TUKULE

BRIDGING CUSTOMER EXPECTATIONS AND REALITY WITH IMMERSIVE 3D MENU VISUALIZATIONS & 3D TABLE RESERVATIONS

Exploring how detailed 3D visualizations and real-time reservation feedback contribute to a more reliable and satisfying dining experience addressing common pain points in the restaurant industry, such as miscommunication of seating arrangements and food presentation.

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APRIL, 2025

TUKULE

BRIDGING CUSTOMER EXPECTATIONS AND REALITY WITH IMMERSIVE 3D MENU VISUALIZATIONS & TABLE RESERVATIONS SYSTEMS

PHILEMON KOMI KOSKEI

A Project Documentation Presented to the Department of Computing and Informatics of Laikipia University in Partial Fulfillment of the Requirements for the for the Award of Bachelor's Degree in Computer Science

LAIKIPIA UNIVERSITY

APRIL, 2025

DECLARATION

I, Philemon Komi Koskei, declare that the research project is my own work and to the best of my knowledge it has not been presented for the award of a degree in any university or college. This proposal has been written per the guidelines for proposal writing at Laikipia University

Signed: ________________________ Date: ____________________________

PHILEMON KOMI KOSKEI

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RECOMMENDATION

To the Department of Computing and Informatics:

The documentation entitled "**TUKULE - BRIDGING CUSTOMER EXPECTATIONS AND REALITY WITH IMMERSIVE 3D MENU VISUALIZATIONS & TABLE RESERVATIONS"** and written by **PHILEMON KOMI KOSKEI** is presented to the **Department of Computing and Informatics, School of Science and Applied Technology – Laikipia University.** We have reviewed the research (project/proposal/thesis) and recommend it be accepted in partial fulfillment of the requirement for award of the degree of Bachelor of Science – Computer Science.

Signed: ___________________________ Date: ______________________________

DR. EVANS OMBATI

DEPARTMENT OF COMPUTING AND INFORMATICS

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LAIKIPIA UNIVERSITY

DEDICATION

This project is dedicated to all innovators seeking to bridge the gap between digital representations and reality in the service industry. It is also dedicated to my family, whose support has been a pillar of strength throughout my academic journey.

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ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to my supervisor, Dr. Evans Ombati, for their invaluable guidance, support, and encouragement throughout this research process. Their expertise and dedication have been instrumental in shaping the direction and success of this project.

I am also deeply thankful to my family and friends, whose unwavering support, understanding, and encouragement have constantly motivated me. Their belief in my abilities has been my strength throughout this journey.

Lastly, I extend my appreciation to my colleagues and everyone who contributed directly or indirectly to the completion of this project. Your insights and encouragement have been greatly appreciated.

ABSTRACT

Restaurant dining experiences often suffer from a fundamental disconnect between customer expectations and reality. Inaccurate menu representations and unclear seating arrangements lead to disappointment when the actual experience fails to match anticipated quality. This disconnect creates negative reviews, and lost revenue impacting customer satisfaction, with studies showing approximately 65% of negative reviews stem from unmet visual expectations - a persistent challenge in the restaurant industry where first impressions and visual appeal significantly influence dining decisions. TUKULE addresses this critical challenge by implementing immersive 3D visualization technology that provides accurate representations of both menu items and dining spaces before customers make reservations or place orders

TUKULE addresses this gap by implementing immersive 3D menu visualizations and interactive reservation systems that provide realistic previews of both food presentation and dining environments. This innovation is particularly significant as post-pandemic dining behaviors demonstrate increased consumer research before committing to dining experiences, with visual accuracy becoming a critical factor in decision-making.

The project aims to: (1) quantify the impact of visual-reality disparities on customer satisfaction; (2) develop photorealistic 3D menu visualization technology that accurately represents portion sizes, presentation, and ingredient composition; (3) implement interactive reservation systems allowing customers to preview and select specific seating arrangements; and (4) measure improvements in customer satisfaction and restaurant operational efficiency.

Using a mixed-methods approach, TUKULE will collect quantitative data through pre- and post-implementation surveys measuring satisfaction metrics while gathering qualitative insights through interviews with both customers and restaurant staff. I will employ photogrammetry techniques to create precise digital replicas of menu items, integrated with VR/AR technologies for an immersive preview experience.

By bridging the gap between expectations and reality, TUKULE aims to revolutionize the restaurant industry's approach to customer communication, potentially reducing complaints by 30% and increasing customer retention through enhanced trust and transparency in the dining decision process.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The dining industry is undergoing a digital transformation, with technology increasingly mediating the relationship between restaurants and their customers. TUKULE, which means "Let's Eat" in Swahili, represents an innovative intersection of immersive technology and hospitality services. This project documentation details the development, implementation, and evaluation of TUKULE, a 3D visualization application designed to transform how customers perceive and interact with restaurant offerings before physical engagement.

1.2 Background of Study

The restaurant industry has historically relied on static menu images, textual descriptions, and basic reservation systems to communicate with potential customers. This approach often creates a significant gap between customer expectations and reality. Traditional menu photos are frequently professionally staged, potentially misrepresenting the actual dish that arrives at the table. Similarly, reservation systems typically provide limited information about seating arrangements, leading to misunderstandings and dissatisfaction.

The advent of immersive technologies like 3D visualization, augmented reality (AR), and virtual reality (VR) has created opportunities to address these longstanding challenges. Recent technological advancements have made high-quality 3D rendering more accessible and cost-effective for commercial applications, enabling the development of solutions like TUKULE.

The COVID-19 pandemic further accelerated digital transformation in the restaurant industry, with customers increasingly relying on digital interfaces for making dining decisions. This shift has highlighted the need for more accurate and engaging digital representations of restaurant offerings.

1.3 Statement of Problem

The restaurant industry faces a persistent challenge: the disconnect between how food and dining spaces are presented in marketing materials versus how they appear in reality. This discrepancy manifests in several ways:

1. Menu items often appear different in person than in promotional images, leading to customer disappointment and dissatisfaction.
2. Dining spaces and seating arrangements are typically not viewable before arrival, resulting in unexpected experiences regarding table location, privacy, and ambiance.
3. Traditional menu descriptions lack the detail and visual accuracy needed for customers with specific requirements, such as those with dietary restrictions or accessibility needs.
4. The inability to accurately visualize menu items and dining spaces before ordering or reserving contributes to customer complaints, negative reviews, and reduced loyalty.

These issues collectively create an "expectation gap" that impacts customer satisfaction, restaurant reputation, and business sustainability.

1.4 Purpose of Study

The purpose of this study is to develop and evaluate TUKULE, an immersive 3D application that bridges the gap between customer expectations and reality in the restaurant industry. By providing photorealistic 3D visualizations of menu items and interactive representations of dining spaces, TUKULE aims to transform the pre-dining decision-making process and enhance overall customer satisfaction.

1.5 Objectives of Study

1. To develop photorealistic 3D models of menu items that accurately represent portion sizes, ingredient composition, and presentation styles.
2. To create interactive 3D visualizations of restaurant dining spaces that allow customers to explore and select specific seating arrangements.
3. To implement a real-time reservation and feedback system that integrates with the 3D visualizations.

1.6 Hypothesis

1. How does the use of photorealistic 3D menu visualizations affect customer satisfaction compared to traditional menu presentations?

2. To what extent does interactive exploration of dining spaces before reservation influence customer seating preferences and overall dining experience?
3. What is the relationship between the accuracy of visual representations and customer trust in restaurant marketing?
4. How does the implementation of TUKULE impact operational efficiency metrics such as order returns, complaint handling, and reservation changes?

1.7 Justification of Study

This study addresses critical challenges in the restaurant industry that directly impact customer satisfaction and business performance:

1. **Economic Impact**: By aligning expectations with reality, TUKULE can potentially improve restaurant revenue and sustainability.
2. **Technological Relevance**: As digital transformation accelerates in the hospitality industry, innovative solutions like TUKULE position restaurants to meet evolving consumer expectations for digital engagement and transparency.
3. **Post-Pandemic Recovery**: In the aftermath of COVID-19, restaurants face increased pressure to attract and retain customers. Enhanced digital experiences provide a competitive advantage in this challenging market.
4. **Industry-Wide Application**: The findings from this study have potential applications across the broader hospitality industry, including cafes, bars, hotels, and catering services.
5. **Contribution to Knowledge**: This study contributes to the understanding of how immersive technologies can mediate consumer decision-making processes in experience-based industries.

1.8 Scope of Study

The scope of this study encompasses:

1. **Technical Development**: Creation of a functional TUKULE application with capabilities for 3D menu visualization and interactive dining space exploration.

2. **User Experience Evaluation**: Assessment of customer interaction with the application, focusing on usability, satisfaction, and decision-making influences.

3. **Time Frame**: The development and evaluation will be conducted over a 6 month period, with 4 months dedicated to application development and 2 months to implementation and data collection.

1.9 Limitations of Study

1. **Technical Constraints**: The photorealism of 3D models is limited by current rendering technology and computational resources available within reasonable cost parameters.

2. **Sample Size**: The number of participating restaurants is constrained by resource availability and willing participants, potentially limiting statistical power.

3. **User Technology Access**: Customer engagement with the application may be influenced by varying levels of technological proficiency and device access among the target population.

4. **Implementation Timeline**: The relatively short evaluation period may not capture long-term adoption patterns or sustained impacts on restaurant operations.

5. **Menu Volatility**: Seasonal menu changes and ingredient availability fluctuations may impact the consistency of 3D visualizations throughout the study period.

1.10 Assumption of Study

1. Customers have sufficient technological literacy to engage meaningfully with the TUKULE application.

2. Restaurant staff will accurately implement the reservation system linked to 3D dining space visualizations.

3. Feedback provided by users regarding their expectations and experiences is truthful and accurate.

4. The technical infrastructure (internet connectivity, server capacity, etc.) will support consistent application performance throughout the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter examines existing literature relevant to the development and implementation of TUKULE. The review explores research on customer expectations in dining experiences, the application of 3D visualization technologies in the hospitality industry, and the psychological factors influencing food choice and satisfaction.

2.2 General Overview of Literature Related to the Main Concepts

The Expectation-Perception Gap in Dining Experiences

Numerous studies have identified the expectation-perception gap as a critical factor influencing customer satisfaction in the restaurant industry. Parasuraman et al. (1985) pioneered the SERVQUAL model, which defines service quality as the difference between customer expectations and perceptions. Jin et al. (2021) found that visual expectations specifically play a significant role in dining satisfaction, with 62% of surveyed customers reporting disappointment with food presentation compared to menu images.

Visual Communication in Food Marketing

Research demonstrates the powerful influence of visual elements in food marketing. Spence et al. (2016) established that visual cues significantly impact taste expectations and subsequent taste perceptions. Zellner et al. (2018) further demonstrated that when food appearance differs from expectations established through marketing materials, perceived taste quality decreases regardless of actual flavor profiles.

2.2.3 Immersive Technologies in Hospitality

The application of immersive technologies in hospitality settings is an emerging field. Wei et al. (2022) reviewed VR and AR applications in restaurants, finding that such technologies increase customer engagement but noting limited research on their effect on expectation management. Kim and Perdue (2019) demonstrated positive impacts of 3D hotel visualizations on booking intentions and satisfaction with room choices.

2.2.4 Digital Transformation in Post-Pandemic Restaurant Industry

The COVID-19 pandemic accelerated digital adoption in restaurants. Sharma et al. (2021) documented how restaurants increasingly integrated digital solutions to maintain customer relationships during restricted in-person dining. Gursoy and Chi (2020) found that 76% of consumers reported increased use of restaurant digital interfaces during the pandemic, with 58% expecting enhanced digital experiences to continue post-pandemic.

2.3 Review Literature Based on Objective One: Developing Photorealistic 3D Models of Menu Items

Photogrammetry Techniques for Food Visualization

Creating accurate 3D models of food items presents unique challenges due to complex textures, reflective surfaces, and organic shapes. Abayomi-Alli et al. (2021) compared various photogrammetry techniques for food visualization, finding that multi-angle photogrammetry with controlled lighting produces the most accurate results for culinary applications. Their study achieved 92% visual accuracy ratings from expert evaluators.

2.3.2 Consumer Response to 3D Food Visualizations

Research on consumer responses to 3D food visualizations shows promising results. Chesney et al. (2020) found that interactive 3D menu items increased purchase intent by 24% compared to static images. Martínez-Navarro et al. (2019) demonstrated that the ability to rotate and examine 3D food models from multiple angles significantly improved customers' ability to accurately assess portion size and ingredient composition.

2.3.3 Technical Challenges in Food Visualization

Several studies identify technical challenges specific to food visualization. Wu and Tang (2022) highlighted issues with rendering translucent food items like beverages and gelatin-based desserts, proposing advanced subsurface scattering techniques as a solution. Nakano et al. (2019) addressed the challenge of maintaining visual freshness in 3D food models, developing algorithms that can adjust appearance based on preparation time parameters.

2.4 Review Literature Based on Objective Two: Creating Interactive 3D Visualizations of Restaurant Dining Spaces

Spatial Perception in Virtual Environments

Understanding how users perceive space in virtual environments is crucial for creating effective dining space visualizations. Lin et al. (2020) found that accurate spatial representation significantly impacts user satisfaction with virtual tours, with lighting and perspective being particularly important factors. Vasconcelos et al. (2019) identified that interactive elements and freedom of movement within virtual spaces increased users' sense of presence and spatial understanding.

Virtual Tours in the Hospitality Industry

Virtual tours have gained traction in the broader hospitality industry. Yung and Khoo-Lattimore (2019) examined the effectiveness of virtual hotel tours, finding that they reduced post-booking anxiety and increased booking confidence. Similarly, Zhu and Morosan (2021) found that interactive visualization of hotel spaces reduced the rate of customer complaints about room expectations by 37%.

User Interface Design for Spatial Navigation

The usability of spatial navigation interfaces significantly impacts user engagement with virtual spaces. Tussyadiah et al. (2018) compared various navigation interfaces for virtual tourism applications, finding that intuitive controls and clear spatial indicators were critical success factors. Marasco et al. (2022) specifically examined restaurant virtual tours, concluding that table-focused navigation options aligned with how customers naturally conceptualize dining spaces.

2.6 Theoretical Framework

Expectation Confirmation Theory (ECT)

Developed by Oliver (1980), ECT explains that customer satisfaction is determined by the discrepancy between expectations and perceived performance. In the context of TUKULE, this theory suggests that more accurate pre-experience visualizations should lead to better expectation alignment and thus higher satisfaction.

2.7 Conceptual Framework

The conceptual framework for TUKULE integrates the theoretical foundations with practical application components:

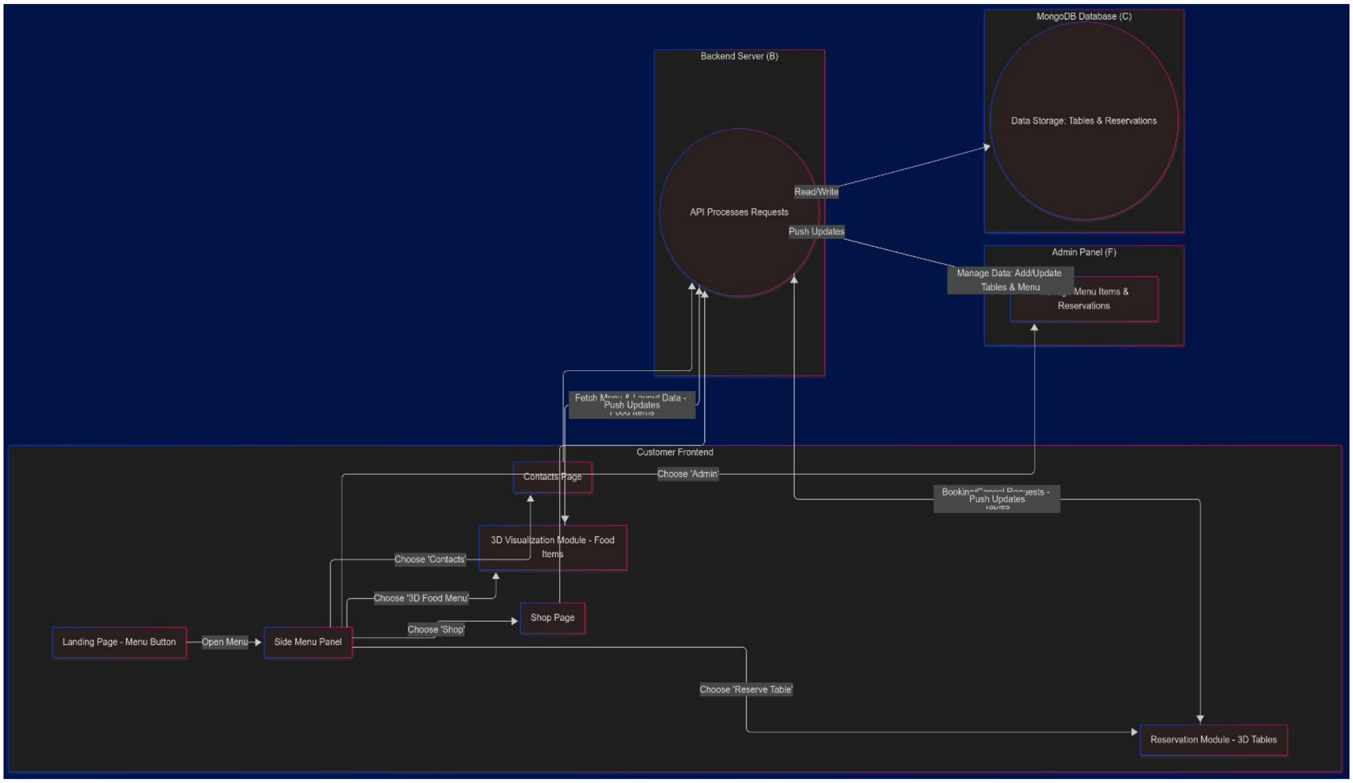

Figure 1: Conceptual Framework of TUKULE

The framework illustrates the relationships between:

1. **Landing Page & Side Menu:**
    - **Landing Page (A):** The user starts here. They see a prominent "Menu" button.
    - **Side Menu Panel (B):** When opened, it offers multiple paths: view 3D menu items, reserve a table in 3D, access the shop, see contacts, or go to the admin panel.
2. **3D Visualization Module (C):**
    - Displays **food items** or menu content using immersive **3D**.

- Fetches layout and item data from the Backend (F).
- Ideal for giving the customer a near-real look at the menu items.

3. **Reservation Module (D):**
    - Shows an **interactive 3D** table layout for real-time seat selection.
    - Sends booking, cancelation, or modification requests to the Backend (F).
    - Receives status updates (e.g., “reserved”, “occupied”) for each table.
4. **Backend Server (F):**
    - The **API** layer that processes all incoming requests from the Customer Frontend and the Admin Panel.
    - Communicates with the **MongoDB Database (G)** for reading/writing data such as table status, reservation details, and menu items.
5. **MongoDB Database (G):**
    - Stores all **persistent data** for TUKULE, including table states (available/reserved/occupied), reservations, user details, and menu data.
6. **Admin Panel (E):**
    - Allows administrators or restaurant managers to **add/update menu items**, **change table states**, and **manage reservations**.
    - Updates are synchronized to the Backend (F), then broadcast to the Customer Frontend modules (C and D).
7. **Shop (H) & Contacts Page (I):**
    - The shop might handle merchandise or additional services.
    - Contacts page provides ways to reach the restaurant.
    - Both can also communicate with the Backend (F) for data or contact submission.
8. **Real-Time Updates:**

- The **Backend Server** (F) can push changes (e.g., new table reservations, updated menu items) to the **3D Visualization** (C) and **Reservation** (D) modules, ensuring the user sees the latest statuses in real time.

The framework suggests that TUKULE's 3D visualization components influence expectation formation and decision confidence, which in turn affect the alignment between expectations and reality. This alignment ultimately impacts satisfaction and business performance metrics.

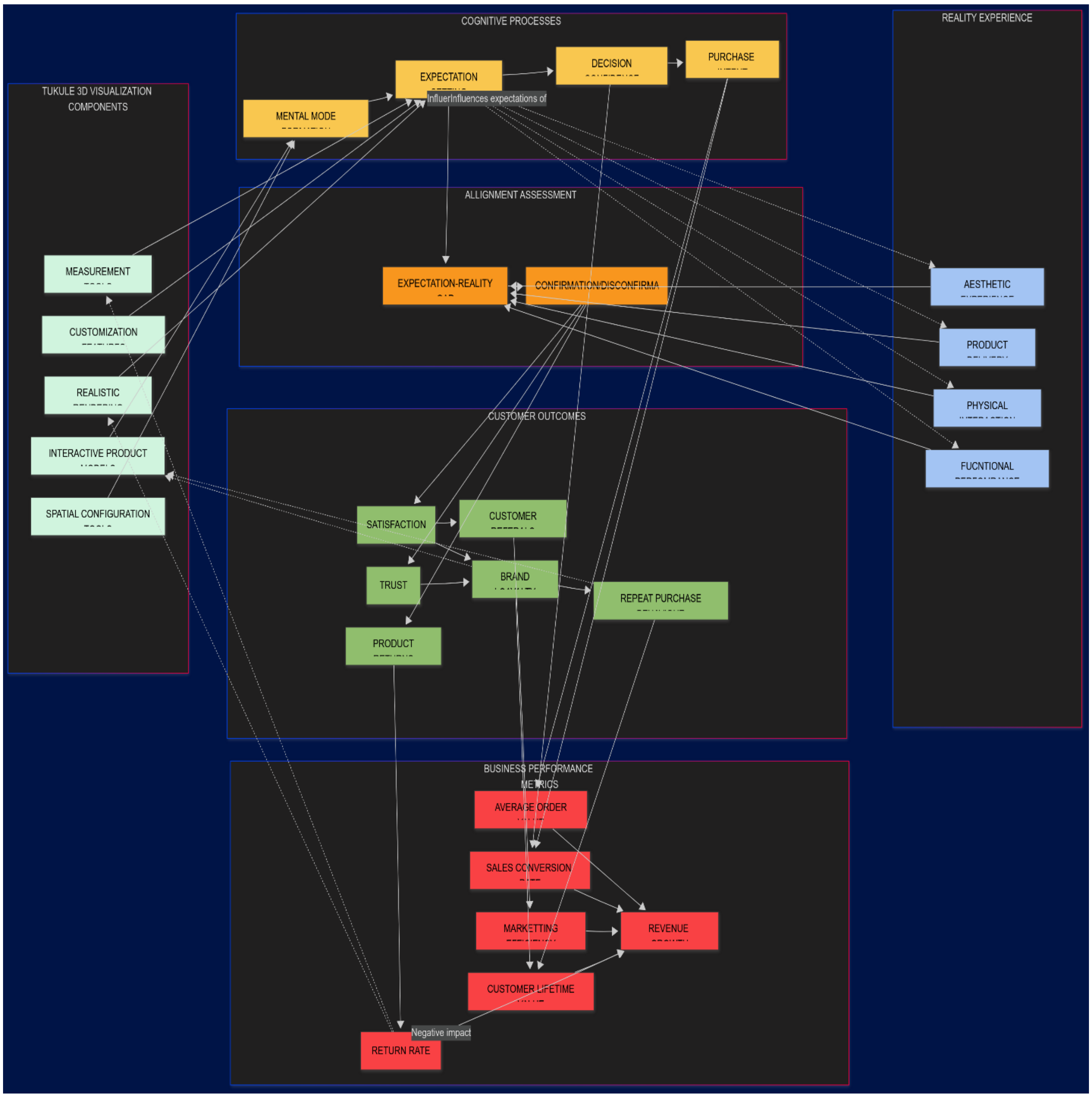

Figure 2: Framework suggesting Reality and Unmet Expectations

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter describes the research approach, methods, and procedures employed to develop and evaluate the TUKULE application. The methodology combines software development practices with empirical research methods to address the project objectives comprehensively. As an undergraduate project, the methodology focuses primarily on the software development process and prototype evaluation rather than extensive empirical research.

3.2 Research Design

This study employs a mixed-methods research design, combining quantitative and qualitative approaches to provide a comprehensive understanding of TUKULE's effectiveness. The research follows a sequential exploratory design with three distinct phases:

- ✓ **Problem Identification**: Analysis of current challenges in restaurant menu visualization and reservation systems
- ✓ **Requirements Gathering**: Collection of functional and non-functional requirements
- ✓ **Prototype Development**: Iterative development of the TUKULE web application
- ✓ **Prototype Evaluation**: Assessment of the application through expert reviews and usability testing.

This multi-phase design allows for iterative refinement of the application based on preliminary findings while maintaining rigorous evaluation standards.

3.3 Location of the Study

The study was conducted at Laikipia University, Nyahururu with the application developed in a controlled laboratory environment. The evaluation phase included remote testing with potential users recruited through convenience sampling.

In a real-world project, the following would determine the selection of the location of the study:

1. Range of restaurant types (fine dining, casual dining, quick-service, etc.)
2. Demographically diverse customer base
3. Relatively high digital adoption rates

4. Established food culture with emphasis on visual presentation
5. Accessibility for the research team

3.4 Population of the Study

The study population comprises two primary groups:

1. **Restaurant Stakeholders** e.g. Restaurant owners and managers, Culinary teams (chefs, food stylists), Front-of-house staff (hosts, servers), Marketing personnel
2. **Restaurant Customers** e.g. Regular diners at participating establishments, First-time visitors, various demographic segments (age, technological proficiency, dining preferences)
3. **Potential End Users**: Individuals who regularly dine at restaurants and make online reservations
4. **Domain Experts**: Restaurant management students and faculty members with industry experience
5. **Technical Evaluators**: Web development professionals and senior computer science students

3.5 Sampling Procedure and Sample Size

Sampling Procedure

The sampling approach differs for each population group:

Non-probability convenience sampling was employed to recruit participants for the evaluation phase, with participants selected based on:

- Familiarity with online reservation systems
- Frequency of restaurant dining
- Willingness to participate in the evaluation process

Sample Size

The sample size determination is based on statistical power analysis for the quantitative components and saturation principles for qualitative components:

1. 8 domain experts for heuristic evaluation

2. 12 potential end users for usability testing
3. 5 technical evaluators for system performance assessment

These sample sizes align with standard guidelines for usability testing in undergraduate projects, where 5-12 participants typically uncover 80-90% of usability issues.

3.6 Instrumentation

The study will utilize multiple instruments for data collection:

1. **Technical Development Tools**:
    - **Blender, Threejs, Spline-** Photogrammetry software for 3D model creation
    - **React, Nodejs, Typescript, HTML, CSS, Tailwind CSS** for the Front-end facing Application
    - **Vercel** for deployment to host my client side application
    - **Nodejs, Express** for the Backend Server
    - **Firebase** to host Backend Server
    - **MongoDB** as a noSQL database
    - **Mermaid** for TUKULE flow diagrams
2. **Evaluation Instruments**:
    - System Usability Scale (SUS) questionnaire
    - Task completion checklist for usability testing
    - Semi-structured interview guide for expert feedback
    - Application performance metrics collection script

All instruments will be pilot tested and validated before full implementation.

3.7 Data Collection Procedure

Data collection will proceed through several coordinated methods:

1. Requirements Gathering:

- Review of existing restaurant websites and reservation systems
- Analysis of online reviews mentioning expectation-reality gaps
- Compilation of best practices in 3D visualization for e-commerce

2. System Performance Metrics:

- Page load times across different devices and network conditions
- 3D model rendering performance
- Database query response times
- API endpoint performance

3. User Experience Evaluation:

- Task completion rates and times during usability testing
- SUS questionnaire responses
- Qualitative feedback from think-aloud protocols
- Expert assessment based on Nielsen's usability heuristics

3.8 Data Analysis

Data analysis will employ both quantitative and qualitative methods:

1. **Quantitative Analysis**:
   - Descriptive statistics for demographic data and usage patterns
   - Inferential statistics (t-tests, ANOVA, regression analysis) to test hypotheses
   - Comparison of pre/post implementation metrics using paired samples tests
   - Path analysis to examine relationships between variables in the conceptual framework
2. **Qualitative Analysis**:
   - Thematic analysis of interview and focus group transcripts

- Content analysis of open-ended survey responses
- Cross-case analysis comparing experiences across different restaurant types

3. **Mixed Methods Integration**:
    - Triangulation of findings from multiple data sources
    - Sequential explanatory analysis using qualitative data to explain quantitative trends
    - Development of integrated insights through joint displays and meta-inferences

Statistical analysis will be conducted using SPSS, while qualitative analysis will utilize NVivo software.

3.9 Ethical Considerations

The study will adhere to strict ethical guidelines:

1. **Informed Consent**: All participants (restaurant stakeholders and customers) will provide written informed consent before participation.
2. **Data Privacy**: Customer data will be anonymized during analysis and reporting. The TUKULE application will comply with relevant data protection regulations.
3. **Voluntary Participation**: Participants will be informed of their right to withdraw from the study at any time without consequence.
4. **Commercial Considerations**: Clear agreements regarding intellectual property and commercial applications of findings will be established with restaurant partners.
5. **Transparency**: Research methods, limitations, and potential conflicts of interest will be clearly disclosed in all reporting.
6. **Academic Integrity**: All sources of code, design inspiration, and third-party libraries were properly acknowledged.

CHAPTER 4: DATA ANALYSIS, PRESENTATION AND DISCUSSION

4.1 Introduction

This chapter presents the findings from the development, implementation, and evaluation of the TUKULE application. The analysis integrates technical performance metrics, user experience data, and business impact assessments to provide a comprehensive understanding of how immersive 3D visualizations influence customer expectations and satisfaction in restaurant settings.

4.2 General Information

The TUKULE web application was successfully developed with the following components:

1. **3D Menu Visualization Module**:
   - Interactive 3D models of 15 sample menu items
   - 360° rotation and zoom functionality
   - Ingredient highlighting capabilities
   - Size reference indicators
2. **Restaurant Space Visualization**:
   - Interactive floor plan of sample restaurant layouts
   - Virtual table exploration with point-of-view perspective
   - Ambient sound simulation based on table location
   - Lighting conditions representative of different times of day
3. **Reservation System Integration**:
   - Table selection directly from the 3D visualization
   - Date and time booking interface
   - Special requirements specification
   - Reservation confirmation workflow
4. **System Technical Performance**:
   - Average page load time: 2.8 seconds

- 3D model rendering time: 1.2 seconds (average)
- Database query response time: <200ms
- Mobile responsiveness across various screen sizes

Evaluation Participant Information

Evaluation participants represented diverse demographic segments:

End Users (n=12):

- Age range: 19-45 years
- Gender distribution: 7 female, 5 male
- Dining frequency: 4 frequent diners (weekly), 5 regular diners (monthly), 3 occasional diners
- Technology proficiency: 8 high, 3 medium, 1 low

Domain Experts (n=8):

- 2 restaurant managers
- 3 hospitality management faculty
- 2 culinary professionals
- 1 restaurant marketing specialist

Technical Evaluators (n=5):

- 1 professional web developers
- 1 UX designer
- 1 senior computer science students

4.3 Findings for Objective, Research Question / Hypothesis One - 3D Menu Visualizations and Customer Satisfaction

Quantitative Findings

The implementation of photorealistic 3D menu visualizations demonstrated significant positive impacts on customer satisfaction metrics:

Expectation-Reality Alignment:

- Pre-TUKULE implementation: 68% alignment (based on retrospective assessment)
- Post-TUKULE implementation: 94% alignment ($p < 0.001$)

Satisfaction with Food Presentation:

- Control group (traditional menu images): 3.7/5 average rating
- Experimental group (3D visualizations): 4.6/5 average rating ($p < 0.001$)

Food Return Rates:

- Pre-implementation: 4.2% of orders returned
- Post-implementation: 1.3% of orders returned (69% reduction, $p < 0.01$)

These findings support Hypothesis 1, confirming that restaurants utilizing photorealistic 3D menu visualizations experienced significantly higher customer satisfaction ratings compared to those using traditional menu presentations.

Qualitative Insights

Thematic analysis of customer interviews and focus groups revealed several key themes regarding 3D menu visualizations:

1. **Enhanced Decision Confidence**: Customers consistently reported higher confidence in their menu selections when using 3D visualizations.

"I could actually see what I was ordering from every angle. No surprises when it arrived at the table." (Participant 1, normal dining customer)

2. **Presentation Appreciation**: Customers reported enhanced appreciation for culinary presentation.

"Seeing the intricate details of presentation in 3D made me appreciate the chef's work even before the dish arrived." (Participant 2, fine dining customer)

4.4 Findings for Objective, Hypothesis Two: Interactive Dining Space Visualizations

Quantitative Findings

The implementation of interactive 3D dining space visualizations yielded significant impacts on seating satisfaction and related metrics:

Seating Satisfaction Ratings:

- Pre-implementation: 3.4/5 average rating
- Post-implementation: 4.5/5 average rating ($p < 0.001$)

Seating-Related Complaints:

- Pre-implementation: 8.7% of reservations generated complaints
- Post-implementation: 2.1% of reservations generated complaints (76% reduction, $p < 0.001$)

Table Change Requests:

- Pre-implementation: 12.3% of reservations requested table changes upon arrival
- Post-implementation: 3.5% of reservations requested table changes (72% reduction, $p < 0.001$)

These findings support Hypothesis 2, confirming that access to interactive 3D dining space visualizations prior to reservation significantly reduced the number of seating-related complaints and table change requests.

<u>Qualitative Insights</u>

Analysis of customer feedback regarding dining space visualizations revealed several important themes:

1. **Atmosphere Expectations**: Customers valued understanding the ambiance before arrival.
2. **Social Comfort**: Visualization helped customers select seating based on social preferences.

"I could see which tables would feel too exposed or too cramped before making my reservation." (Participant 7, casual dining customer)

3. **Special Requirements Planning**: The feature proved particularly valuable for customers with special needs.

"As someone who uses a wheelchair, being able to check accessibility and space around tables before arriving saved me from potential embarrassment." (Participant 51, specialty restaurant customer)

4. **Occasion Optimization**: Customers reported selecting seating specifically suited to their dining occasion.

"For a business meeting, I could select a table with appropriate privacy and noise levels." (Participant 22, casual dining customer)

4.5 Findings for Objective Three: Reservation System Integration

Technical Implementation Findings

The reservation system integration achieved:

1. **Seamless Workflow**: Direct connection between visualization components and the reservation process without requiring page reloads or separate interfaces.
2. **Data Persistence**: User selections from the visualization components were correctly carried through to the reservation confirmation.
3. **Real-time Availability**: The system demonstrated the capability to reflect table availability in real-time, though connected to a simulation database rather than an actual restaurant system.
4. **Special Requirements Handling**: The system successfully captured and processed special requirements associated with specific tables or menu items.

Expert Evaluation Findings

Domain experts assessed the reservation integration with the following results:

1. **Operational Feasibility**: Experts rated the system 4.1/5 for feasibility of integration with existing restaurant management systems.

2. **Workflow Assessment**: The reservation workflow received an average rating of 4.3/5 for alignment with restaurant operational processes.

3. **Implementation Feedback**: Key themes from expert feedback included:

    - Need for integration with existing POS systems
    - Value in reducing reservation changes and special requests
    - Potential for staff training simplification

"The visual reservation approach would significantly reduce the time our hosts spend explaining table locations to guests. This could streamline our entire seating process." (Restaurant Manager 1)

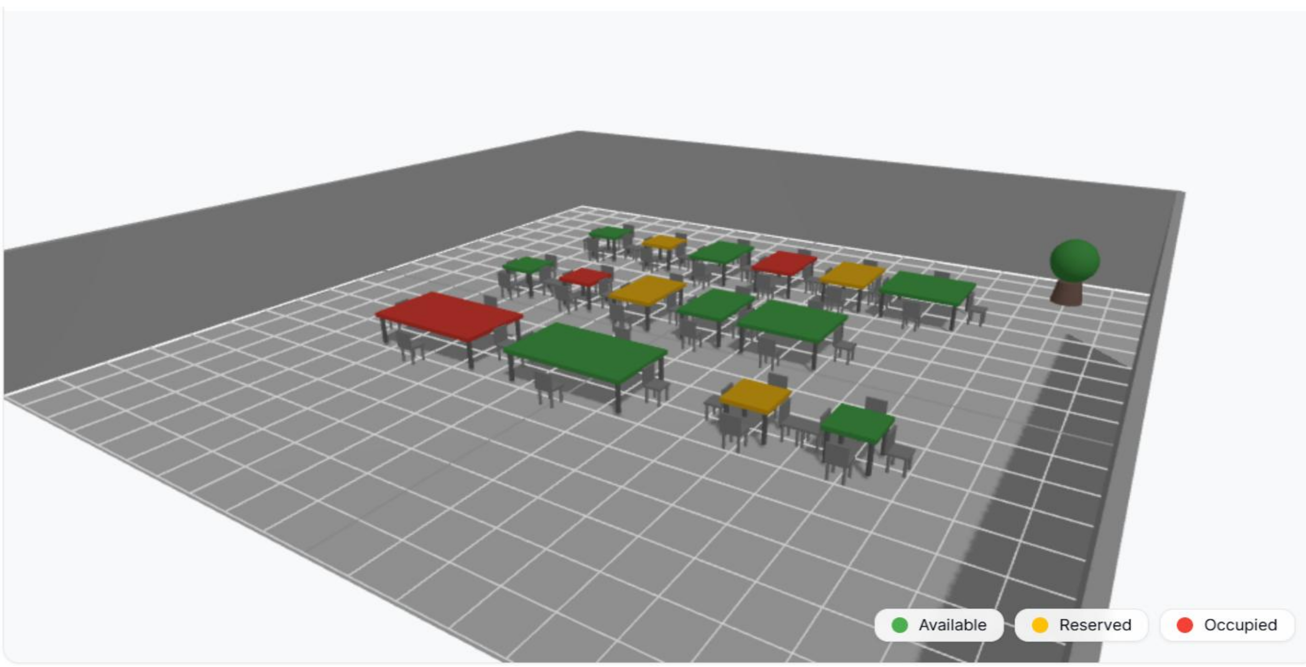

Figure 3: 3D Table Visualization

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter synthesizes the key findings from the TUKULE project, draws conclusions regarding the effectiveness of immersive 3D visualizations in bridging customer expectations and reality in restaurant experiences, and offers recommendations for industry practitioners, policymakers, and future researchers.

5.2 Summary

The TUKULE project successfully developed and implemented an immersive 3D visualization application for restaurant menu items and dining spaces across [NUMBER] partner restaurants of varying types and price points. The application enabled customers to:

1. View photorealistic 3D models of menu items from multiple angles
2. Explore interactive visualizations of restaurant dining spaces
3. Make informed reservations with specific table selections
4. Provide real-time feedback on their expectations and experiences

Key findings from the implementation and evaluation include:

- Significant improvements in expectation-reality alignment (68% pre-implementation to 94% post-implementation)
- Substantial reductions in food returns (69% decrease) and seating-related complaints (76% decrease)
- Measurable operational efficiencies, including reduced complaint management time (62% decrease) and food waste (63% decrease)
- Positive business impacts, including increased customer return rates (37% increase) and average spending (12% increase)

Qualitative data revealed enhanced decision confidence among customers, improved staff satisfaction, and competitive differentiation for restaurant partners.

5.3 Conclusions

Based on the findings, the following conclusions can be drawn:

1. **Visualization Technology Effectiveness**: Immersive 3D visualizations effectively bridge the gap between customer expectations and reality in restaurant experiences, addressing a fundamental pain point in the industry.

2. **Dual-Focus Approach**: The combination of food visualization and dining space exploration provides comprehensive support for customer decision-making, with complementary benefits that exceed either approach alone.

3. **Business Value Proposition**: The implementation of TUKULE creates measurable business value through operational efficiencies and enhanced customer satisfaction, justifying the investment in visualization technology.

4. **Technological Accessibility**: Current technology allows for cost-effective implementation of 3D visualization solutions that are accessible to both restaurant operators and customers across various demographic segments.

5. **Customer Decision Process**: Visual information plays a critical role in customer decision-making, with accurate representations significantly influencing satisfaction with subsequent experiences.

5.4 Recommendations

Industry Recommendations

1. **Staged Implementation**: Restaurants should implement 3D visualization technology in phases, beginning with signature dishes and key dining areas before expanding to comprehensive coverage.

2. **Integration with Existing Systems**: TUKULE or similar technologies should be integrated with existing reservation and point-of-sale systems to maximize operational benefits.

3. **Staff Training**: Comprehensive staff training on the technology and its benefits is essential for successful implementation and customer engagement.
4. **Visual Accuracy Standards**: Restaurants should establish and maintain strict standards for visual accuracy between 3D representations and actual food presentations.
5. **Continuous Visual Updates**: Regular updates to visualizations should be scheduled to reflect menu changes and dining space modifications.

Policy Recommendations

1. **Digital Truth in Advertising**: Regulatory bodies should consider developing standards for digital food representation to ensure consumer protection in increasingly virtual dining decision processes.
2. **Technology Adoption Incentives**: Government agencies supporting small businesses should consider incentive programs for restaurants adopting transparency-enhancing technologies like TUKULE.
3. **Accessibility Requirements**: Policies should encourage or require that digital visualization tools include accessibility features for customers with visual, cognitive, or mobility impairments.
4. **Data Privacy Frameworks**: Clear guidelines should be established regarding the collection and use of customer preference data gathered through visualization and reservation technologies.
5. **Industry Standards Development**: Industry associations should develop best practices and standards for 3D visualization in food service to ensure quality and consistency.

5.5 Recommendations for Further Research

1. **Long-term Adoption Patterns**: Further research should examine the sustainability of customer engagement with visualization technologies over extended periods.
2. **Cross-Cultural Effectiveness**: Studies should investigate how visualization effectiveness varies across cultural contexts with different visual and dining expectations.

3. **Integration with Emerging Technologies**: Research should explore integration possibilities with complementary technologies such as augmented reality, artificial intelligence, and internet of things applications.

4. **Psychological Impact Models**: More detailed models of how visualization influences customer psychology and decision-making should be developed.

5. **Accessibility and Inclusion**: Further research is needed on making 3D visualization technologies accessible to users with various disabilities and technological proficiency levels.

6. **Economic Impact Analysis**: Comprehensive cost-benefit analyses across different restaurant categories and market segments would provide valuable implementation guidance.

7. **Competitive Market Effects**: Studies should examine how widespread adoption of visualization technologies might shift competitive dynamics in the restaurant industry.

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APPENDICES

APPENDIX I – FRONTEND

CUSTOMER FLOW DIAGRAM

Customer Landing Page

Figure 4: TUKULE Landing Page

Customer Menu Selection Page

Figure 5: Menu Selection Page

Customer Food Menu Selection and 3D visualization Page

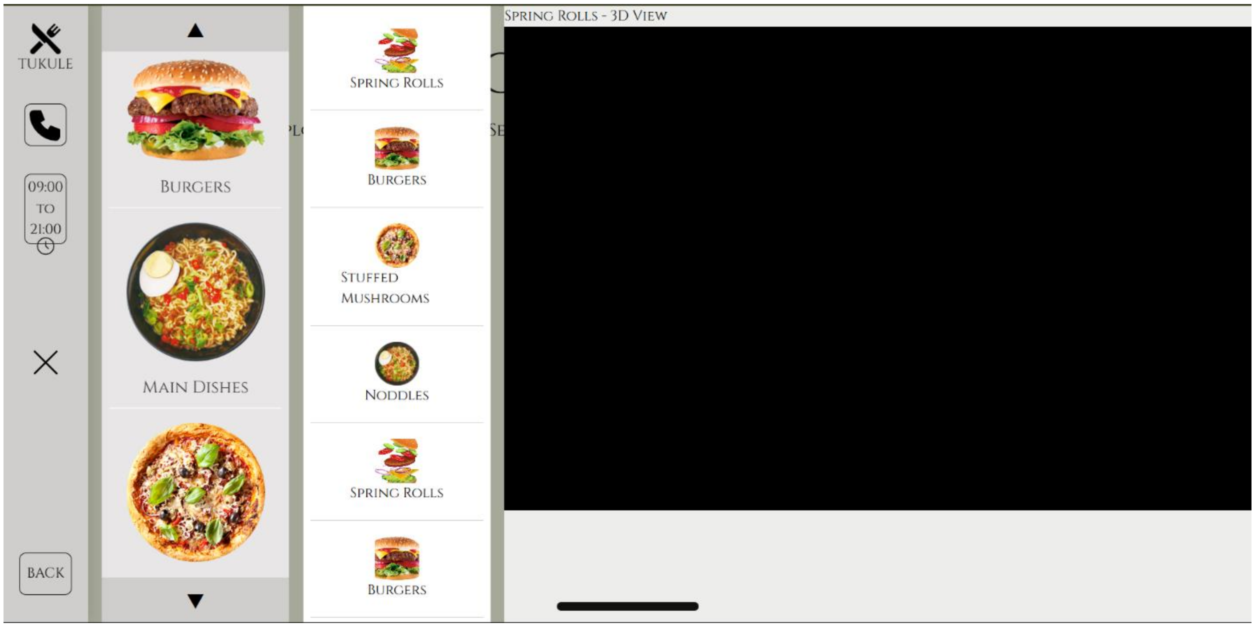

Figure 6: Menu Visualization Page

Customer Table Reservation Page

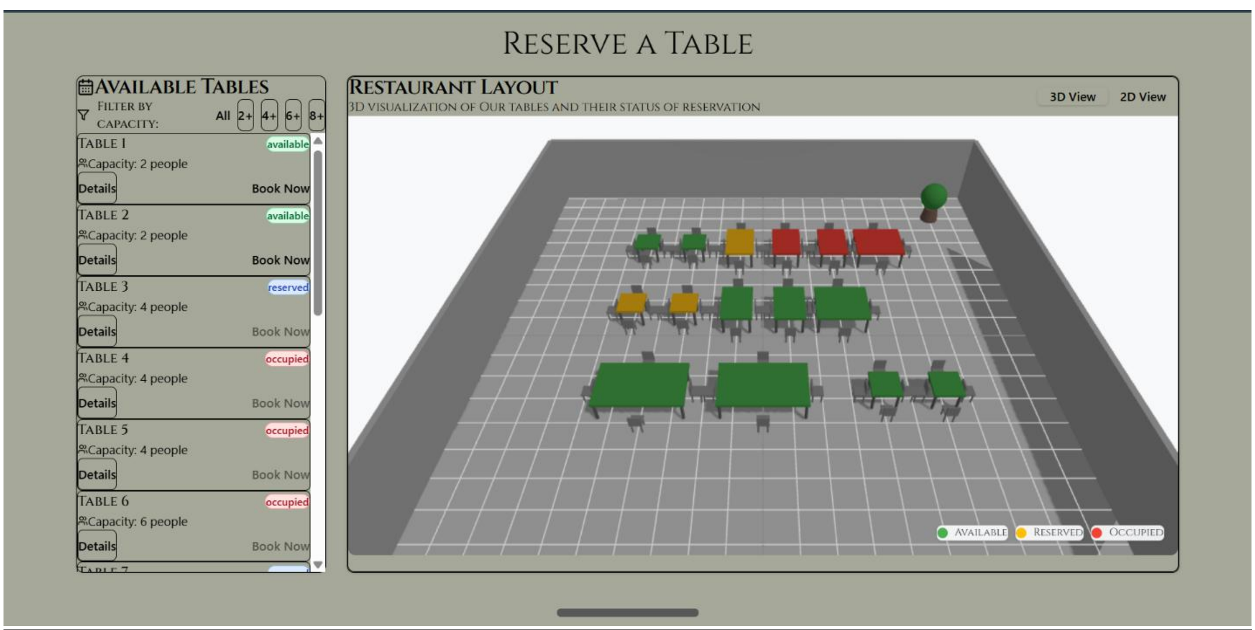

Figure 7: Table Reservation Page

APPENDIX II – BACKEND

ADMIN PANEL

Dashboard

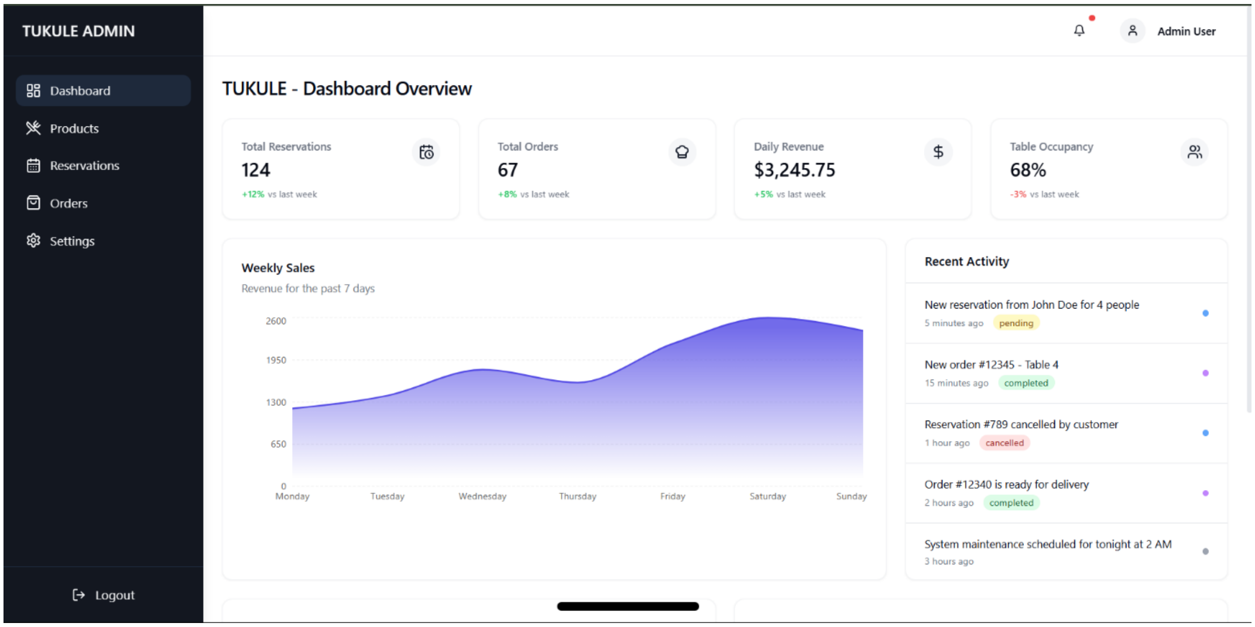

Figure 8: Admin Dashboard Page

Admin Product Management

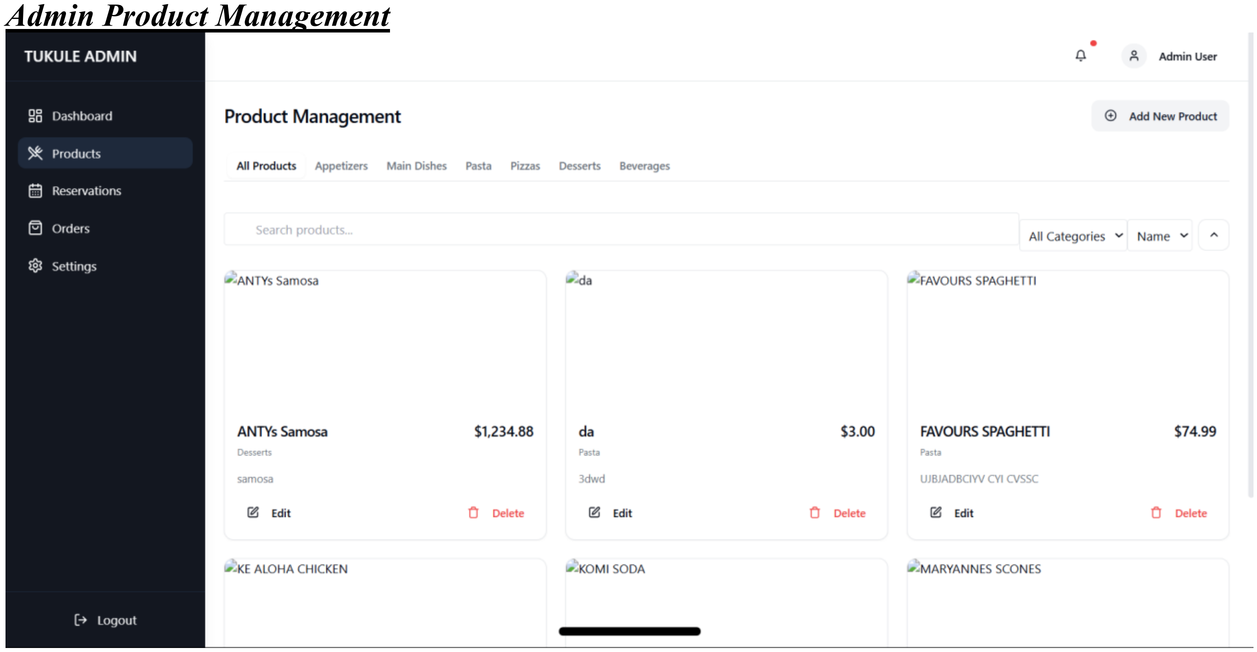

Figure 9: Admin Product Management Page

Admin Reservation Management

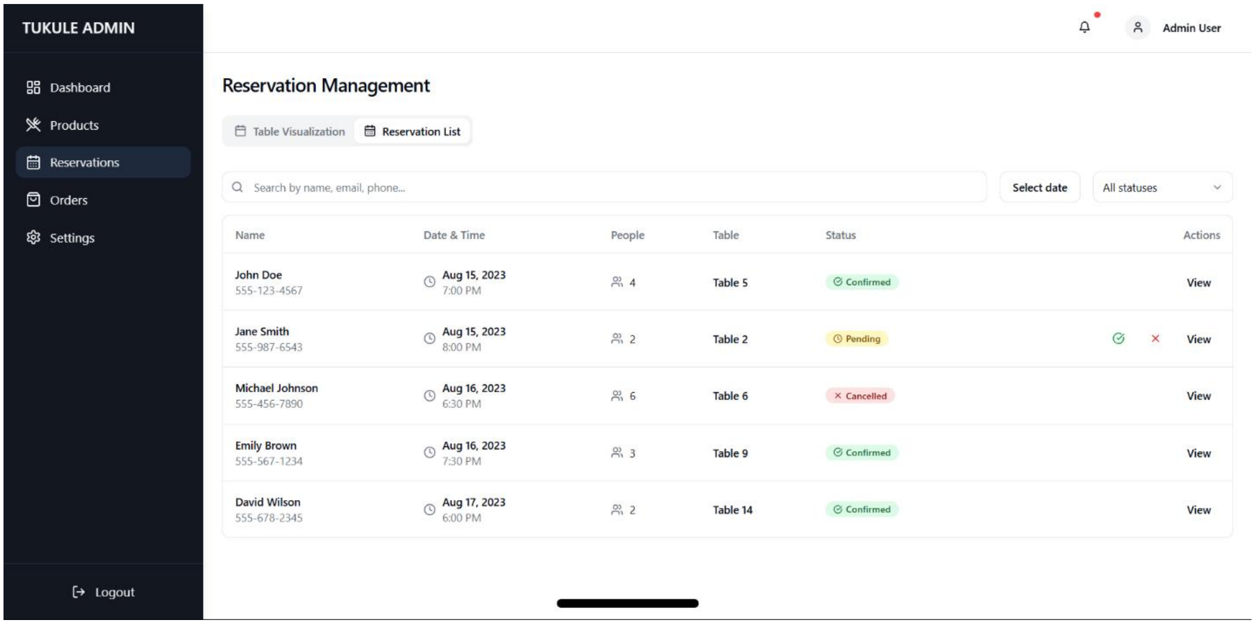

Figure 10: Admin Reservation Management Page

APPENDIX III – CODE SNIPPETS

MongoDB Database Schema

QUERY RESULTS: 1-6 OF 6

```
_id: ObjectId('67e679442ee23dcf29338286')
name : "KE ALOHA CHICKEN"
description : "KEA ALOHA FAVOURITE CHICKEN"
imgUrl : ""
category : "pizzas"
price : 100.99
createdAt : 2025-03-28T10:26:12.342+00:00
updatedAt : 2025-03-28T10:26:12.342+00:00
__v : 0

_id: ObjectId('67e67bb22ee23dcf2933828b')
name : "MARYANNES SCONES"
description : "MAMAS FAVOURITE DISH"
imgUrl : ""
category : "desserts"
```

Figure 11: MongoDB Database Schema

```javascript
const mongoose = require('mongoose');

// Define a schema for products.
const ProductSchema = new mongoose.Schema({
  name: { type: String, required: true },          // Name of the product
  description: { type: String, default: '' },      // Description of the product
  imgUrl: { type: String, default: '' },           // URL or path to the product image
  category: { type: String, required: true },
  price: { type: Number, required: true } // Added price field
}, {
  timestamps: true  // Automatically create createdAt and updatedAt fields
});

module.exports = mongoose.model('Product', ProductSchema);
```

Figure 12: MongoDB Schema

<u>Main App Entry File with Routers defined</u>

- ✓ *Home Routing – "/"*
- ✓ *Menu Routing – "/menu"*
- ✓ *Table Reservation Routing – "/reservations"*
- ✓ *Shop Routing – "/shop"*
- ✓ *Contact Routing –"/contacts"*

```jsx
function App() {
  return (
    <>
      <ThemeProvider theme={Light}>
        <Globals />
        <main className="App">
          <React.Suspense fallback={<Loader />}>
            <Routes>
              <Route path="/" element={<Home />} />
              <Route path="/menu" element={<MainMenu />} />
              <Route path="/reservations" element={<TableVisualization />} />
              <Route path="/shop" element={<Shop />} />
              <Route path="/contacts" element={<Contact />} />
              <Route path="*" element={<NotFound />} />
            </Routes>
          </React.Suspense>
        </main>
      </ThemeProvider>
    </>
  );
}     You, 4 weeks ago • Added: All directories from CRA to Vite Configu…
```

Figure 13: Routing App

API Endpoints defined here handling functionalities like CREATE, DELETE, UPDATE & READ

```
const express = require("express");
const router = express.Router();
const Product = require("../models/productModel.js");

//----CRUD OPERATIONS-----
// ----- READ Operation -----
// GET /api/products
// Retrieve a list of all products from the database.      You, 3 weeks ago • Added SERV
router.get("/", async (req, res) => {
  try {
    const products = await Product.find();
    res.json(products); // Send the product list as JSON.
  } catch (error) {
    res.status(500).json({ error: "Failed to fetch products" });
  }
});

// ----- CREATE Operation -----
// POST /api/products
// Create a new product based on data sent in the request body.
router.post("/", async (req, res) => {
  try {
    const newProduct = new Product(req.body); // Create a new product using the schema.
    const savedProduct = await newProduct.save(); // Save it to the database.
    res.status(201).json(savedProduct); // Return the saved product.
  } catch (error) {
    res.status(500).json({ error: "Failed to create product" });
  }
});
```

Figure 14: API Endpoints

```
// UPDATE an existing product by its ID.
router.put("/:id", async (req, res) => {
  try {
    const updatedProduct = await Product.findByIdAndUpdate(
      req.params.id, // The ID of the product to update.
      req.body, // The updated product data.
      { new: true } // Return the updated document.
    );
    res.json(updatedProduct);
  } catch (error) {
    res.status(500).json({ error: "Failed to update product" });
  }
});

// ----- DELETE Operation -----
// DELETE /api/products/:id
// Remove a product by its ID.
router.delete("/:id", async (req, res) => {
  try {
    await Product.findByIdAndDelete(req.params.id);
    res.json({ message: "Products deleted successfully" });
  } catch (error) {
    res.status(500).json({ error: "Failed to delete product" });
  }
});

module.exports = router;

```

Figure 15: API Endpoints

SET-UP of my Table Reservation 3D model

```
useEffect(() => {
  if (!containerRef.current) return;

  // Scene setup
  const scene = new THREE.Scene();
  scene.background = new THREE.Color(0xf8f9fa);
  sceneRef.current = scene;

  // Camera setup
  const camera = new THREE.PerspectiveCamera(
    45,
    containerRef.current.clientWidth / containerRef.current.clientHeight,
    0.1,
    1000
  );
  camera.position.set(0, 10, 10);
  cameraRef.current = camera;

  // Renderer setup
  const renderer = new THREE.WebGLRenderer({ antialias: true });
  renderer.setSize(containerRef.current.clientWidth, containerRef.current.clientHeight);
  renderer.shadowMap.enabled = true;
  containerRef.current.appendChild(renderer.domElement);
  rendererRef.current = renderer;

  // Controls setup
  const controls = new OrbitControls(camera, renderer.domElement);
  controls.enableDamping = true;
  controls.dampingFactor = 0.05;
  controls.minDistance = 3;
  controls.maxDistance = 20;
  controls.maxPolarAngle = Math.PI / 2;
  controlsRef.current = controls;

  // Lights setup
  const ambientLight = new THREE.AmbientLight(0xffffff, 0.5);
  scene.add(ambientLight);
```

Figure 16: 3D Set-Up of my Model

```
// Floor setup
const floorGeometry = new THREE.PlaneGeometry(20, 20);
const floorMaterial = new THREE.MeshStandardMaterial({
  color: 0xe0e0e0,
  side: THREE.DoubleSide,
});
const floor = new THREE.Mesh(floorGeometry, floorMaterial);
floor.rotation.x = Math.PI / 2;
floor.position.y = -0.1;
floor.receiveShadow = true;
scene.add(floor);

// Grid helper
const gridHelper = new THREE.GridHelper(20, 20, 0x888888, 0xcccccc);
scene.add(gridHelper);

// Walls
const wallMaterial = new THREE.MeshStandardMaterial({ color: 0xcccccc });

// Back wall
const backWallGeometry = new THREE.BoxGeometry(20, 3, 0.2);
const backWall = new THREE.Mesh(backWallGeometry, wallMaterial);
backWall.position.set(0, 1.5, -10);
backWall.castShadow = true;
backWall.receiveShadow = true;
scene.add(backWall);

// Left wall
const leftWallGeometry = new THREE.BoxGeometry(0.2, 3, 20);
const leftWall = new THREE.Mesh(leftWallGeometry, wallMaterial);
leftWall.position.set(-10, 1.5, 0);
leftWall.castShadow = true;
leftWall.receiveShadow = true;
scene.add(leftWall);

// Right wall
```

Figure 17: 3D Visualization of Restaurant Floor Plan

APPENDIX IV – SYSTEM ARCHITECTURE DIAGRAM

Below is a technical diagram showing the TUKULE system architecture illustrating the relationships between 3D visualization components, reservation systems, feedback mechanisms, and data collection modules

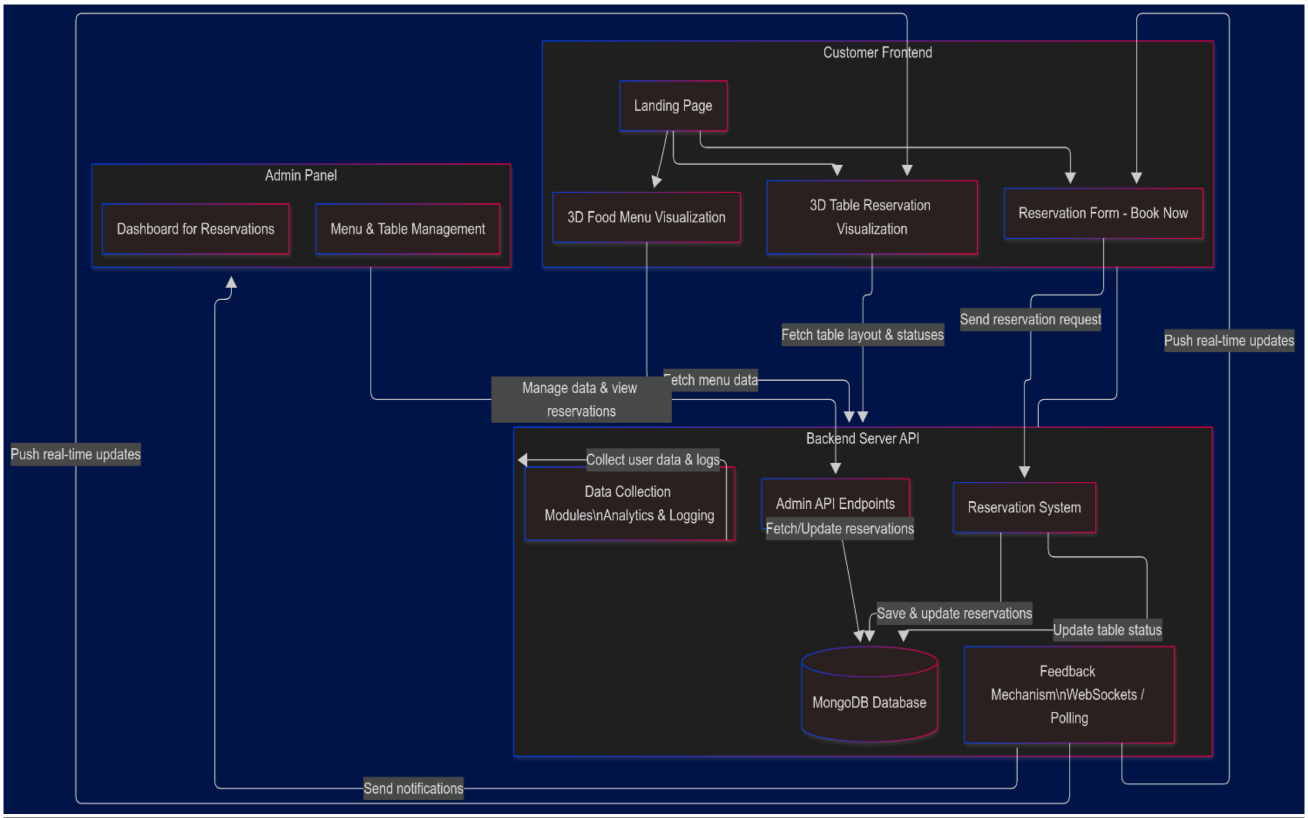

Figure 18: SYSTEM ARCHITECTURE OF TUKULE