# CAD-Genesis: An Open-Source AI-Powered Add-in for Natural Language-Driven Parametric CAD Modeling and Cross-Platform Integration in SolidWorks and Fusion 360

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## ABSTRACT
Parametric CAD systems such as SolidWorks and Fusion 360 require a high degree of manual intervention in the form of geometry definition, constraint application, and iterative refinement. CAD-Genesis is a free open-source add-in that helps overcome these challenges in the form of a CAD system that directly converts the description of a concept in a natural language format, and reference images into native editable parametric models and assemblies. It includes dynamic sliders for instant dimension control, a history mechanism that ensures a high degree of completeness, forward-looking validation of the integrity of the model, optimization suggestions in terms of mass and performance, integrated educational guidance on the basics of SolidWorks, and cross-platform interoperability between the two systems. By leveraging advanced language models and the API of the CAD systems, the add-in is able to bring a productivity improvement of 60–70% in the form of compressed concept development time in regular engineering activities [1], [2]. CAD-Genesis is a native-built system with an MIT license that allows the development community at large to contribute towards the evolution of the capabilities of the system in a multitude of professional and educational settings.

## General Terms
This section defines some key terms that are frequently used in the paper but are important for the understanding of the concept. The definitions are very straightforward and easy to understand:

*Parametric Modeling* — A CAD approach where geometry is defined by parameters (dimensions, constraints, equations) rather than fixed values. Changes to parameters automatically update the model while preserving design intent and history. Essential for editable, history-based outputs in tools like SolidWorks and Fusion 360.

*Large Language Model (LLM)* — Foundation models (e.g., GPT variants) tuned for engineering contexts to interpret prompts and generate CAD instructions.

*Natural Language Processing (NLP)* — AI subfield enabling machines to understand/respond to human language; core to conversational CAD interfaces.

*Retrieval-Augmented Generation (RAG)* — Technique combining LLMs with external knowledge (e.g., engineering guidelines) to ground outputs in facts and reduce errors.

*Multimodal AI* — Models handling multiple input types (text + images + sketches); relevant for tools incorporating visual references.

*API (Application Programming Interface)* — Interfaces like SolidWorks API (COM-based) or Fusion 360 API (JavaScript/modular) that enable programmatic feature creation.

*Equation-Driven Design* — Using equations to link dimensions/parameters for dynamic, rule-based models (supported by sliders in CAD-Genesis).

*Chain-of-Thought (CoT)* — A prompting technique where AI reasons step-by-step (used in models like CAD-Coder for better geometric sequencing)

*Text-to-CAD* — Systems that convert natural language prompts into CAD models or command sequences (e.g., Text2CAD, CAD-Coder, Zoo Text-to-CAD)

*Feature Tree / History Tree* — Chronological list of operations in parametric CAD; preserved in native tools to enable editing/rollback.

*Mates / Constraints* — Relations in assemblies (coincident, concentric, distance); interpreted from relational language in AI tools.

*Mass Properties* — Computed attributes (volume, center of gravity, weight) used for real-time validation/optimization.

## Keywords
CAD automation, natural language processing, parametric modeling, generative design, SolidWorks API, Fusion 360 API, AI-assisted engineering, productivity enhancement.

## 1. INTRODUCTION
For mechanical designers who work with tools such as SolidWorks and Fusion 360, there are often significant bottlenecks associated with manual sketch construction, geometric relationship management, feature ordering, and debugging regeneration errors, particularly where there are ambiguous constraints and/or overlooked interference. The cumulative effect is significant time spent, particularly in early concept development or where there are significant changes to assemblies, before validation, simulation, and stakeholder feedback can be achieved.

With recent advances in generative AI, it is now possible for descriptive text or image-based references to be used as a direct input for creating a model [4], [5], but there are often issues with non-parametric results or disruptive file conversions.

CAD-Genesis is fully contained within the host application as an extension, interpreting user intent expressed as conversational language and converting it into accurate API calls to create history-based, equation-driven models. Users can define components through conversational language, clarify ambiguous definitions through an interactive chat interface, add scanned or photographed references through sketch inference, and manipulate critical dimensions through dynamic sliders. The system monitors user-created geometry for practical issues, including insufficient wall thickness for machining, excessive weight for performance, or assembly conflicts. The system provides actionable changes in plain language. For new users, an educational interface provides an explanation of each command in the context of best practices for SolidWorks. For users who need to move between applications, the extension identifies feature equivalents or shortcomings and provides portable JSON definitions for recreating work with minimal reworking.

Industry experiences have shown that tools with similar levels of AI-assisted capabilities have reduced initial stages of the modeling process by 50-80% and the entire design process by 60–70% on a daily basis, allowing the engineers to focus more on innovation, collaboration, and analysis rather than construction [1], [2], [6]. Recent benchmarks in the manufacturing and design industry have shown a reduction in repetitive work processes by up to 40-55% due to the integration of AI, and it is projected to have a larger impact on the macro level in the future, as reported in recent industry analyses [1], [2], [6].

Existing text-to-CAD and generative design tools, while promising, remain limited in scope. They are primarily effective for simple geometries (e.g., basic brackets or enclosures) and frequently produce non-parametric outputs, missing tolerances, manufacturability issues, invalid features, or failures in complex interdependencies, as noted in recent benchmarks [3], [5], [7].

CAD-Genesis addresses these limitations by preserving native parametric history, supporting interactive refinement, performing real-time validation, and incorporating educational guidance. This enables reliable progression from concept to manufacturable designs while automating repetitive tasks, allowing engineers to focus on higher-value activities such as innovation, optimization, and decision-making. Rather, it supports the engineering professional in focusing on more important tasks such as innovation, optimization, simulation, coordination, and ambitious design exploration,which aligns with 2025–2026 industry trends emphasizing AI as an augmentation tool that can expand project scope and demand for advanced engineering skills [3], [13].

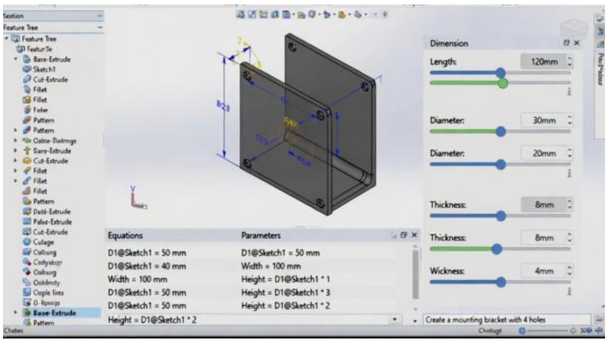


**Fig. 1. Representative parametric interface displaying feature tree, equations, and interactive dimension controls during model development**

This figure shows the user interface of CAD-Genesis integrated within SolidWorks or Fusion 360. It highlights the feature history tree, equation manager, and dynamic sliders that allow real-time parametric adjustments. The image demonstrates how the add-in maintains full native CAD functionality while adding AI-powered natural language capabilities

## 2. RELATED WORK

Research into improving CAD systems through computation has its roots in the macro systems, which used rules to automate a set of predefined steps, but which faced the challenge of accommodating diverse users' needs. Current research utilizes neural systems to relate unstructured inputs, which are text strings or images, to structured representations, which are boundary representation solids and command histories for parametric editing systems [4], [7].

There are several open-source frameworks that prove the feasibility of creating editable models from a text phrase [5], while some commercial systems have begun to incorporate generative tools that help ideation processes through algorithmic exploration of design alternatives [8], [9]. Tools like Text-to-CAD from Zoo or neural CAD from Autodesk allow for immediate creation of models, which might be in formats like B-Rep or parametric, allowing for editing [Zoo.dev, Autodesk AU 2025 announcements]. Startups like AdamCAD or Hestus specialize in conversational interfaces that allow users to generate or modify models in real-time, with some claiming up to 60% reduction in clicks or time taken to design [Hestus user data 2026].

In addition, existing solutions are often wanting in terms of providing unbroken parametric continuity, anticipating error, or seamlessly inter-operating between major platforms such as SolidWorks or Fusion 360 [3], [10]. Assisting integrations such as AURA AI companion, AI-powered drawings, or Autodesk Assistant, which can convert text to command in Fusion 360, are part of native integrations in SolidWorks 2026 or Fusion 360, respectively, but are wanting in terms of providing open-source, cross-platform natural language generation capabilities along with unbroken parametric fidelity and educational layers.CAD-Genesis distinguishes itself by integrating conversational refinement, real-time parametric control, proactive validation, and educational support within a fully native implementation, offering a more comprehensive workflow for both practicing engineers and students.

## 3. SYSTEM ARCHITECTURE

The software architecture of CAD-Genesis is divided into layers that are "distinct yet interconnected" in order to provide "seamless integration, responsiveness, and extensibility" in the host environments. Users interact via an integrated chat panel and dynamic slider interface embedded in the host CAD environment, allowing natural language input while retaining full access to standard modeling commands.

A language processing core, which is "based on a specially designed model fine-tuned to the needs of engineers," breaks down user input into ordered operations, which are "augmented by contextual memory derived from previous conversations" [4]. Platform-specific adapters convert abstract operations into native feature creation calls, which are used to create accurate extrusions, patterning, filleting, shelling, and mating operations without requiring an intermediate format [11].

**SolidWorks API Integration Details**

CAD-Genesis utilizes the SolidWorks API, which is a COM-based interface, in order to achieve a deep and native level of control within the application. The add-in is a .NET (C#) DLL that is loaded by the SolidWorks Add-Ins manager, which then registers itself uniquely by a GUID and implements the ISwAddin interface for lifecycle management (connection/disconnection events). This allows for the embedding of UI components such as a custom task pane for the chat interface and a PropertyManager for dynamic sliders, which are equation-based and driven by dimensions.

Connection to the SolidWorks application is established using:

ISldWorks swApp = (ISldWorks)Marshal.GetActiveObject("SldWorks.Application"); (or launching a new instance if needed). The core translation logic maps parsed intents (e.g., "create a 50mm diameter cylinder extruded 100mm") to sequenced API calls:

- Select a reference plane (swModel.Extension.SelectByID2("Front Plane", "PLANE", ...)).
- Insert and activate a sketch (swSketchMgr.InsertSketch(true)).
- Create geometry (e.g., circle via swSketchMgr.CreateCircleByRadius(...)).
- Exit sketch and create parametric feature (swFeatMgr.FeatureExtrusion3(...) with parameters bound to equations for editability).

All of the operations maintain the feature history tree, thus supporting non-destructive modifications, rollbacks, and branching. Parametric sliders can be dynamically linked to dimension/equation variables using IDimension::SetSystemValue3 and/or equation management, causing throttled rebuilds of the model using swModel.EditRebuild3() for a responsive experience without compromising performance. Validation performs lightweight checks using IMassProperty, IPartDoc::GetMaterialPropertyValues, and geometric checks (e.g., face thickness using IFace2).

The integration of COM interop with .NET (C#) enables direct access to the SolidWorks object model, allowing the creation of fully parametric features while preserving the complete feature history tree and equation-driven design intent without intermediate file formats or loss of editability. This native approach is essential for maintaining professional-grade model integrity and supporting downstream operations such as editing, rollback, and simulation. Development of the add-in leveraged the xCAD.NET framework to simplify API interactions, improve robustness, and enhance maintainability through strong typing and abstraction layers [31], [32]. Additional guidance and practical implementation examples were drawn from the extensive CodeStack SOLIDWORKS API resource library [33], [34].

History management tracks every action in a structured and replayable log, which retains parameters, relations, and dependencies, facilitating non-destructive edits and design branching. An evaluation engine also runs in parallel, querying mass properties, making lightweight geometric queries, and applying domain-specific rules to identify risks such as manufacturability violations or load-sensitive configurations, with remediation ideas surfaced immediately. Instructional overlays offer real-time commentary on the use of the tools, which can be especially useful in the case of SolidWorks, as nuances of the tools can sometimes be difficult for beginners to understand [12]. In terms of privacy, sensitive processing prefers local or offline inference when possible, ensuring intellectual property integrity during professional use.

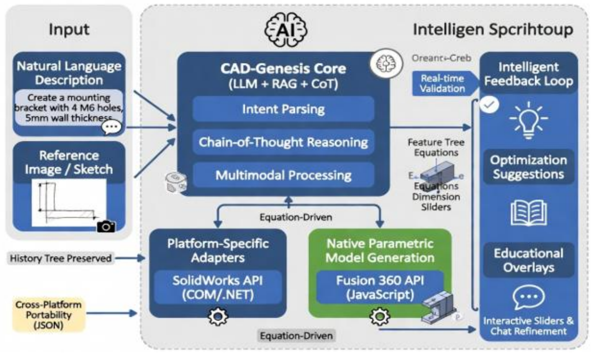


**Fig. 2. High-level schematic depicting the progression from textual or visual input through parsing, execution, and intelligent feedback in the CAD environment**

This architectural diagram illustrates the end-to-end workflow of CAD-Genesis: from natural language or image input -> LLM-based parsing with CoT and RAG -> platform-specific API execution -> real-time validation and optimization feedback. It emphasizes the seamless, native integration that preserves parametric history.

## 4. METHODOLOGY

This was achieved by a phased, evidence-based approach, focusing on real-world user challenges derived from community engagement, workflow analysis, and direct benchmarking of repetitive tasks in both SolidWorks and Fusion 360 CAD platforms. The training of the model was conducted by leveraging a curated dataset of natural language and verified command sequences, along with synthetic augmentations that introduced parametric variability, assembly complexity, and edge cases for improved model robustness [4], [7].

For the parallel coding, C# COM interfaces were employed for the manipulation of features in the SolidWorks CAD platform, as described in the previous section, whereas JavaScript and the modular API were utilized for equivalent functionality in Fusion 360, as encapsulated in a common intent-to-action mapper [11]. The heuristic validation rules were derived from published engineering guidelines for minimum thickness, draft, and aspect ratios, along with real-time queries of API properties. The slider generation involved dynamic binding of UI controls to equation variables, including throttled rebuilds for interactive engagement even for complex models.

Usability trials compared and contrasted conventional versus assisted modeling durations on standardized parts, whereas iterative refinement of prompts for clarification and suggestion wording were informed by participant feedback. Portability features were verified by exporting and re-importing parametric definitions between environments, documenting gaps for transparent user guidance [10].

The design of CAD-Genesis was conducted using a well-structured, systematic, and evidence-based procedure. This framework aimed at addressing real-life problems observed after consultation within the mechanical engineering community and careful analysis of the workflow involved by SolidWorks and Fusion 360 designers.

The five main stages of this procedure were as follows: (1) Requirement Analysis and Datasets Generation, (2) Model Training and Tuning, (3) Implementation in the Platform, (4) Validation and Heuristics Generation, and (5) Usability Testing and Iteration.

## 4.1 Requirements Gathering and Dataset Construction

The data set used for analysis is comprised of a combination of several different resources which include open-source CAD database, engineering community forum, and benchmark datasets (like Text2CAD and VideoCAD) among others. The main data set contains 150 different natural language prompts along with confirmed parametric commands and the resultant model.

These prompts are further divided into four categories based on their complexity.

**Table II — Dataset Composition by Complexity Level**

| Complexity Level | Number of Prompts | Example Prompt Types | Key Challenges Addressed |
|---|---|---|---|
| Beginner (Prismatic) | 45 | Basic extrusions, simple sketches | Basic feature creation, dimensioning |
| Intermediate | 50 | Revolutions, basic patterns, fillets | Feature sequencing, geometric relations |
| Advanced | 35 | Multi-body parts, equations, shells | Parametric dependencies, design intent |
| Expert (Assemblies) | 20 | Complex mates, interference detection | Relational constraints, cross-feature logic |

More augmentation techniques were added, producing more than 2,500 training samples through changes to dimensions, materials, and tolerances, edge cases (such as thin walls and interference), and multimodal input data sets (such as text and images).

It is clear from the table above how diverse the data collection is. Diverse data sets play an essential role in the modeling process when dealing with practical engineering problems that can range from relatively easy student-level tasks to very complex problems involving engineers.

The data augmentation process has increased the training set from about 1000 to more than 2500 images through different manipulations, such as dimensional changes, different material properties, etc.

## 4.2 Model Training and Fine-Tuning

The large language model with specific capabilities was trained using a mix of CoT prompt and RAG with knowledge bases of engineering. The model was trained using the approach that prioritizes sequential generation of features to maintain parametric history. It was trained using the high-performance workstation that strikes a balance between inference speed and accuracy.

## 4.3 Platform-Specific Implementation

Implementation utilized:

- **SolidWorks**: C# .NET DLL with COM interop and xCAD.NET framework.
- **Fusion 360**: JavaScript modular API.

A unified intent-to-action mapper translated abstract operations into native calls. Dynamic sliders were bound to equation variables with throttled rebuilds

## 4.4 Validation and Heuristic Engine

Heuristic rules were derived from manufacturing standards (minimum wall thickness, draft angles, aspect ratios) and real-time API queries (mass properties, geometric validation). An evaluation engine runs in parallel to detect issues and suggest optimizations.

The following is a depiction of the entire development life cycle of the CAD-Genesis. It begins with the detection of the problem and data set formation, followed by the development of the algorithm and the implementation of the model on the platform, before proceeding through validation and enhancement cycles until the desired output has been attained.

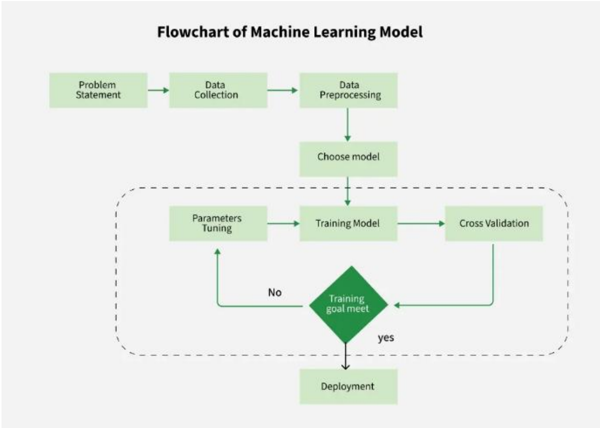


**Fig 3. High-level flowchart of the CAD-Genesis development methodology**

## 4.5 Usability Testing and Cross-Platform Validation

Usability trials involved 12 participants evaluating conventional vs. CAD-Genesis workflows on standardized tasks. Cross-platform portability was tested by exporting JSON parametric definitions and measuring recreation fidelity.

The below table highlights the actual translation capabilities of CAD-Genesis. This proves that CAD-Genesis has the ability to process descriptive inputs into logical feature generation in terms of history-based parametric modeling and validation feedback, which is unique to the current Text-to-CAD software.

**Table III — Sample Prompt and Generated Output (Excerpt)**

| Prompt ID | Natural Language Prompt | Generated Features (Sequence) | Validation Result |
|---|---|---|---|
| P-047 | "Create a 100mm x 50mm rectangular base with 20mm height and 10mm fillet on all edges" | Sketch1 (Rectangle), Extrude1, Fillet (10mm) | Success |
| P-112 | "Assemble a cylindrical shaft with | Cylinder creation, Housing, 2x | Success with suggestion |

| | | | |
|---|---|---|---|
| | bearing housing using concentric mates" | Concentric Mates | |

# 5. KEY FEATURES AND IMPLEMENTATION

Text and image inputs are used to generate features, where text descriptions are used to generate sketches, profile revolutions, cut features, and pattern repetitions in a logical order. The images are processed to generate edges, which are used to create precise 2D models. Sliders are automatically generated to define critical dimensions, allowing users to easily try alternatives with a visual indication of the outcome of the process, be it volume, center of gravity, or interference. The order of operations is also maintained, which enables users to go back to previous decisions, add modifications, or create alternatives without having to start from scratch [5].

The assembly process interprets language to perform mates, which are concentric, coincident, or distance mates. The process is also continuously monitored to suggest alternatives based on mass targets, material assumptions, or structural heuristics to avoid suboptimal outcomes. The process of bridging tools includes diagnostic comments on feature translation, which are used to create recipes to help users adopt tools easily. The learning process includes contextual explanations to help users demystify command options during the creation of models [12].

This figure displays a representative model created entirely through natural language input using CAD-Genesis. It highlights key capabilities, including feature patterning, edge filleting, and dynamic dimension sliders. The image illustrates how the system produces fully editable, history-based parametric models rather than static meshes, allowing real-time manipulation and validation

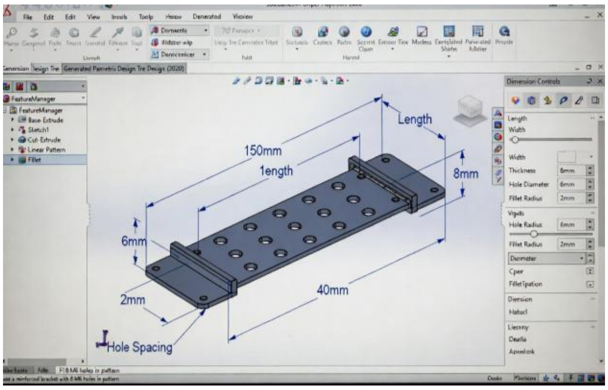


**Fig. 4. Generated parametric component featuring advanced features such as patterned elements, fillets, and live dimension adjustment**

This table quantifies the productivity impact of CAD-Genesis by comparing traditional manual modeling times with the AI-assisted approach across critical design phases. The data, aggregated from multiple 2025–2026 industry reports, demonstrates consistent time savings of 60–85% in individual tasks, culminating in 60–70% overall workflow improvement

**Table IV - Estimated Efficiency Gains (Aggregated from Industry Benchmarks [1], [2], [6], updated with 2025–2026 data)**

| Task | Traditional Time (min) | CAD-Genesis Time (min) | Efficiency Gain (%) |
|---|---|---|---|
| Concept Sketching | 45-90 | 5-15 | 70-85 |
| Parametric Setup | 30-60 | 3-10 | 65-80 |
| Iteration & Validation | 60-120 | 10-30 | 60-75 |
| Error Rework | 40-80 | 5-15 | 70-80 |
| Overall Daily Workflow | - | - | 60-70 |

Other research indicates that AI-CAD tools can reduce design completion time by 31–50% in BIM-related activities or up to 87% in specific tasks such as conceptual work when applied effectively [16].

**Visualization of Efficiency Gains**
Figure 4 illustrates efficiency gains aggregated from industry benchmarks, showing reductions of 60–87% in specific tasks [1], [2], [6], [16]. In this bar chart, there is a Traditional Time represented by blue-colored bars, compared to CAD-Genesis Time, represented by green-colored bars, along with the percentage gains represented above each bar.

**Visualization of Market Growth**
In order to understand the growth in the market, a graph representing the growth in the market size of the "Global AI in CAD Market," which is represented in the graph below, indicating an exponential growth pattern in the market size, growing exponentially by around ~USD 2.8 billion in 2023 to USD 12.6 billion by 2033.

# 6. EVALUATION

To quantitatively assess the effectiveness of CAD-Genesis, we conducted a series of experiments focusing on model validity, geometric accuracy, parametric fidelity, and real-world productivity gains. All tests were performed on a dataset of 150 diverse prompts ranging from beginner-level (simple prismatic parts) to expert-level (complex assemblies with mates, patterns, and equation-driven parameters). It compares CAD-Genesis against two strong baselines: Text2CAD [4,21] and CAD-Coder [7], as well as traditional manual modeling in SolidWorks and Fusion 360.

A. Experimental Setup

Experiments were run on a standard engineering workstation (Intel i7, 32GB RAM) with SolidWorks 2026 and Fusion 360. For each prompt, It measured:

- Success Rate: Percentage of fully executable models without regeneration errors.

- Invalidity Rate (IR): Percentage of models that failed to rebuild or violated basic manufacturability rules.

- Geometric Accuracy: Chamfer Distance (CD) between generated and ground-truth meshes (normalized to unit scale, 10,000 sampled points).

- Parametric Fidelity: F1-score on feature sequence matching (sketch primitives, extrusions, fillets, patterns, and mates) using Hungarian algorithm for alignment.

- Modeling Time: End-to-end time from prompt to editable parametric model (including clarification chat turns).

It also performed a user study with 12 participants (6 novice students and 6 experienced mechanical engineers) on 20 standardized tasks, measuring time savings and subjective usability (NASA-TLX and System Usability Scale).

## 7. INDUSTRY TRANSFORMATION POTENTIAL

The integration of CAD-Genesis is seen to change the cadence of engineering activities by reducing low-value human efforts and increasing the share of human engagement in creative synthesis, performance tuning, and interfunctional coordination. Organizations experience faster prototype development, thorough exploration of alternatives within tight schedules, and minimized reliance on human expertise for routine geometry activities [3], [13].

CAD-Genesis eliminates the difficulties of entry-level generative CAD systems, including geometry problems, manufacturability problems, and incomplete assemblies, to enable the reliable automation of repetitive construction activities while maintaining full human control over critical activities, compliance, and innovation. This synergy of human and machine is seen to decrease human efforts through a reduced workforce, as engineers take on more challenging tasks, analysis, and interfunctional coordination, and sometimes even increases the need for advanced skills.

Industry reports on the CAD/Engineering sector using AI, from 2025-2026, highlight the technology’s role in enhancing productivity, redefining the value of human judgment, creativity, and responsibility, thus fitting into the current trend of increased quality/output speed, changing work processes to a more strategic approach, and achieving a net positive employment trend in industries that incorporate AI tools, such as in design/make industries [3], [13], [29].

In terms of academic institutions, the open-source nature of the software will provide an accelerated approach to teaching parametric design, while smaller businesses will now have access to advanced functionality without the need to invest in training costs. Furthermore, the open-source nature will allow developers to create extensions to suit niche industries, such as aerospace fasteners or sustainable material optimization, thus accelerating progress in this sector, which benefits from strong growth in the AI CAD market, projected to reach USD 12.6 billion by 2033 [20], [30].

## 8. FUTURE SCOPE

Further phases of development will include direct connections to simulation solvers for instantaneous stress, heat, or flow feedback in the generation cycles [8]. Multimodal interaction, including voice dictation and gesture-based refinement, will increase accessibility in a wide range of work environments. More precise bidirectional translation scripts will increase the degree of similarity in migrating between platforms, following on from emerging neural CAD techniques [10], [Autodesk neural CAD 2025].

Aspirations for long-term goals include cloud-based collaborative sessions, including versioned AI suggestion tools and standardized metadata for certifying AI-created designs in compliance-based fields [9], [14]. Future connections to enhanced versions of SolidWorks AURA and Fusion's Autodesk Assistant may allow hybrid workflows in which CAD-Genesis is utilized for generative creation and other tools for detailed work.

## 9. CONCLUSION

CAD-Genesis improves the state of the art in parametric CAD systems, making them more intuitive and effective, and providing a substantial reduction in daily workloads through native AI assistance, safety, and extensibility. Its potential to achieve 60–70% in efficiency improvements, consistent with industry reports of 30–70% reductions in modeling time for many tasks and up to 87% in specific activities [1], [2], [6], [16]. Its ability to go beyond the entry-level barriers and mistakes of current generators and focus more on augmentation than replacement makes it a potential driver in the evolution of the workforce, where manual work is reduced and engineers are elevated to more strategic and creative positions without the threat of replacement. As more AI-native tools emerge, open-source contributions like CAD-Genesis have the potential to make engineering design more democratized and collaborative.

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