1 Abstract

This invention presents a novel system and method for automated training data generation in AI-assisted design, leveraging object groupings and semantic labeling in CAD models. The system utilizes existing CAD functionalities to define hierarchical object relationships, facilitating semantic understanding and automated label generation. By systematically varying visual properties while maintaining core design forms, the system generates diverse training datasets that emphasize form recognition. Automated semantic label generation captures object groupings, applied variations, and design intent. The system employs Low-Rank Adaptation (LoRA) for efficient AI model training and includes an advanced user interface for enhanced design exploration and workflow optimization.

2 Background of the Invention

The field of AI-assisted design has seen significant advancements in recent years, yet challenges persist in creating efficient workflows that seamlessly integrate AI capabilities with traditional Computer-Aided Design (CAD) processes. Existing systems often struggle to generate diverse and semantically rich training data, limiting the AI's ability to understand and manipulate complex design elements effectively.

Current CAD workflows typically involve manual processes for organizing design elements, applying variations, and generating training data for AI models. This manual approach is time-consuming, prone to inconsistencies, and often fails to capture the full range of design possibilities. Moreover, existing AI-assisted design tools frequently lack the ability to understand hierarchical object relationships and design intent, leading to suboptimal results and increased designer workload.

3 Description of the Related Art

Several attempts have been made to address the challenges in AI-assisted design:

1. Patent US10885440B2 describes a system for generating synthetic data for machine learning models in computer vision applications. While this system offers methods for data augmentation, it does not specifically address the unique requirements of CAD-based design workflows or the need for semantic understanding of design elements.

2. Patent US20200334456A1 presents a method for automated 3D model generation using machine learning. However, this approach focuses primarily on generating 3D models from 2D inputs and does not address the need for diverse training data generation from existing CAD models.

3. Research paper "Deep learning for CAD data retrieval and 3D shape classification" by Furuya et al. (2020) explores the use of deep learning for CAD model retrieval and classification. While this work demonstrates the potential

of AI in CAD applications, it does not provide a comprehensive solution for training data generation or semantic labeling in design workflows.

The present invention addresses the limitations of these existing approaches by providing a unified system that leverages CAD object groupings, systematic variation, and semantic labeling to generate rich, diverse training datasets while streamlining the AI-assisted design process.

4 Summary of the Invention

The present invention provides a system and method for automated training data generation in AI-assisted design, utilizing object groupings and semantic labeling in CAD models. Key components and functionalities include:

4.1 Object Grouping in CAD Models

The system leverages existing CAD functionalities such as layers, groups, and tags to define hierarchical object relationships that reflect design intent. This structured organization facilitates semantic understanding and automated label generation, mirroring the way designers conceptualize their creations.

4.2 Form Isolation through Systematic Variation

The invention generates diverse variations of CAD models by systematically altering visual properties, camera viewpoints, lighting conditions, and backgrounds while maintaining the core design form as the invariant element. This approach enables the AI model to learn form independently of other visual attributes, preventing overfitting and generating a robust training dataset.

4.3 Automated Semantic Label Generation

The system automatically creates descriptive text labels for each generated variation, capturing object groupings, applied variations, and design intent. These labels provide the necessary textual context for training the AI model and facilitating natural language interaction with the system.

4.4 AI Model Training using LoRA

The invention employs Low-Rank Adaptation (LoRA) to fine-tune pre-trained text-to-image AI models efficiently. This method adapts the model to specific design data without retraining the entire model, preserving computational resources and accelerating the training process.

4.5 AI-Assisted Design Interface with Advanced Features

A user-friendly interface enables designers to interact with the trained AI model through natural language prompts. The interface includes advanced features such as automated file management, detailed close-ups, location-based backgrounds, mass and volume calculations, design callouts, character continuity, dynamic UI sliders, patent drawing generation, design analysis, client annotation tools, image security, vision tracking, modular UI, style references, thematic sliders, preset management, export options, and history tree with visual diff functionality.

5 Brief Description of the Drawings

Figure 1: System architecture diagram illustrating the key components and data flow of the automated training data generation system.

Figure 2: Flowchart depicting the process of object grouping and hierarchical relationship definition in CAD models.

Figure 3: Diagram showing the systematic variation process, including examples of form isolation through changes in materials, lighting, and viewpoints.

Figure 4: Illustration of the automated semantic label generation process, with examples of generated labels for various design variations.

Figure 5: Schematic representation of the LoRA-based AI model training process.

Figure 6: User interface mockup showcasing the AI-assisted design interface and its advanced features.

Figures 7-10: Detailed illustrations of specific UI elements and functionalities, including the modular UI, thematic sliders, and history tree with visual diff.

6 Detailed Description of the Invention

6.1 Object Grouping in CAD Models

The present invention leverages existing CAD functionalities to define hierarchical object relationships that reflect design intent. This process involves:

1. Utilizing CAD layers, groups, and tags to organize model components. 2. Establishing parent-child relationships between objects to represent design hierarchy. 3. Applying semantic tags to object groups to capture design intent and functionality.

For example, in a chair design, the system might organize components as follows:

- Chair (root object) - Seat - Cushion - Frame - Backrest - Support - Padding - Legs - Front Left - Front Right - Back Left - Back Right

This hierarchical structure enables the system to understand the relationships between components and apply variations or generate labels accordingly.

6.2 Form Isolation through Systematic Variation

The system generates diverse variations of the CAD model while maintaining the core design form as the invariant element. This process includes:

1. Identifying the core form elements that should remain constant. 2. Systematically altering visual properties such as: - Colors, materials, and finishes (CMF) - Camera viewpoints and perspectives - Lighting conditions (intensity, color, direction) - Backgrounds and environments

The variation process is controlled by parameters that ensure a wide range of visually distinct outputs while preserving the essential design characteristics.

6.3 Automated Semantic Label Generation

For each generated variation, the system automatically creates descriptive text labels. The label generation process involves:

1. Extracting information from the CAD model's hierarchical structure. 2. Incorporating details about applied variations (materials, lighting, viewpoint). 3. Capturing design intent based on semantic tags and object relationships.

A typical generated label might look like:

"Modern office chair with ergonomic backrest, viewed from a 45-degree angle. Matte black metal frame with light gray fabric upholstery. Soft ambient lighting from above."

These labels provide the necessary context for training the AI model and enable natural language interaction with the system.

6.4 AI Model Training using LoRA

The system employs Low-Rank Adaptation (LoRA) to fine-tune pre-trained text-to-image AI models efficiently. This method adapts the model to specific design data without retraining the entire model, preserving computational resources and accelerating the training process.

6.5 AI-Assisted Design Interface with Advanced Features

A user-friendly interface enables designers to interact with the trained AI model through natural language prompts. The interface includes advanced features such as:

6.5.1 Automated File Management

The system automates file organization and storage in the cloud, simplifying asset management and facilitating collaboration.

6.5.2 Detailed Close-Ups

The system generates high-resolution close-up renders of specific design elements.

6.5.3 Location-Based Backgrounds

The system incorporates real-world locations as backgrounds, enhancing realism and context. This feature integrates with Google Maps API, depth map generation, and ControlNet for precise background placement and control.

6.5.4 Mass & Volume Calculations

The system calculates mass, volume, estimated cost, and environmental impact based on CMF properties and CAD data. It also generates automated RFQs for materials and components.

6.5.5 Design Callouts

The system automatically generates professional-style design callouts using image segmentation and prompt generation. Users can edit and customize the callouts as needed.

6.5.6 Character Continuity

The system maintains character consistency across multiple renders by implementing techniques such as face swapping and text-based character description analysis.

6.5.7 Dynamic UI Sliders

The system dynamically generates sliders based on the prompt context, providing intuitive control over rendering parameters.

6.5.8 Patent Drawing Generation

The system automates the creation of patent drawings from the CAD model, including line art generation and annotation placement.

6.5.9 Design Analysis

The system integrates with a GPT-based model for design analysis. It identifies potential problems and areas for improvement, providing valuable feedback to designers.

6.5.10 Client Annotation Tools

The system facilitates collaborative annotation by allowing clients and reviewers to provide feedback directly on rendered images.

6.5.11 Image Security

The system protects intellectual property and tracks image usage through watermarking and serialization techniques.

6.5.12 Vision Tracking

The system implements eye-tracking analysis and generates heatmaps to visualize user attention patterns.

6.5.13 Modular UI

The system offers a flexible and customizable interface for applying materials and styles. It includes drag-and-drop functionality and texture blending capabilities.

6.5.14 Style References

The system allows designers to apply different artistic styles to their renders. It provides control over style parameters and supports style transfer techniques.

6.5.15 Thematic Sliders

The system includes sliders for controlling mood and overall style, enabling designers to adjust the aesthetic of the render.

6.5.16 Preset Management

The system enables efficient reuse of rendering settings and styles through a preset management system. Users can save, load, and share rendering configurations.

6.5.17 Export Options

The system supports various output formats for different applications, such as 3D printing, foldable models, and more.

6.5.18 History Tree and Visual Diff

The system tracks design iterations and provides visual comparison capabilities, allowing designers to compare and analyze variations.

7 Claims

TO DO: Draft clear and concise claims that cover both the broad aspects and specific features of the invention.

8 Conclusion

The present invention provides a comprehensive solution for automated training data generation in AI-assisted design, addressing the limitations of existing approaches. By leveraging object groupings, systematic variation, and semantic labeling in CAD models, the system generates rich, diverse training datasets that enable the AI model to understand and manipulate complex design elements effectively. The advanced user interface and workflow optimization features streamline the design process, enhancing creativity and efficiency.