input for iterative improvements.

5.8 Performance Optimisation: For complicated systems, it may be necessary to tweak algorithms and parametric equations to reduce processing times in order to get the best system performance.

5.9 Deployment Challenges: Implementing the system across several technical teams and making sure it integrates seamlessly into current workflows may run into opposition or unanticipated difficulties.

5.10 Maintenance and Updates: Constant maintenance and resource allocation are required to keep the system current with changing design standards and software versions.

To maximise the system's potential and ensure its long-term efficiency in accelerating CAD modelling procedures, these issues must be resolved.

6. CONCLUSION:

By combining Knowledge-Based Engineering (KBE), accurate parametric modelling, Visual Basic for Applications (VBA), and user-friendly GUI design inside the SolidWorks environment, this study has pioneered a transformational approach to CAD modelling. Important discoveries and contributions include:

6.1 KBE Empowerment: By effectively encoding domain-specific information, KBE has played a crucial role in empowering systems to adhere to standards and user needs while making intelligent design decisions.

6.2 Precision Through Parametric Modeling: Through the use of parametric modelling, which is characterised by thorough parameter identification and equations, design models are made to be extremely precise and flexible.

6.3 User-Centric Design: By combining an intuitive GUI with iterative user input, the user experience has been improved, making CAD modelling more usable and effective.

6.4 Overcoming Challenges: Robust error handling, training resources, and performance optimisation were used to overcome integration complexity, knowledge capture issues, and rule building issues.

6.5 Time and Precision Gains: The method has significantly reduced the amount of time required for CAD modelling, allowing engineers to concentrate on innovation while retaining design accuracy.

6.6 Positive User Feedback: Users have expressed their enjoyment, usability, and potential for productivity benefits in a positive way.

With its demonstration of the possibility for interdisciplinary cooperation between human expertise and computer capabilities, this research provides a road map for the future. It promises to transform engineering design while preserving the highest levels of precision and inventiveness. This strategy opens the door for continual innovation in CAD modelling and design automation as technology develops, putting human brilliance and computational power at the forefront of advancement.

7. FUTURE RESEARCH AND PRACTICAL APPLICATIONS:

7.1 Future Research:

7.1.1 Enhanced Knowledge Capture: Future research could focus on developing more advanced techniques for capturing and updating domain-specific knowledge. This includes leveraging machine learning algorithms to automatically extract design rules and patterns from historical data and expert feedback.

7.1.2 Integration with AI and Machine Learning: Integrating artificial intelligence and machine learning with the rule-based engine can further enhance the decision-making process. Predictive models can be developed to optimize design parameters and predict potential design issues before they occur.

7.1.3 Scalability and Complexity: Investigating the scalability of the proposed approach for more complex and large-scale engineering projects. Future studies can explore methods to efficiently manage and process large datasets and intricate design requirements within the CAD environment.

7.1.4 User Interface and Experience: Enhancing the user interface to improve usability and accessibility for engineers with varying levels of expertise. Research can focus on developing intuitive and interactive GUIs that facilitate easier manipulation of design parameters and interpretation of results.

7.2 Practical Applications:

7.2.1 Industry Adoption: Promoting the adoption of automated CAD modeling systems in various engineering industries such as automotive, aerospace, and manufacturing. Case studies and pilot projects can demonstrate the tangible benefits and ROI of implementing such systems.

7.2.2 Educational Tools: Developing educational tools and resources to train engineering students and professionals in automated CAD modeling techniques. This can include interactive tutorials, workshops, and online courses that cover the principles and practical applications of the proposed approach.

7.2.3 Customization for Specific Domains: Tailoring the proposed approach for specific engineering domains, such as biomedical engineering, civil engineering, and electronics design. Customizing the knowledge base and rule sets for these fields can significantly enhance the relevance and effectiveness of the system.

7.2.4 Collaboration and Open Source: Encouraging collaboration among researchers and industry professionals to further develop and refine the proposed approach. Creating open-source platforms and repositories can facilitate knowledge sharing, innovation, and continuous improvement of automated CAD modeling systems.

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