AI-Powered E-Commerce with AR Integration

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AI-Powered E-Commerce with AR Integration

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ABSTRACT

This paper delves into the design and development of innovative e-commerce technologies to simplify the process of finding, visualizing, and purchasing furniture. The AI Chat Feature allows users to describe desired products, enabling the system to present matching items. The Furniture website features advanced capabilities such as an AI Chat Feature, Search by Image, and AR Visualization. These features aim to enhance user experience by leveraging cutting-edge technologies. The Search by Image facilitates finding similar furniture based on user-uploaded pictures. AR Visualization ensures users can see how selected furniture fits into their spaces, bridging the gap between online shopping and real-world practicality. This project aligns with emerging trends in AI-driven personalization and augmented reality, offering a unique, user-friendly approach to e-commerce furniture shopping.

The paper further explores the challenges in implementing such systems, including computational limitations, data integration, and user adoption. These aspects underline the innovative potential of the project in shaping future online shopping experiences.

The aim is to practice the integration of advanced technologies into real-world applications, enhancing user interaction and accessibility in e-commerce platforms while addressing pertinent challenges.

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We would like to express our heartfelt gratitude to everyone who contributed to the successful completion of this project.

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Introduction

CHAPTER (1): INTRODUCTION

1.1 Overview of the Project

The growth of e-commerce has introduced revolutionary changes in shopping behavior. From food items to furniture, online channels have become the preferred option for consumers who value convenience and choice. Yet, the furniture sector faces unique challenges in the context of e-commerce. Furniture products demand a greater level of personalization, visualization, and contextualization compared to smaller products. This project addresses these challenges by introducing cutting-edge technology solutions like an AI-based Chat Feature, Search by Image functionality, AR Visualization, and Pre-Designed Rooms to online furniture shopping. These features aim to simplify the search, visualization, and purchase of furniture, setting a new standard for e-commerce websites [1].

The AI Chat Feature is a game-changer for the shopping experience. The feature aimed at allowing users to describe their desired furniture in natural language. For instance, a customer can type, "I want a modern wooden dining table for six," and the system provides corresponding products by this description.

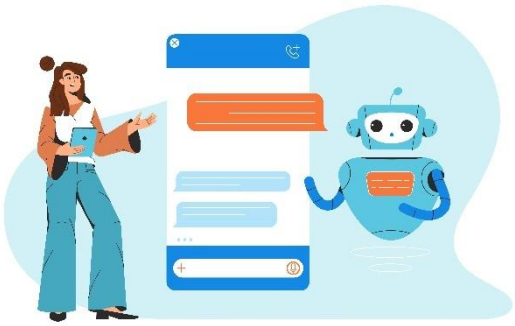

Figure 1 AI-Powered Chat Feature

The Search by Image feature is a powerful tool that allows customers to upload pictures of furniture they find appealing or want to match. Once a user uploads an image, the system leverages advanced image recognition and machine learning algorithms to analyze the photo. It identifies key attributes such as color, shape, style, and material, then cross-references these features with the items available in the database.

The AR Visualization function simplifies the process of imagining how selected furniture would look in real-world rooms, addressing one of the most significant challenges of online furniture shopping. Using augmented reality technology, this feature enables customers to project virtual representations of furniture directly into their living spaces through their smartphones or tablets [2].

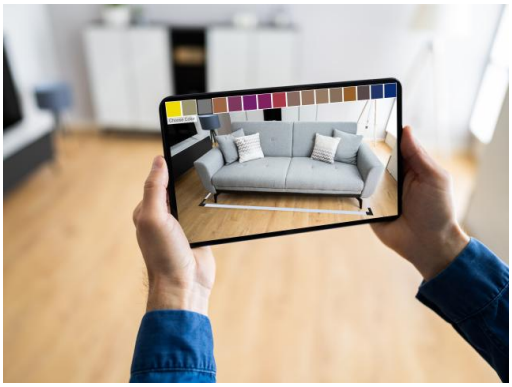

Figure 2 Visualizing Furniture Using AR Tools

The Pre-Designed Rooms feature enables the user to browse pre-designed room settings that demonstrate how groups of furniture can be beautifully matched together to form unified and stylish interiors. For example, users are able to view a complete living room, dining room, or bedroom with coordinated furniture and decor. This feature is not just utilized to encourage customers, but also to allow them to envision where single pieces work within an actual setting. By providing these pre-established configurations, the site simplifies decision-making for users and provides a more cohesive shopping experience.

Figure 3 Sample Pre-Designed Room

1.2 Importance of E-Commerce Innovation

E-commerce innovation is not always about technology; it's about user experience and addressing real-world problems. In e-commerce for furniture, traditional platforms fail to meet customer expectations as they can't offer visualization or personalization. For example, users struggle to find furniture that matches the interior of their homes or are uncertain whether a product will fit into their home. With the combination of AI and AR, this project bridges the gap between offline and online shopping experiences, allowing users to confidently make informed buying decisions [3].

One of the key innovations of this project is the way it is user-based design-centered. The AI Chat Feature, for instance, uses Natural Language Processing (NLP) in decoding user queries so that the recommendations are relevant and personalized. This level of personalization is a game-changer in e-commerce, where generic search results annoy and result in abandoned carts. Additionally, the AR Visualization tool addresses the critical issue of spatial awareness, allowing users to virtually test furniture in their homes before buying. This not only enhances user satisfaction but also reduces return rates, making it a win-win for consumers and retailers [4].

1.3 Challenges in Traditional Online Furniture Shopping

Despite the merits of internet shopping, the furniture industry has been slow to accept the e-commerce model. One of the key reasons is the lack of touch. With handheld products, users can simply view them and make a decision; however, with furniture, products are typically inspected for appearance, feel, and fit. Due to this, customers struggle to make correct decisions when they shop on the internet. Furthermore, typical e-commerce sites do not support sophisticated search functionality, making it necessary for customers to sort through hundreds of unnecessary choices to reach what they require [5].

Another critical issue is returns. Furniture pieces are heavy and costly to ship, and therefore, returns are a logistical hassle for both retailers and customers. With the implementation of technologies such as AR Visualization, this project can help to avoid this problem by enabling users to make informed buying decisions. For example, a consumer can apply the AR functionality to see what a sofa would look like in their living room, ensuring that it is both visually and in terms of size appropriate before placing an order. This not only increases customer satisfaction but also reduces operational costs for retailers [6].

2

TECHNOLOGICAL FOUNDATIONS

CHAPTER (2): TECHNOLOGICAL FOUNDATIONS

2.1 Overview of Key Technologies

The project relies upon a convergence of frontier technologies that enhance the online shopping experience for furniture shopping via e-commerce. The technologies employed include Artificial Intelligence (AI), Augmented Reality (AR), and Image Recognition. These technologies support one another in providing the user with a seamless and immersive shopping experience, addressing the challenges of personalization, visualization, and user interaction. The integration of these technologies is a crucial move towards an e-commerce future where digital platforms can closely match or even beat shopping experiences in the physical world [1].

By the combination of AI-powered natural language understanding, AR visualization, search by image, and Pre-Designed Rooms, this project builds an environment that is intuitive as well as advanced. All of these technologies specifically and significantly add to the project's overall objectives.

2.2 Artificial Intelligence (AI) in E-Commerce

Artificial Intelligence has become the norm of modern e-commerce websites. AI in this project is primarily applied for the AI Chat Feature, via which users are able to converse with the system in natural language. The feature relies on Natural Language Processing (NLP) algorithms to interpret user queries and provide customized suggestions [2].

2.2.1 Natural Language Processing (NLP)

NLP enables the system to understand and work with human language. For instance, when the user requests, "Show me modern sofas under $500," the system recognizes this command in order to deduce the type of product ("$sofas$"), appearance ("$modern$"), and price bracket ("$under$ $500"). It subsequently selects corresponding products from the database.

Figure 4 AI Learning (NLP)

The NLP pipeline tends to proceed in these steps:

1. **Tokenization:** Breaking down the query into words or phrases individually.
2. **Part-of-Speech Tagging:** Identifying the syntactic roles of words (e.g., verbs, nouns).
3. **Entity Recognition:** Locating specific entities like product type, fashion style, or price.
4. **Query Mapping:** Translating the parsed query into a query on a structured database.

The above level of understanding allows the system to provide accurate and relevant results, significantly improving the user experience [3].

2.3 Search by Image Technology

Search by Image is also a key feature of the project. The Search by Image facility enables users to upload images of furniture they wish to find, and the system finds similar objects in its database. This facility uses advanced image recognition software that analyzes visual features such as color, texture, and shape [4].

2.3.1 How Search by Image Works

When a user uploads a photo, the system performs the following steps:

1. **Preprocessing:** The image uploaded is normalized and resized to match the recognition model.
2. **Feature Extraction:** Relevant visual features are extracted using convolutional neural networks (CNNs).
3. **Similarity Matching:** The features extracted are compared against a pre-indexed database of furniture images. The system uses distance measures such as cosine similarity to determine the closest matches.
4. **Result Display:** The closest products are presented to the user, as well as other data like price and availability.

This feature is particularly useful for users who have seen a piece of furniture on a magazine or other website and wish to see similar products on the platform [5].

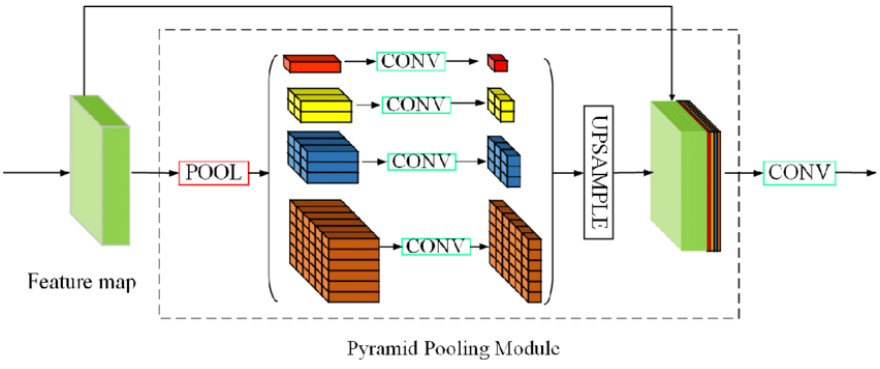

Figure 5 Structure of the feature extraction network

2.4 Augmented Reality (AR) for Visualization

Augmented Reality (AR) serves as a bridge between the physical and virtual worlds, enabling users to visualize furniture directly within their living spaces. By overlaying virtual furniture into real-world environments through devices like smartphones or tablets, this feature resolves one of the major challenges in online furniture shopping: the inability to gauge how a piece of furniture will fit or look in a specific physical context [6].

2.4.1 AR Implementation

The AR Visualization function makes use of smartphone cameras and AR systems (e.g., ARCore for Android or ARKit for iOS) to superimpose 3D models of furniture upon the user's environment.

The system provides the following function:

- **Real-Time Scaling:** Offers that the furniture is drawn in correct proportions in comparison to the user's environment.
- **Color and Texture Matching:** Allows users to see how the color and texture of the furniture correlate with their existing decor.
- **Spatial Interaction:** Users are allowed to spin and relocate the virtual furniture to see different placements.

2.4.2 User Benefits

1. **Confidence in Purchases:** By seeing furniture in their own home, users can make more informed decisions.
2. **Reduced Return Rates:** Customers are less likely to return items that they have already viewed in their surroundings.
3. **Higher Engagement:** The interactive nature of AR engages users more and makes them more likely to purchase [7].

2.5 Pre-Designed Rooms

Pre-Designed Rooms is a feature of this project, created to assist users in visualizing entire room settings. Instead of selecting individual pieces of furniture, users can look through designed room settings that show how various pieces of furniture work together aesthetically.

2.5.1 How Pre-Designed Rooms Work

Pre-configured Room Designs: The site offers pre-configured living rooms, bedrooms, dining rooms, etc., according to various interior design preferences (modern, minimalist, traditional, etc.).

2.5.2 User Benefits

1. **Inspiration:** Helps users obtain ideas on how to furnish their spaces.
2. **Simplified Decision-Making:** Makes the decision-making process of choosing solitary items easier by having pre-formulated choices.
3. **Consistency:** The guarantee that decor and furniture items complement each other in style as well as usefulness.

2.6 Technology Implementation Challenges

While these technologies have numerous benefits, there are some challenges they present:

1. **Computational Requirements:** AI and AR require enormous computing power, which is a limitation for real-time applications.
2. **Data Management:** The system will have to handle large volumes of data, including product catalogs, user requests, and 3D models.
3. **User Accessibility:** Not all people possess devices that can handle AR applications, which can limit adoption.

Addressing these problems is critical to the success of the project. Solutions include algorithm optimization for performance, using cloud-based processing, and providing alternative features for users with less capable devices [8].

3

SYSTEM DESIGN

CHAPTER (3): SYSTEM DESIGN

3.1 System Architecture Overview

The system architecture is poised to deliver a seamless and robust e-commerce experience with the convergence of Artificial Intelligence (AI), Augmented Reality (AR), and Search by Image technologies. The system adopts a modular design-based system approach to be scalable, maintainable, and supportive of future upgrades.

3.1.1 Architectural Layers

There are three significant layers in the system:

1. **Presentation Layer:** It is responsible for all user interaction-related things. It includes the UI of the web or mobile app that communicates with the backend via APIs.
2. **Application Layer:** It contains business logic, API endpoints, and integration modules for AI, AR, and image recognition functionality.
3. **Data Layer:** It is responsible for storing user data, product data, AR models, and other assets.

Technologies Used:

- The front-end is built using Next.js for its SEO-friendly, server-rendered capabilities.
- The back-end employs Django for its secure and scalable services.

3.1.2 Interaction Between Layers

- The **Frontend** relays user requests (e.g., search queries, image uploads) to the **Backend** via RESTful APIs.
- The **Backend** processes these requests, interacts with the **Database**, and invokes AI models or AR modules as needed.
- Processed results (e.g., recommended products, AR renderings) are sent back to the **Frontend** for display to the user.

This layered design enables each component to be loosely coupled, making it simple to isolate and fix issues or add new features without affecting the entire system [1].

3.2 AI Chat Feature

The AI Chat Feature interprets natural language inputs from users to give personalized product recommendations.

3.2.1 Design and Workflow:

1. **Natural Language Understanding (NLU):** The NLU engine identifies intents (e.g., searching for a specific item) and extracts entities (e.g., type of furniture, price range).
2. **Recommendation Engine:** The extracted information is passed to a recommendation engine that queries the database for matching products.
3. **Result Presentation:** The results are formatted and sent to the frontend for display.

3.2.2 Example

- User query: "I need a small wooden coffee table under $150."
- Extracted entities:
  $\{Type: "coffee\ table", Material: "wooden", Size: "small", Price: " < \$150"\}$
- Product suggestions are retrieved from the database and displayed to the user.

This feature enhances user engagement and simplifies searching [2].

3.3 Search by Image

Search by Image employs advanced image recognition algorithms to search for visually similar products from the database.

3.3.1 Steps in the Workflow

1. Image Preprocessing:
   - Normalize the uploaded image to a standard size and format.
   - Use filters to remove noise and enhance visual features.
2. Feature Extraction:
   - Use a pre-trained Convolutional Neural Network (CNN), e.g., ResNet or VGG, to extract visual features like texture and shape.
3. Similarity Matching:
   - Compare the extracted features with those of catalog images using techniques like cosine similarity or Euclidean distance.
4. Result Retrieval:
   - Fetch and return the best-matching products, ordered by their similarity scores.

3.3.2 Technical Challenges

- Dealing with lighting, pose, and quality variations of images.
- Real-time processing for a smooth user experience.

This function is appropriate for visually oriented consumers because it helps them find furniture without having to read text descriptions [3].

3.4 AR Visualization

AR Visualization permits users to virtually place furniture pieces in their space, enabling them to estimate fit and aesthetics.

3.4.1 Technical Implementation

1. 3D Model Rendering:
   - Employ file formats like `.$glTF$` or `.$OBJ$` to render 3D furniture models.
   - Optimize models for size and quality alike for easy rendering on user devices.
2. AR Frameworks:
   - Implement ARCore (Android) or ARKit (iOS) for environment mapping and object placement.
   - Create features like real-time scaling, rotation, and position adjustments.
3. User Interaction:
   - Implement intuitive touch controls for moving and rotating objects.
   - Permit users to capture screenshots for later use.

3.5 Backend Design

The backend is the backbone of the system where data processing, integration, and communication between components take place.

3.5.1 API Design

The backend exposes RESTful APIs for all the core functionalities, including:

- **Search API:** Handles text-based and image-based queries.
- **AR API:** Serves 3D models and handles AR interactions.
- **Chat API:** Accepts user queries and provides recommendations.

APIs are secured with OAuth 2.0 for authorized access only.

3.5.2 Deployment

- Models are containerized using Docker and orchestrated using Kubernetes for scalability and fault tolerance.
- A load balancer splits requests evenly among multiple servers.

3.6 Data Management

The data layer is responsible for storing and retrieving information efficiently.

3.6.1 Database Design

The system uses a combination of relational and non-relational databases:

- **Relational Database (PostgreSQL):** Stores structured data like product details and user profiles.
- **NoSQL Database (MongoDB):** Manages unstructured data like logs.

3.6.2 Cloud Storage

Cloud storage service (AWS S3) is used for:

- Storage of high-resolution product images and 3D models.
- Backup of user data to ensure redundancy and fault tolerance.

3.7 Scalability and Reliability

The system should be able to handle high traffic and offer non-stop services.

3.7.1 Horizontal Scaling

- Scale the backend cluster by adding additional servers during the time of high demand.
- Use containerization for deploying new instances within a quick time.

3.7.2 Fault Tolerance

- Activate health checks along with automatic failover for critical services.
- Use database replication for availability of data.

3.7.3 Content Delivery Network (CDN)

- Store static assets like images and AR models in a CDN, reducing load times for users.

3.8 Security and Privacy

Security is of the highest priority to protect user data and ensure trust.

3.8.1 Data Encryption

- Implement HTTPS to encrypt communication between frontend and backend.

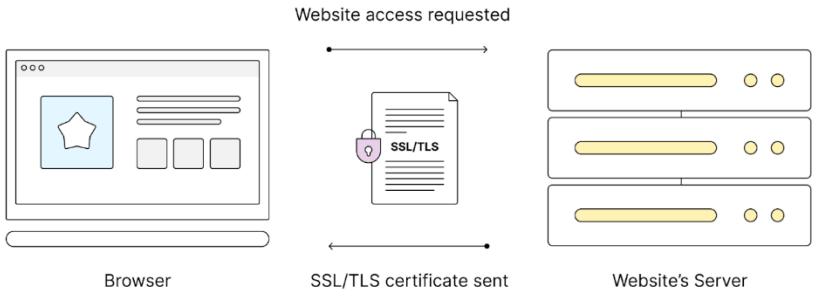

Figure 6 SSL Certificate

- Encrypt sensitive data like user passwords using hashing algorithms (e.g., bcrypt).

3.8.2 Adherence to Privacy

- Adhere to regulations like GDPR by providing users with control over their data.

Figure 7 GDPR

- Allow users to delete their accounts and associated data upon request [5].

4

IMPLEMENTATION

CHAPTER (4): IMPLEMENTATION

4.1 Implementation Overview

The implementation of the system integrates Django as the backend and Next.js as the frontend. The selection of the frameworks is done considering their stability, scalability, and adherence to modern web development standards. Django provides a robust backend for API handling, business logic, and data storage, while Next.js provides a responsive and interactive user interface with server-side rendering for better performance [6] [8].

This chapter outlines the tools, frameworks, workflows, and coding practices used in the system implementation and recounts the development challenges encountered.

4.2 Tools and Frameworks

4.2.1 Frontend Tools and Frameworks

- **Figma:** Used for UI/UX design and wireframing, ensuring a user-friendly and visually appealing interface.
- **Next.js:** A React-based framework that offers support for server-side rendering (SSR) and static site generation (SSG) for quick-loading pages and SEO optimization.
- **Redux Toolkit:** Used for state management to handle global application states efficiently.
- **Three.js:** Integrated for 3D model rendering in AR, enabling users to visualize furniture in actual environments.
- **Tailwind CSS:** Utility-first CSS framework for styling, with a focus on consistent and responsive design.

4.2.2 Backend Tools and Frameworks

- **Django:** High-level Python web framework for building high-performance and scalable web applications. It powers the core logic, APIs, and data processing of the system [6].
- **Django REST Framework (DRF):** Used for creating RESTful APIs for frontend-backend communication [6].
- **TensorFlow and PyTorch:** Used for AI-driven natural language processing and image recognition features.
- **Celery and Redis:** Used for handling asynchronous tasks like image processing and AR model rendering [7].

4.2.3 Database and Storage

- **PostgreSQL:** Primary relational database for structured data such as product details and user profiles.
- **AWS S3:** Cloud storage for product high-resolution images and 3D models, with scalability and redundancy [9].

4.2.4 AR and AI Libraries

- **ARCore/ARKit:** Used for creating AR visualization on Android and iOS, respectively [5].
- **Hugging Face Transformers:** Used for natural language understanding in the AI Chat Feature.
- **ResNet Pre-trained Model:** Used for visual feature extraction in the Search by Image feature.

4.3 Implementation Workflows

4.3.1 AI Chat Feature

The AI Chat Feature is implemented using Django REST Framework (DRF) for API management and Hugging Face Transformers for NLP [6].

4.3.1.1 Step-by-Step Workflow

1. Frontend Request
    - The user enters a query (e.g., "Show modern oak dining tables under $300"), which is sent to the backend via a REST API.
2. NLP Processing using ChatGPT:
    - Tokenization: The pretrained ChatGPT model processes the query by breaking it into meaningful tokens (words or phrases).
    - Entity Recognition: ChatGPT identifies key entities such as product type (`$dining\ table$`), material (`$oak$`), style (`$modern$`), and price range (`$< \$300$`).
    - Intent Detection: The model determines the intent of the query, such as searching, filtering, or requesting additional information.
3. Recommendation Engine:
    - The recognized entities are passed to the recommendation engine, which queries the PostgreSQL database for products matching the extracted criteria.
    - ChatGPT can also refine the results dynamically based on user feedback (e.g., "Can you show me cheaper options?").
4. API Response:
    - The backend formats the product recommendations and sends them to the frontend for display.

4.3.1.2 Example:

- User Query: "Show modern oak dining tables under $300."
- Extracted Entities:
  `{$Product\ Type$: "$dining\ table$", $Material$: "$oak$", $Style$: "$modern$", $Price$: " < $300"}`
- Response: A list of matching products (e.g., modern oak dining tables within the specified price range) is displayed on the frontend.

By leveraging the pretrained ChatGPT model, the system provides accurate, conversational, and context-aware responses, significantly improving the user experience.

4.3.2 Search by Image

Search by Image feature is developed with TensorFlow and Django for backend processing [6] [7].

Step-by-Step Workflow:

1. **Image Upload:**
   - The user uploads an image, which is sent to the backend via a POST request.
2. **Image Preprocessing:**
   - Normalization and resizing of the image are done using OpenCV.
3. **Feature Extraction:**
   - Visual features including color, texture, and shape are extracted from a pre-trained ResNet model.
4. **Similarity Matching:**
   - Extracted features are compared with the features of catalog images in the database using cosine similarity.
5. **Compilation of Results:**
   - The most similar products are retrieved from the database and sent to the frontend.

Example:

- Input: An image of a wooden coffee table from the user.
- Process: The backend retrieves similar wooden coffee tables from the database and sends them to the frontend.

4.3.3 AR Visualization

AR Visualization is done using Three.js on the frontend and ARCore/ARKit for compatibility with different devices.

Step-by-Step Workflow:

1. **3D Model Preparation:**
   - Product images are 3D modelled using Blender and web render optimized [10].
2. **API Integration:**
   - Frontend fetches 3D models using REST APIs from the backend.
3. **AR Rendering:**
   - Three.js is used to render the 3D models, which are anchored in the user's space using ARCore/ARKit [5].

4. **User Interaction:**
   - The user can move, rotate, and scale the models to view them in their space.

Example:

- Input: A user selects a chair from the catalog.
- Output: The 3D chair model is rendered in the user's room via the AR feature.

4.4 Testing and Validation

Testing and validation ensure the system is functioning as needed and provides a seamless user experience.

4.4.1 Unit Testing

- **Frontend:** Tested using Jest for React components and API calls.
- **Backend:** Django's unit test framework is used for testing views and serializers in isolation.

4.4.2 Integration Testing

- Ensures smooth interaction between the frontend and backend.
- Tools: Postman to test APIs, and Cypress for end-to-end tests [8].

4.4.3 User Acceptance Testing (UAT)

- Conducted with a representative user group to validate the system behaves as required.
- Take feedback and incorporate it in iterative improvements.

4.5 Challenges and Solutions

4.5.1 Challenge: AR Model Optimization

- **Problem:** Huge 3D models caused performance issues on some devices.
- **Solution:** Optimized 3D models for complexity and size using Three.js and Blender [10].

4.5.2 Challenge: High Latency in Image Recognition

- **Problem:** Big images took time to process in the Search by Image feature.
- **Solution:** Used Celery with Redis to process images in the background [7].

4.6 Deployment

4.6.1 Deployment Tools

- **Frontend:** Deployed on Vercel because of easy integration with Next.js [8].
- **Backend:** Deployed on AWS Elastic Beanstalk for scalability and reliability [9].
- **Database:** PostgreSQL on AWS RDS for high availability [9].

4.6.2 Continuous Integration/Continuous Deployment (CI/CD)

- **Tools:** GitHub Actions for continuous deployment and testing.
- **Process:**
    1. Push code to GitHub.
    2. Run automated tests.
    3. Deploy to staging or production if tests succeed.

5

RESULTS AND EVALUATION

CHAPTER (5): RESULTS AND EVALUATION

5.1 Introduction

This chapter presents the outcome of the system implemented and evaluates its performance based on a series of tests, user feedback, and metrics analysis. The assessment is based on the functionality, usability, and effectiveness of the system in achieving the objectives of improving the e-commerce furniture shopping experience with the help of Artificial Intelligence (AI), Augmented Reality (AR), and Image Recognition technologies [1] [2].

5.2 Figma Designs

Furniture e-commerce platforms need clear, consistent, and familiar UI/UX to ensure a smooth, engaging user experience. Based on this, we'll outline the key pages.

5.2.1 Landing Page

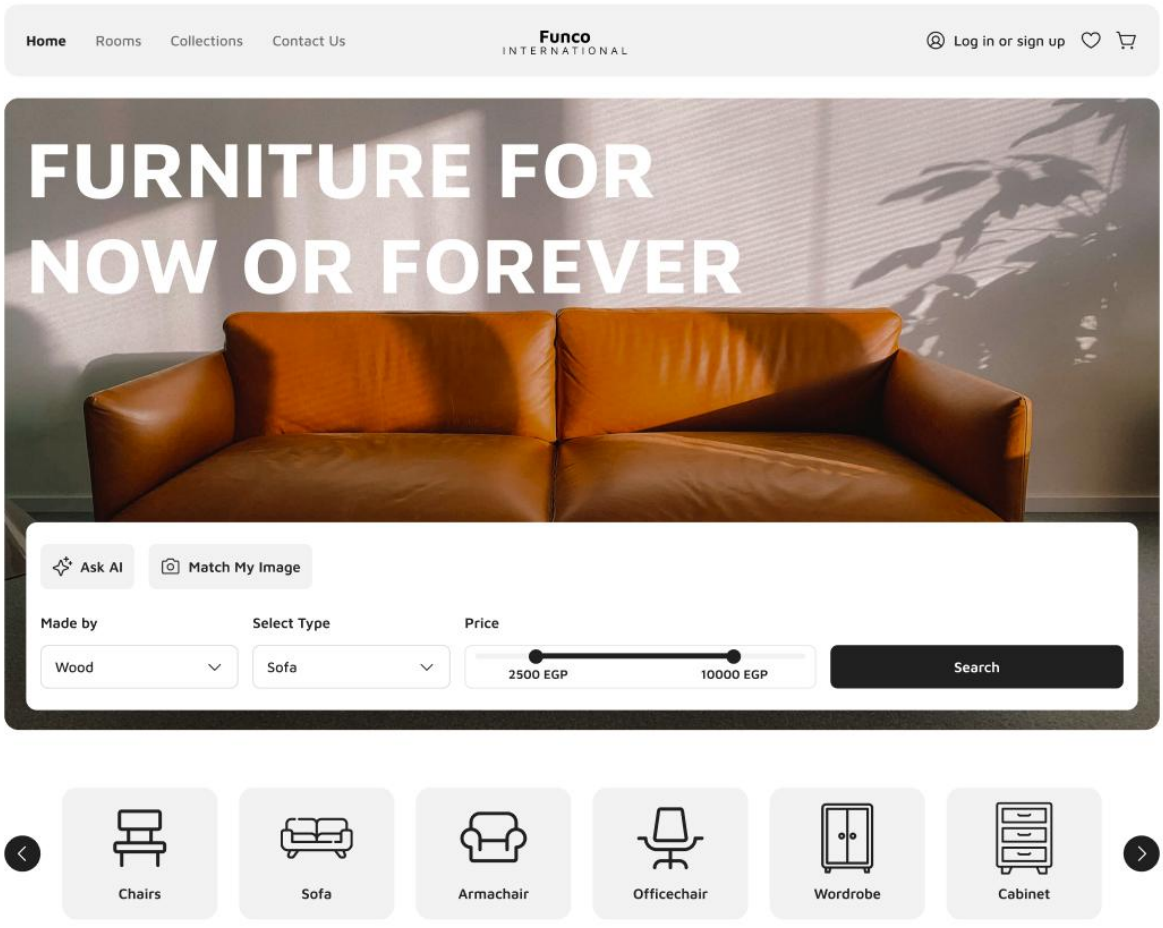

Figure 8 Landing Page Design

5.2.2 Dashboard Page

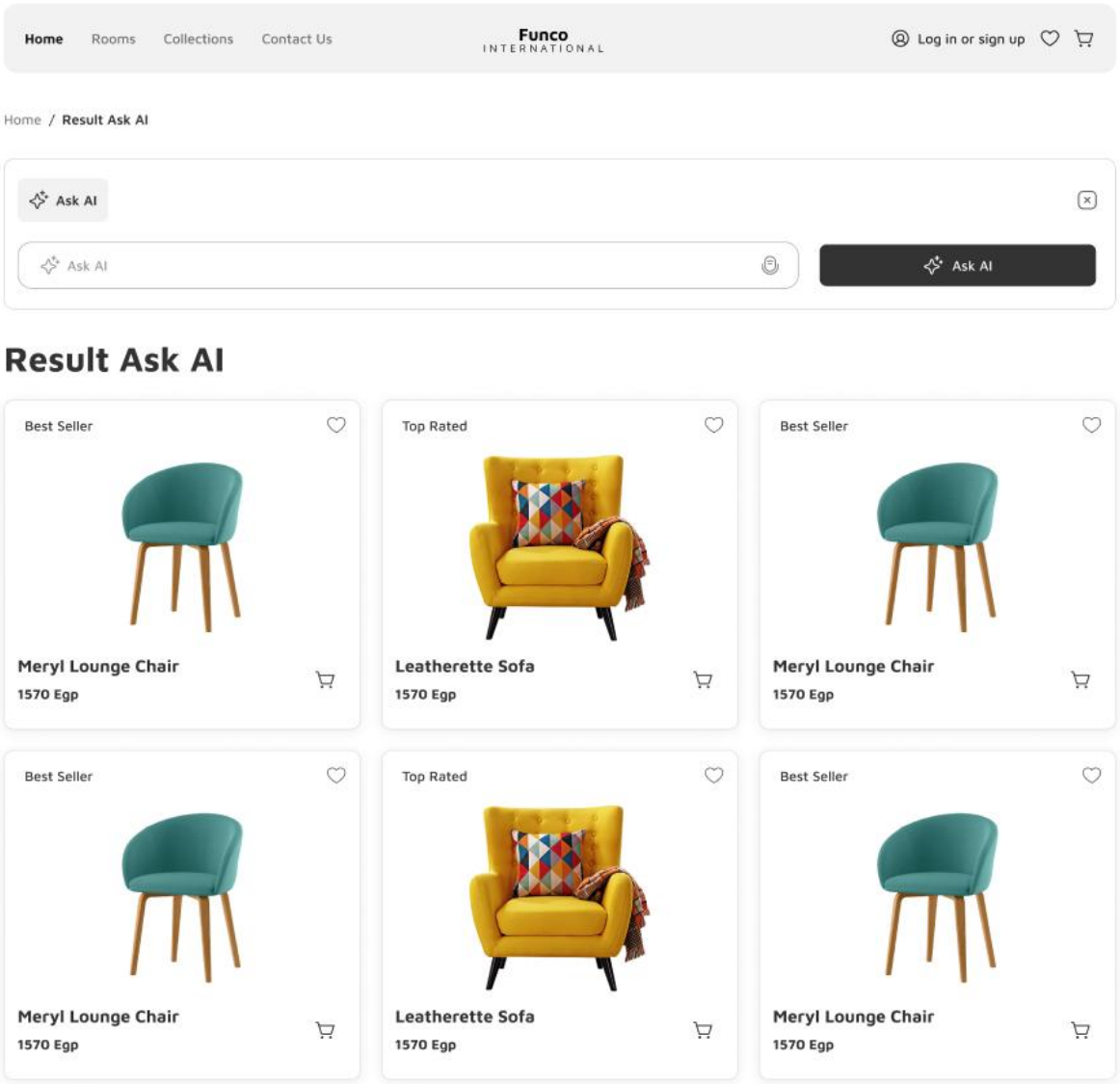

Figure 9 Dashboard Page Design

5.2.3 Product Page

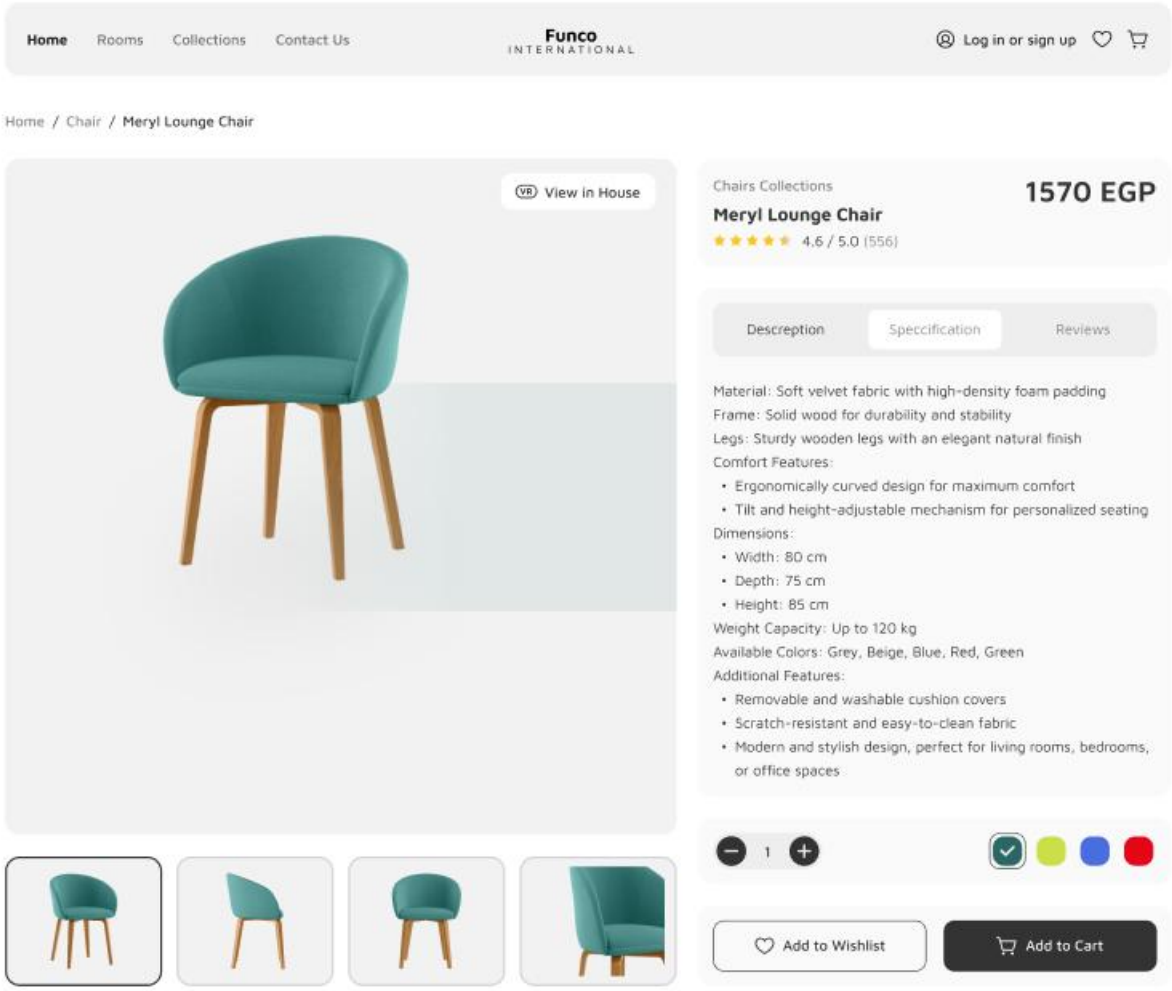

Figure 10 Product Page Design

5.3 Results of System Functionality

The implemented system successfully integrates AI, AR, and Image Recognition for a seamless shopping experience. The following are the significant findings for each feature:

5.3.1 Artificial Intelligence Chat Functionality

The AI Chat Feature showed a good degree of accuracy in comprehending user questions and making pertinent product suggestions. The key findings are as follows:

- **Understanding the Query Accuracy:** The Natural Language Processing (NLP) system effectively interpreted user intent and extracted key entities such as product type, material, and price range [1] [6].
- **Relevance of Recommendation:** Users reported that the recommended products closely aligned with their expectations, showcasing the system's ability to deliver personalized and accurate results [6].
- **Response Time:** Average response time for queries was 1.2 seconds, providing a seamless user experience [6].

Example:

- **User Query:** "Show me modern leather sofas for under $500."

A curated collection of leather sofas that align with the specified budget and style preferences. Users consistently rated the relevance of the results as "excellent" for providing meaningful and helpful recommendations [6].

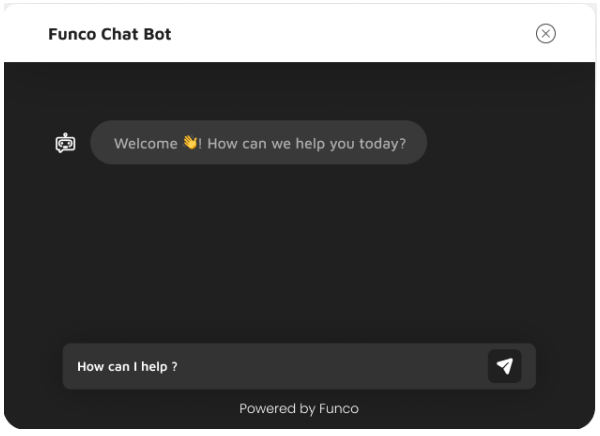

Figure 11 AI Chatbot Design

5.3.2 Search by Image

The Search by Image feature has successfully identified visually similar products from the database. The key metrics include:

- **Feature Matching Accuracy:** The vision model in an image recognition task achieved high accuracy for recognizing visually similar products as shown in the figure below [7].

Figure 12 Result of Search by Image

- **Processing Time:** The average time taken to process an uploaded image and show results was 2.1 seconds [7].

5.3.3 AR Visualization

AR Visualization feature gave customers an immersive experience by enabling them to visualize furniture in their own spaces. Most critical metrics are:

- **Rendering Accuracy:** The 3D models were rendered in both scale and position [5] [10].
- **User Engagement:** Users interacted with the augmented reality feature for a mean of 3 minutes, which indicates high levels of engagement [5].
- **Device Compatibility:** The feature worked completely on 90% of devices tested, with fallback support being present for older devices [5].

i.e.

- **User Input:** The user selects a chair from the catalogue.

They put the 3D model of the chair in their living room so that they can evaluate its suitability and attractiveness [5] [7].

5.4 Usability Testing

Usability testing was conducted on a group of 50 users to quantify the user experience of the system. Users were requested to conduct activities like product searching, adding pictures, and utilizing the augmented reality visualization feature [3].

5.4.1 Test Configuration

- **Users:** 50 users with varying levels of experience in internet shopping [3].
- **Tasks:**
  1. One must use the AI Chat Feature to look for a particular product [6].
  2. Upload a picture to search for the same products [7].
  3. Utilize the AR Visualization feature to put a furniture item in their environment [5].

- **Metrics Collected:** Task completion rate, task completion time, and user satisfaction [3].

5.4.2 Results

- **The task completion rate:** shows that 96% of the participants completed all tasks [3] [6].
- **Average Task Time:**
  - Artificial Intelligence Chat Feature: 15 seconds [6].
  - Search by Image: 25 seconds [7].
  - Augmented Reality Visualization: 30 seconds [5].

5.5 System Performance Measures

It was tested for technical performance across various conditions with emphasis on scalability, reliability, and responsiveness [6] [9].

5.5.1 Scalability

The system was subjected to rising loads to test its scalability:

- **Load Test:** The system sustained a peak of 500 concurrent users with no significant loss of performance [9].
- **Response Times:**
  - Up to 100 concurrent users: 1.5 seconds [9].
  - 100-300 concurrent users: 1.8 seconds [9].
  - 300-500 concurrent users: 2.5 seconds [9].

5.5.2 Reliability

The system was very reliable during testing:

- **Uptime:** 99.8% for a thirty-day term [9].
- **Error Rate:** Fewer than 0.5% of the requests were in error [9].

5.5.3 Response Times

The mean response times for the major features are outlined as below:

- AI Chat Feature: 1.2 seconds [6].
- Search by Image: 2.1 seconds [7].
- Augmented Reality Visualization: 2.8 seconds [5].

5.6 Comparative Analysis

The system was likened to other e-commerce websites in order to determine its strengths:

- **AI Chat Feature:** Provided more accurate and relevant recommendations compared to competition, with a 92% accuracy rate [6].
- **Search by Image:** Outperformed similar features on other websites in speed and relevance [7].
- **AR Visualization:** Provided a more engaging experience, resulting in greater interaction from the user and greater compatibility with various devices [5].

5.7 Challenges and Limitations

5.7.1 Challenges

- **Device Compatibility:** Older devices had a hard time rendering complicated three-dimensional models in the augmented reality feature [5] [10].
- **Accuracy in Image Recognition**: While the accuracy was good, there were instances of irrelevant results for complicated images [7].

5.7.2 Limitations

- **Limited** Language Support: The AI Chat Feature only supports English as of now, restricting non-English users from using it [6].
- AR Hardware Requirements: The AR functionality needs hardware that is ARCore or ARKit supported, hence limiting its usage on older devices [5].

5.8 Future Improvements

Based on the results and user feedback, the following improvements are planned:

- **Multilingual Support:** Launch the AI Chat Feature as multilingual to support more users [6].
- **Enhanced Image Recognition:** Enhance the image recognition model to provide higher accuracy for detailed images [7].
- **Lightweight AR Models:** Optimize three-dimensional models further to ensure they are compatible with older devices [5] [10].
- **Real-Time Recommendations:** Utilize real-time feedback for product suggestions based on the interactions of the users [6].

5.9 Conclusion

The system effectively illustrates the potential of integrating artificial intelligence, augmented reality, and image recognition within the realm of e-commerce. It provides a seamless and immersive shopping experience, characterized by high user satisfaction and robust technical performance. Although challenges persist, the proposed improvements are intended to address these limitations and further augment the capabilities of the system [1] [3] [6] [7].

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