

3D Digital Technology in Sustainable Apparel Design: Developing a Modular Redesign Framework and Designer Insights

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Abstract

The world of fashion design continues to evolve due to advances in technology, with AI-driven 3D garment design leading the way. The intended project will develop an AI powered 3D garment designing platform that allows users to generate their own garment designs using AI prompts and create their own designs manually and preview them in a 3D environment. Designing garments with a system that incorporates artificial intelligence and 3D modeling takes the design process and makes it faster and easier by giving designers an intuitive and effective way to think through, develop, modify and finalize garment designs. While AI-generated prompts will doll up chances of formatting creativity into a garment design, users will have the ability to create the designs manually as well if they feel comfortable. There will also be a component that allows users to preview their garment designs in a 3D environment which improves the user experience because this tool will aid in evaluating garment designs while still in progress and before they move into an actual production stage.

1 Introduction

Fashion design is an agile and boundaryless industry is constantly trying to define its meaning by looking for new opportunities to advance creativity, efficiency and sustainability alike. Historically, garment designing has been viewed as a lengthy process involving multiple cycles of sketches, fabric selection, and physical prototypes prior to developing a final design. While these methods continue to consume time and other resources, they can also contribute to a waste of material and also take away production costs. The emergence of new and modern technology platforms such as artificial intelligence (AI) and 3D modeling employs new exciting ways for designers to study and examine their garment designs.

The project concept is proposing the delivery of a 3D AI Garment Designing platform that integrates artificial intelligence with interactive 3D rendering to enhance a designers' garment design process. Designers can use the platform to offer AI-generated prompts to help support each Unique, and innovative garment design. Users can also manually overlay their own designs using the platform, to allow for full creative ownership Prompts also offer designers with the advantage of 3D visualization which will allow them to view each design at various angles and modify if necessary prior to physical production.

The nice thing about AI is the ability of the system to come up with design ideas based on the users' choices towards history, fashion trends, and preferences, which generate ideas during the design ideation phase. With the 3D modeling feature, designers can save time and resources by reducing the need for prototypes, speeding up design cycles and saving costs. Furthermore, this platform will appeal to more users than just professional designers—students, beginners, and fashion lovers will be able to use this more accessible approach to democratize fashion design and enable more experimentation.

2 Literature Review

The incorporation of Artificial Intelligence (AI)-system applications and models, and 3D-modeling technologies into the fashion industry has greatly altered traditional design and production practices. Brown and Smith (2022) specifically addressed the application of AI methodologies in areas like "trend forecasting, design automation, and optimizing supply chain" and found that AI tools predict fashion trends by analyzing large data sets and automate everyday design tasks, ultimately promoting productivity, and lowering human error. At the same time, the study offered challenges to industry pros, like data privacy and requirements for enormous computing power which can limit scalability for many companies, particularly smaller companies.

Gupta and Mehta (2021) also addressed the role of 3D modeling in apparel design and illustrated how 3D- modeling technology can create a highly detailed virtual garment that requires little physical prototype clothing. Designers can view clothing on digital models via 3D technology and simply alter the digital garments in real time. Besides the obvious advantages of 3D modelling technologies, the study also highlighted challenges for industry professionals, such as the high upfront software and hardware costs, and significant learning curve as the primary challenges to ubiquitous adoption.

Wang and Zhao (2019) explored the future of virtual clothing and elements of AI-driven digital clothing in relation to consumer engagement. They found that virtual try-ons and digital avatars are reshaping e-commerce through AI and delivering increased customer experience through product visualization. Although they noted limitations in simulator technology and limitations in consumer acceptance of virtual clothes.

Overall, it can be seen that these studies offer a variety of impacts shows AI and digital trends are transforming the fashion space, but they also identify crucial areas for further study and work to improve acceptance and integration with users.

3 Methodology

3.1 Data Acquisition

Used or discarded men's and women's garments were selected as the primary raw materials. These original garments (OGs) were digitized into CLO3D virtual project files using standardized templates to simulate a virtual closet environment. Each OG outfit served as the foundational input for the upcycling process.

3.2 Preprocessing

Garment patterns and panels were digitally disassembled within CLO3D. These were then modularized into interchangeable units to facilitate reconstruction. Size and aesthetic adjustments were performed virtually, incorporating extra materials as needed to maintain design integrity.

3.3 Module Generation

- Disassembled panels were stored in a virtual database called the Modular Library.
 - Each module block represented a customizable garment component (e.g., bodice, sleeve, collar).
 - Modules were mixed, reassembled, or replaced digitally to generate new design variations.
 - Six design variations per garment were created using changes in textile, color, size, and detail.
 - Print Layout Mode in CLO3D was used to pre-measure fabric sizes, reducing waste.

3.4 Virtual Design Construction

Garments were reconstructed in CLO3D via a component-based approach. The ideation, construction, and fitting stages occurred simultaneously in the 3D environment, allowing real-time feedback and adjustments. Selected virtual garments were visualized using AfterEffects for demonstrative purposes.

3.5 Physical Construction

Selected digital prototypes were produced physically. This involved dismantling the actual garments and reconditioning the materials based on digital specifications. Physical modules were reassembled to replicate the virtual designs with high fidelity.

3.6 Performance Evaluation

Effectiveness was assessed through:

- Visual inspection of modular combinations and fit accuracy
- Time and material savings during prototype development
- Designer feedback on creativity, flexibility, and sustainability.

The system demonstrated significant improvement in ideation, waste reduction, and design customization.

4 Results and Discussion

The development of a comprehensive AI-powered clothing design app is an exciting step for the fashion industry. The system promotes mixing automatic process and manual design, which allows users to develop designs using AI functions, or users can develop designs using only the manual functions and then modify and adjust their designs as they wish using vision

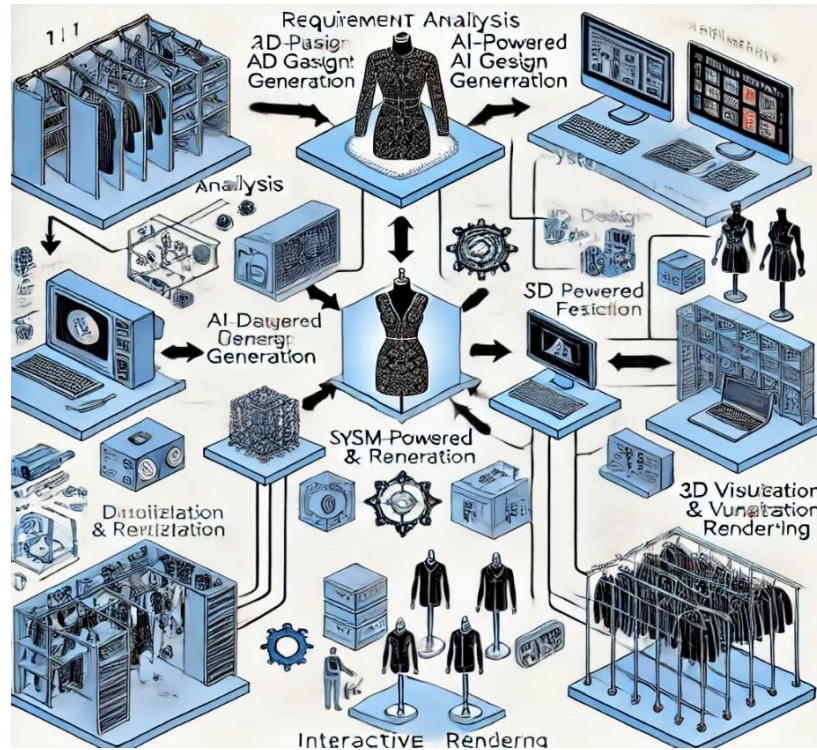


Figure 1:

or intent to create design. This allows for greater creativity from users; the work of talented professionals and the work of those exploring their love of fashion design for the first time.

This project has a powerful advantage in the form of a real-time 3D visualization system. The 3D visualisation system means designers will be able to see beautifully detailed images of their garment designs nearly instantaneously. By allowing designers to see their unique designs to make decisions more expediently, not only reduces the chances of making a mistake with large financial implications, but also increase the speed of the design development cycle whilst drastically reducing the need for physical prototypes which should promote sustainability and conserve resources. In general, this approach will also facilitate the affordability and sustainability in the apparel design process.

Furthermore, employing AI-based tools adds another layer of innovation. Users receive intelligent design recommendations and customized options that allow users to unleash their creativity. Whether experimenting with new fabrics, colors, or styles, the platform has the potential to increase user engagement with the design process. The new process has

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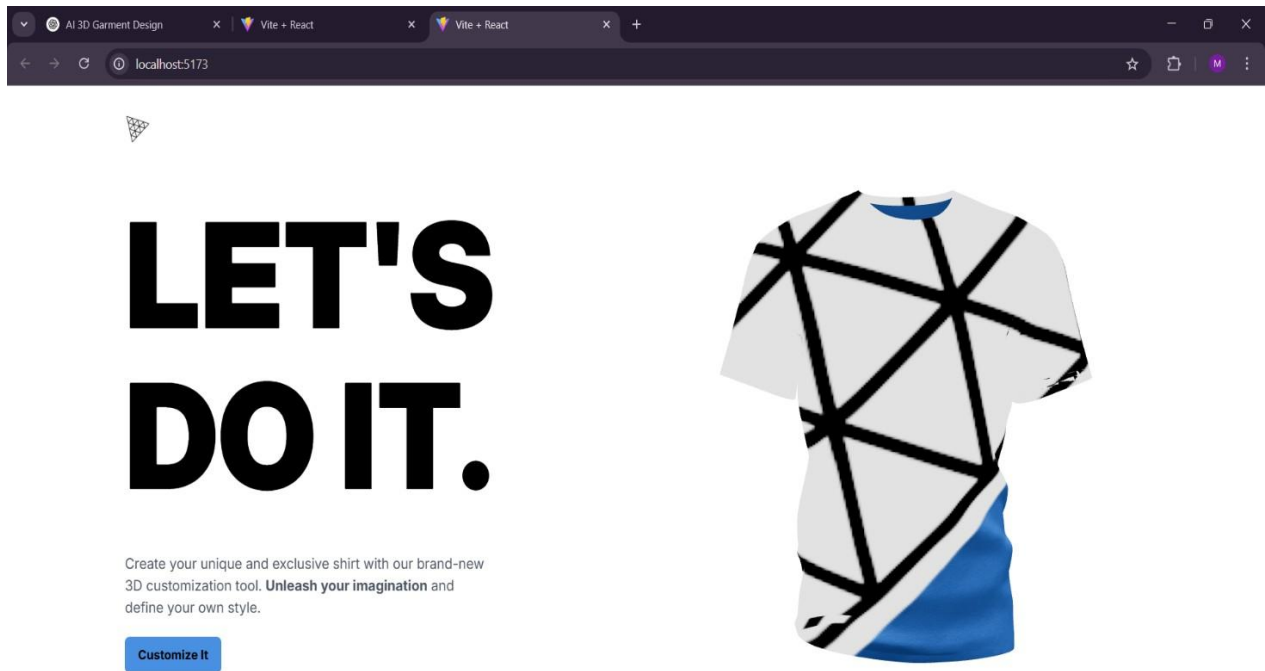


Figure 2: **Interface page 1**

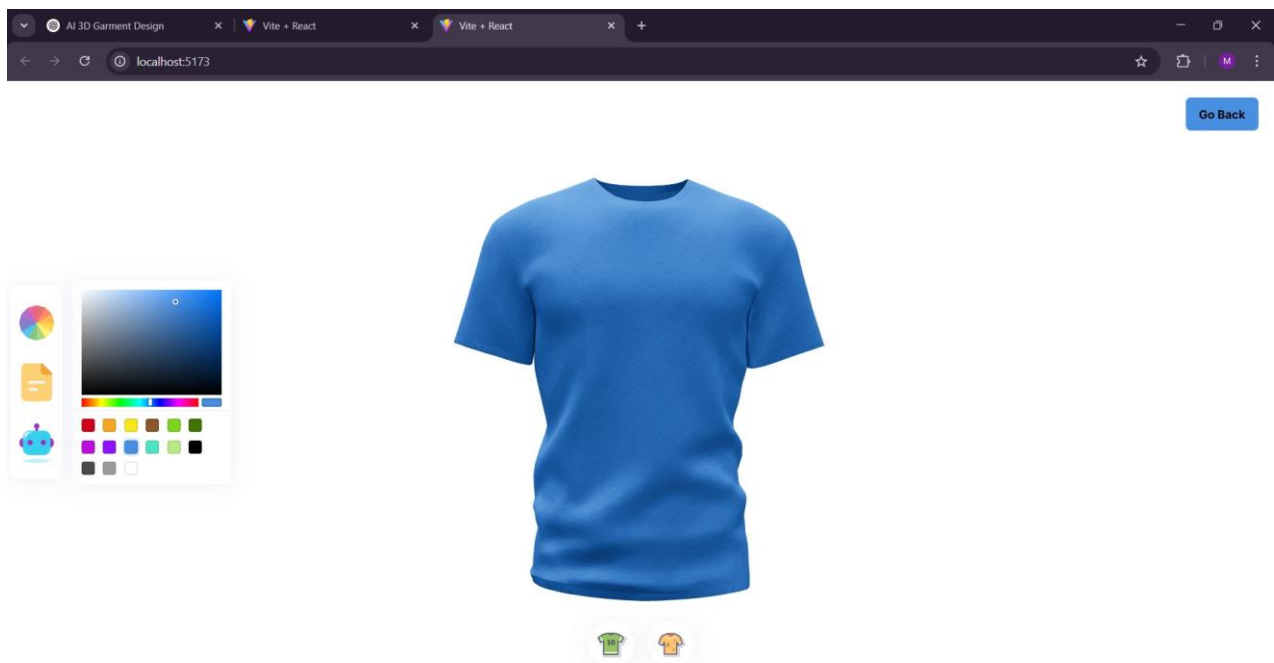


Figure 3: **Interface page 2**

the potential to encourage engagement with the opportunity to explore. The platform is constantly helping create an experience that's more interactive, intuitive, and imaginative. By working creativity in this way, the user experiences less constraint from the technology or processes hanging over these creative processes.

In conclusion, the project intends to transform the user experience for garment design. It allows designers to think and develop more accurately with less dependencies on a series of multiple prototypes. Obviously, the impact of this is streamlining both time and cost implications. In the case of reducing multi-prototyping, it has a positive impact on

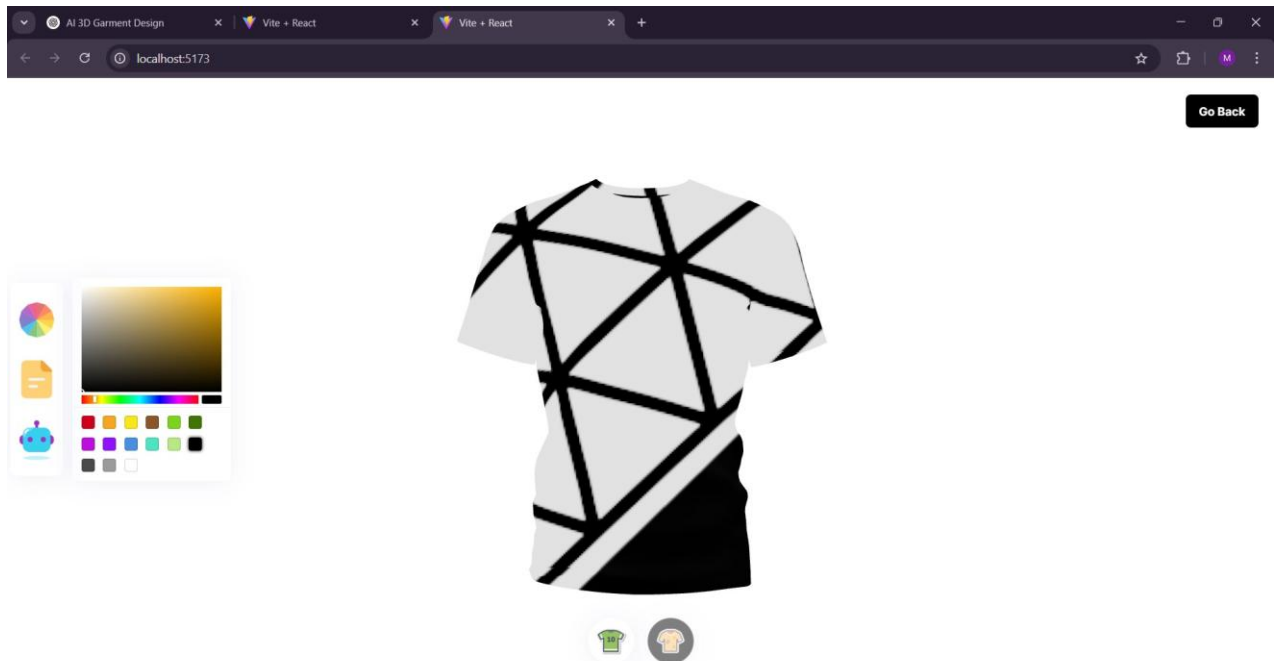


Figure 4: **4.3 Interface page 3**

building a more sustainable fashion ecosystem. Collectively, through multi-modal AI, real-time 3D and user-centric design principles, the platform should potentially be able to provide a standard for experimentation for innovative opportunities for the future of fashion.

5 Conclusion

This project aims to change the way we design garments by introducing an AI-enabled platform that supports automation while preserving manual flexibility. With the power of real-time 3D visualisation, this tool allows designers to assess garment fit and appearance with much greater fidelity and more or less completely eliminates the need for physical prototypes. This enables faster design cycles and a more cost-effective and sustainable production process. Additionally, the introduction of AI-enabled functions provides intelligent design input and better customisation that enable users to take creative liberties to the next degree. This platform allows a more integrated experience for not only professional designers but also fashion enthusiasts who want to create new garment with increased fluidity in the design process. In a larger context, the user-friendly interface, and added interactive features bring joy and approachability to the process of creating garment. As the fashion industry begins to redefine itself in a more digital and sustainable direction, this project is a wonderful design unto itself, as it demonstrates an intelligent and efficient approach to the future of apparel design.