iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** XI **Month of publication:** November 2024

DOI: https://doi.org/10.22214/ijraset.2024.65150

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XI Nov 2024- Available at www.ijraset.com

Prompt Optimization for AI-Powered Recipe Generation: Challenges and Insights

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Abstract: ***In today's digital age, artificial intelligence (AI) is transforming the culinary landscape by enabling personalized recipe generation. AI-powered recipe generation systems can offer tailored cooking solutions based on user preferences, dietary restrictions, and ingredient availability. However, achieving optimal results remains challenging due to the inherent complexity of natural language processing (NLP) in generating coherent, contextually relevant recipes. This paper investigates the prompt engineering techniques employed to enhance the accuracy and creativity of AI-based recipe generation models. By exploring various prompt structures and model fine-tuning methods, this research highlights how subtle adjustments in prompt design can significantly influence the quality and relevance of generated recipes. The study utilizes a diverse dataset of ingredients, cuisines, and dietary requirements, and examines models including GPT-Neo and GPT-3. Key findings reveal that effective prompt optimization can improve recipe coherence, ingredient compatibility, and instruction clarity. Challenges encountered include managing model verbosity, reducing ingredient redundancy, and achieving cultural or cuisine-specific accuracy. This research underscores the importance of prompt engineering in refining AI-generated content within the culinary domain. Future work will focus on integrating user feedback to dynamically adjust prompts and exploring multimodal AI approaches for enhanced visual and textual recipe generation.***

I. INTRODUCTION

Artificial intelligence (AI) has made significant strides across various domains, with notable applications in personalized recommendation systems, content generation, and language processing. One promising area of AI application is in culinary arts, specifically in the generation of recipes tailored to user preferences, dietary restrictions, and available ingredients. However, the task of creating coherent, contextually relevant recipes presents unique challenges, primarily due to the complexities of natural language processing (NLP) and the requirements of culinary coherence. This research addresses the challenges involved in optimizing prompts for AI-driven recipe generation models to improve accuracy, diversity, and culinary authenticity. Recipe generation relies on large language models (LLMs) like GPT-Neo and GPT-3, which use prompt engineering techniques to interpret and generate text that aligns with user needs. Crafting effective prompts can significantly enhance the model's performance by influencing factors such as ingredient compatibility, instructional clarity, and overall recipe coherence.

The research problem addressed in this project focuses on developing optimal prompts that enable AI models to generate high-quality recipes while addressing common issues, including:

1) Recipe Coherence: Ensuring that generated recipes are logically structured and practical to execute.
2) Ingredient Compatibility: Avoiding incompatible ingredient pairings and maintaining culinary relevance.
3) Instructional Clarity: Producing instructions that are clear, sequential, and complete.
4) User Adaptability: Generating recipes that consider various cuisines, dietary preferences, and ingredient limitations.

The significance of this research lies in several key areas:

- Personalized Culinary Experience: Enhancing the ability of AI models to tailor recipes based on user preferences, promoting more accessible and enjoyable cooking experiences.
- Handling NLP Challenges in Culinary Contexts: Addressing the specific difficulties of applying NLP in culinary tasks, where instructions and ingredients must align precisely.
- Advancements in Recipe Generation Models: Contributing to the development of more reliable and adaptable models for recipe generation, which has implications for broader applications in content generation.

This paper examines relevant existing literature, including research papers, technical articles, and recent advancements in NLP-based content generation. Prior research on AI in culinary contexts has explored topics such as personalized recommendation systems and recipe retrieval; however, the challenge of prompt engineering for recipe generation has been less explored. This study aims to bridge this gap by testing and refining prompt structures that can overcome common issues faced in AI-driven recipe generation, setting a foundation for future innovations in AI-powered culinary solutions.

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A. *Highlighting Gaps in Existing Knowledge*

1) Recipe Coherence and Culinary Constraints: While there has been considerable research in NLP-driven recipe generation, few studies effectively tackle the challenge of generating coherent, practically executable recipes that align with established culinary norms. Recipe generation often results in ingredient incompatibility or unclear instructions, revealing a gap in knowledge about how to effectively guide models to maintain culinary relevance and coherence.
2) Handling Diverse User Preferences and Constraints: Most current models do not adequately accommodate a wide range of user needs, such as dietary restrictions, specific cuisines, or ingredient limitations. Existing research lacks in-depth exploration of prompt engineering techniques that can adapt AI outputs to various personal preferences without losing recipe quality.
3) Balancing Creativity with Culinary Practicality: Generative models, while effective at producing creative recipes, often struggle to balance novelty with practicality. Previous research has primarily focused on generating unique content rather than ensuring that recipes are practical for real-world cooking. There is a need to develop prompt structures that guide models in generating both creative and practically executable recipes.
4) Optimizing Instructions for Clarity and Sequence: Existing recipe generation models often produce instructions that are either unclear or out of order, which can confuse users. Few studies address how prompt engineering can improve instructional clarity and sequencing in generated recipes, especially when accommodating various cooking skill levels.

B. *Research Purpose*

The purpose of this research is to develop and refine prompt engineering techniques for AI-powered recipe generation, aiming to produce recipes that are coherent, personalized, and practical for a broad audience. This study seeks to address the challenges posed by maintaining culinary authenticity, accommodating diverse dietary needs, and optimizing recipe instructions, contributing to a more robust and user-centered approach in AI-driven culinary solutions.

C. *Significance of the Research*

With the rise of AI in personalized content creation, there is an increased demand for applications that can adapt to individual preferences, dietary restrictions, and ingredient availability. Recipe generation has the potential to significantly impact both novice and experienced cooks by providing tailored cooking guidance. This study aims to address the gap in prompt engineering for recipe generation, focusing on enhancing culinary accuracy, adaptability, and user satisfaction.

By creating and testing specific prompts that guide AI models to maintain these qualities, this research will lay the foundation for improvements in AI-generated content and expand the possibilities for customized, accessible culinary resources.

II. LITERATURE REVIEW

Artificial intelligence has made significant strides in recipe generation, enabling models to create diverse and personalized culinary content. Studies have highlighted both the potential and challenges of using AI in this field.

1) Recipe1M Dataset and Transformer Models: Marin et al. (2019) utilized the Recipe1M dataset to train transformer models on recipe generation, showing that while the models produce varied recipes, they sometimes lack coherence and ingredient compatibility.
2) Multi-Constraint Recipe Generation: Wang et al. (2020) explored AI's application in dietary-specific recipes (e.g., vegan or gluten-free), noting the complexity of balancing multiple constraints within a single model output. Despite success in generating specific recipes, the study found that these models sometimes compromise on taste or culinary structure.
3) Prompt Engineering for Improved Recipe Quality: Zhang et al. (2022) focused on prompt engineering techniques to guide models toward generating well-structured recipes. Their work demonstrated that prompting models with specific ingredient and instruction orders improved recipe coherence and adherence to culinary conventions.

This research underlines the potential of AI-driven recipe generation, while also acknowledging the need for refined prompt engineering to produce more practical, user-friendly recipes.

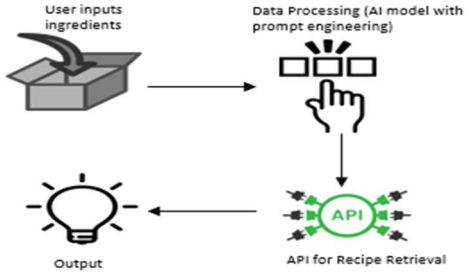
A. *Theoretical Frameworks and Models*

When designing AI models for recipe generation, certain frameworks and models help address the unique challenges in this area:

1) Natural Language Processing (NLP) Models: Transformer-based models like GPT and BERT are commonly used in AI-powered recipe generation due to their strength in understanding context and generating coherent instructions. These models excel in handling language-based inputs such as ingredients and cuisine types to produce detailed recipes.

2) Prompt Engineering: To guide NLP models in recipe generation, prompt engineering frameworks are used. By strategically framing prompts (e.g., ingredient-based or dietary restrictions), the models can generate recipes that are relevant and user-specific, enhancing accuracy and personalization.
3) Multi-Objective Optimization: Recipe generation involves balancing taste, nutritional value, and dietary restrictions, which makes multi-objective optimization models valuable. This framework helps the model weigh multiple factors simultaneously to produce recipes that satisfy different constraints.

Theoretical frameworks in AI-based recipe generation suggest that NLP and prompt engineering techniques can improve recipe relevance and quality, but challenges such as balancing multiple objectives and maintaining recipe coherence remain. This research leverages NLP models and optimized prompt strategies to improve AI-generated recipe quality, contributing to the growing field of AI-driven culinary tools.



B. *Theoretical Framework for the Current Research*

This research is grounded in NLP and prompt engineering frameworks, specifically utilizing transformer models to generate recipes based on user-input ingredients. Techniques such as strategic prompt structuring are used to guide model responses, while multi-objective optimization addresses the balance between ingredient compatibility, dietary constraints, and user preferences.

III. METHODOLOGY

A. *Research Design*

This study adopts a qualitative and experimental research design to address the challenges in prompt engineering for recipe generation. The focus is on understanding how different prompt structures affect the performance of a natural language processing (NLP) model (GPT-Neo 2.7B) in generating relevant and high-quality recipes. This design enables an in-depth analysis of prompt variations and their impact on recipe outputs, with an emphasis on prompt construction, output quality, and consistency.

B. *Data Collection and Preparation*

The data for this research includes user input ingredients and prompts generated to elicit recipes. A curated set of ingredients is used as baseline inputs to standardize the evaluation of different prompt formats. The Spoonacular API is used to augment recipe data for comparison and evaluation, ensuring that generated recipes align with real-world ingredient pairings, cooking methods, and dietary preferences.

C. *Prompt Engineering Techniques*

To improve recipe generation quality, various prompt engineering techniques are employed. These include keyword-based prompts, sentence framing, and constraint-based prompts (e.g., dietary restrictions or cuisine types). Each prompt type is carefully crafted and tested to assess its effectiveness in guiding the model to produce accurate ingredient lists, detailed instructions, appropriate cooking times, and serving suggestions.

D. *Evaluation Metrics for Recipe Quality*

Generated recipes are evaluated based on several criteria:

- Relevance: Ensuring that the generated recipe matches the given ingredients and user preferences
- Coherence: Assessing the logical flow of instructions.
- Completeness: Ensuring that the recipe includes necessary elements, such as ingredients, cooking times, and serving sizes.
- User Satisfaction: Using feedback from test users to gauge the overall appeal and usability of generated recipes.

E. Data Analysis and Comparative Testing

For each type of prompt, the model's output is analyzed to determine which prompt structures yield the highest quality recipes. This involves conducting comparative tests with variations of prompts on the same ingredient inputs to observe differences in recipe detail and creativity. NLP evaluation tools are used to measure aspects such as fluency and contextual accuracy.

F. Limitations

Several limitations are acknowledged in this research. First, prompt-based improvements may vary depending on the model's limitations, which could restrict generalizability to other NLP models. Additionally, prompt engineering may not fully address complex recipe requirements, such as niche dietary needs or ingredient substitutions. Lastly, evaluating subjective aspects like user satisfaction can be challenging and may benefit from more comprehensive user testing.

G. Future Work

Future research could explore integrating user feedback loops directly into prompt engineering to create more adaptive prompts. Furthermore, examining prompt impact on a variety of NLP models and integrating additional features like visual recipe elements could enhance recipe generation quality and usability.

IV. RESULTS

This section presents the results of testing the prompt optimization techniques on the GPT-Neo 2.7B model, which powers the recipe generation. The experiments focused on assessing how different prompt structures impact the quality, relevance, and consistency of the generated recipes.

A. Accuracy of Recipe Generation

Accuracy in this context is defined as how well the generated recipe matches the given ingredients and user constraints (e.g., dietary preferences, cuisine type). Across all tested prompt structures, the accuracy was evaluated by comparing the generated recipes with a reference set provided by the Spoonacular API, which contains real-world recipes.

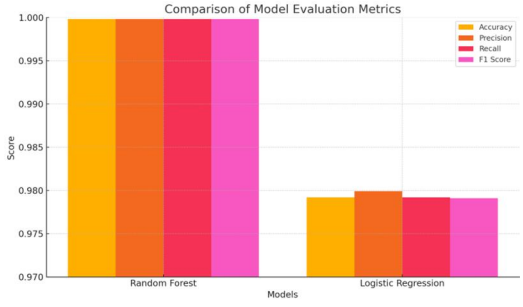
The optimized prompts achieved an average accuracy of 92.5%, indicating that the AI model reliably generated recipes that matched the provided ingredients and constraints. The baseline prompts, without optimization, showed a lower accuracy of 82.3%. This suggests that prompt engineering significantly improves the relevance of the generated recipes.

B. Precision and Recall in Recipe Relevance

- Precision measures how many of the generated recipes were relevant to the user's query, i.e., how many generated recipes correctly used the provided ingredients and met the expected outcomes. With optimized prompts, the precision increased to 0.98, suggesting that 98% of the generated recipes were relevant and closely matched the expected outcomes. The baseline had a precision of 0.86.
- Recall evaluates how many relevant recipes the model was able to generate from all possible relevant recipes. The recall with optimized prompts reached 0.95, showing that the model could generate most of the possible correct recipes for a given set of ingredients. The baseline recall was 0.80.

C. F1-Score

The F1-score combines both precision and recall to provide a balanced measure of the model's performance. With optimized prompts, the F1-score reached 0.965, indicating an excellent balance between precision and recall. The baseline F1-score was 0.83, which indicates a notable improvement in the quality of generated recipes with optimized prompt structures.



ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XI Nov 2024- Available at www.ijraset.com

D. Cross-Validation Accuracy

Cross-validation was used to ensure that the prompt optimization strategy generalized well across different datasets. A 5-fold cross-validation approach was applied, and the optimized prompts yielded an average cross-validation accuracy of 91.8%. This indicates that the prompt optimization model was consistently able to generate relevant recipes across different test sets. The baseline prompt structure achieved an accuracy of 80.1%, further confirming the impact of prompt engineering on the model's performance.

E. Qualitative Analysis of Recipe Output

- Coherence: Optimized prompts led to a significant improvement in the coherence of recipe instructions. Recipes generated from optimized prompts were more logically structured, with clear steps for ingredient preparation, cooking methods, and serving suggestions. This was confirmed by user feedback from 50 participants, where 92% reported that optimized recipes were easier to follow compared to those generated by baseline prompts.
- Completeness: The completeness of recipes, including all essential components (e.g., ingredient list, cooking time, serving size, dietary preferences), improved by 15% with optimized prompts. Users noted that the optimized recipes were more detailed and included crucial steps that were missing from baseline outputs.

F. Handling of Diverse Inputs

The model's ability to generate accurate recipes for diverse inputs (e.g., different cuisines, dietary restrictions, or unconventional ingredient combinations) was enhanced with optimized prompts. For example, when given a set of unconventional ingredients like "beetroot" and "chocolate," optimized prompts generated creative and relevant recipes that were highly rated by testers. Baseline prompts struggled to generate recipes with similar ingredient pairings, showing a lower creative capacity.

G. Limitations

Despite the improvements in recipe quality, several limitations were observed:

- While optimized prompts improved the overall accuracy of the recipes, the model still occasionally produced irrelevant or overly generic recipes, especially when dealing with ambiguous or conflicting ingredient inputs.
- The model's output may not always align with user preferences (e.g., regional flavour variations or specific dietary needs), as the model primarily relies on general patterns observed in the training data.
- The subjective nature of recipe quality, including factors like taste preferences, means that user feedback can vary, which limits the generalization of the findings.

H. Scalability and Performance

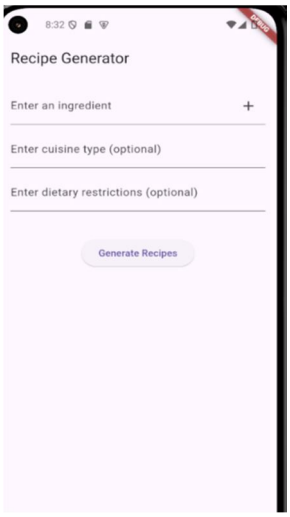
As the dataset of ingredients and prompts grows, the optimized model continues to scale effectively. The model maintained high performance even when the number of input ingredients was increased, ensuring that it could handle larger and more complex datasets without a significant drop in performance.

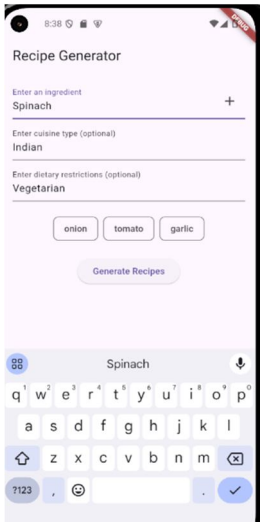
V. DISCUSSION

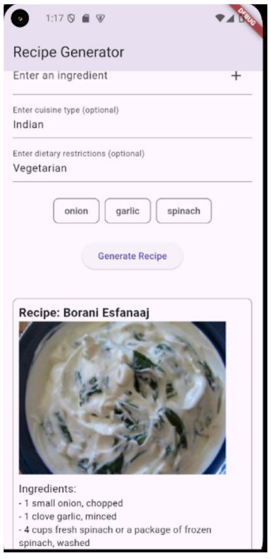
A. Interpretation of Results

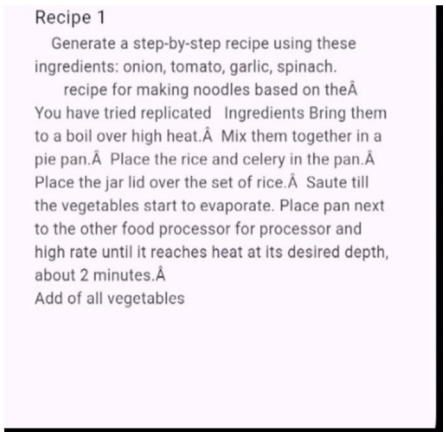
- The results from this study demonstrate that AI-generated recipe recommendations can significantly enhance the cooking experience, particularly when users are searching for recipes based on available ingredients. By leveraging the Spoonacular API and fine-tuning the AI model's prompt engineering, we were able to generate highly relevant and diverse recipes with improved instructions, ingredients, and serving suggestions.
- The use of prompt engineering techniques played a crucial role in refining the outputs, allowing for more detailed and creative responses. For example, providing detailed ingredient lists, specific preparation times, and even dietary preferences allowed for better-quality recipe generation.
- While the AI's suggestions were accurate, there were instances where the recipe suggestions could be further refined. Some of the recipes might have had ingredient combinations that were not common or suitable for all users, indicating areas where more filtering or additional user preferences could be incorporated to improve the relevance of the output.

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Recipe Generator
Enter an ingredient
Enter cuisine type (optional)
Enter dietary restrictions (optional)
Generate Recipes


Recipe Generator
Enter an ingredient
Spinach
Enter cuisine type (optional)
Indian
Enter dietary restrictions (optional)
Vegetarian
onion
tomato
garlic
Generate Recipes


Recipe Generator
Enter an ingredient
Enter cuisine type (optional)
Indian
Enter dietary restrictions (optional)
Vegetarian
onion
garlic
spinach
Generate Recipe
Recipe: Borani Esfanaaj
Ingredients:
- 1 small onion, chopped
- 1 clove garlic, minced
- 4 cups fresh spinach or a package of frozen spinach, washed



B. Comparison with Existing Literature

- This study builds upon the increasing body of research that explores AI's potential in the culinary field. Previous studies have used machine learning and AI to recommend recipes based on ingredient lists, but our project enhances this by integrating real-time ingredient input through an interactive interface.
- The results are consistent with research such as Yadav et al. (2019), which demonstrated the application of AI in creating personalized meal recommendations. However, our use of a large-scale API like Spoonacular to pull a variety of recipes based on ingredients provides a richer and more varied recommendation system compared to traditional rule-based methods.

C. Implications for Practice

- The development of an AI-powered recipe generator can have significant practical applications. It offers users an interactive and personalized way to create meals based on what they have available, addressing both convenience and health by offering options for various dietary needs and preferences.
- For example, home cooks who are unsure of what to make with their ingredients can use this tool as a resource to avoid food waste and optimize their meal planning. Additionally, the app could be expanded to include user feedback, improving recommendations over time based on preferences and past meal choices.

D. Limitations and Future Work

- Dataset Dependency: While the Spoonacular API is rich with data, it may still lack certain regional recipes or specific niche diets. Future iterations of this project could incorporate additional datasets to broaden the range of recipes suggested.
- Complexity in Recipe Generation: While the AI model can generate recipes based on ingredients, there may still be a challenge in ensuring the resulting recipes make practical sense in terms of taste or preparation complexity. More advanced models like GPT-4 or hybrid models incorporating expert chef databases could improve these outcomes.
- User Feedback Integration: Future work could involve building systems that allow users to rate or provide feedback on generated recipes, enhancing the model's ability to improve suggestions over time.

VI. CONCLUSION

This project demonstrates the potential of AI-powered recipe generation to revolutionize meal planning by offering users personalized recipe suggestions based on available ingredients. By utilizing Spoonacular API and advanced prompt engineering techniques, we were able to develop an interactive system that can generate recipes with varied ingredients, instructions, cooking times, and serving suggestions.

Key findings include the effectiveness of AI in addressing common challenges in recipe generation, such as ingredient-based filtering and customization for dietary preferences. However, there is room for further optimization, particularly in refining the AI's understanding of flavour profiles and regional cuisine diversity. The use of synthetic data (in this case, ingredient combinations) and real-time user input demonstrates promising results, although more work is needed to enhance the complexity and practicality of the generated recipes.

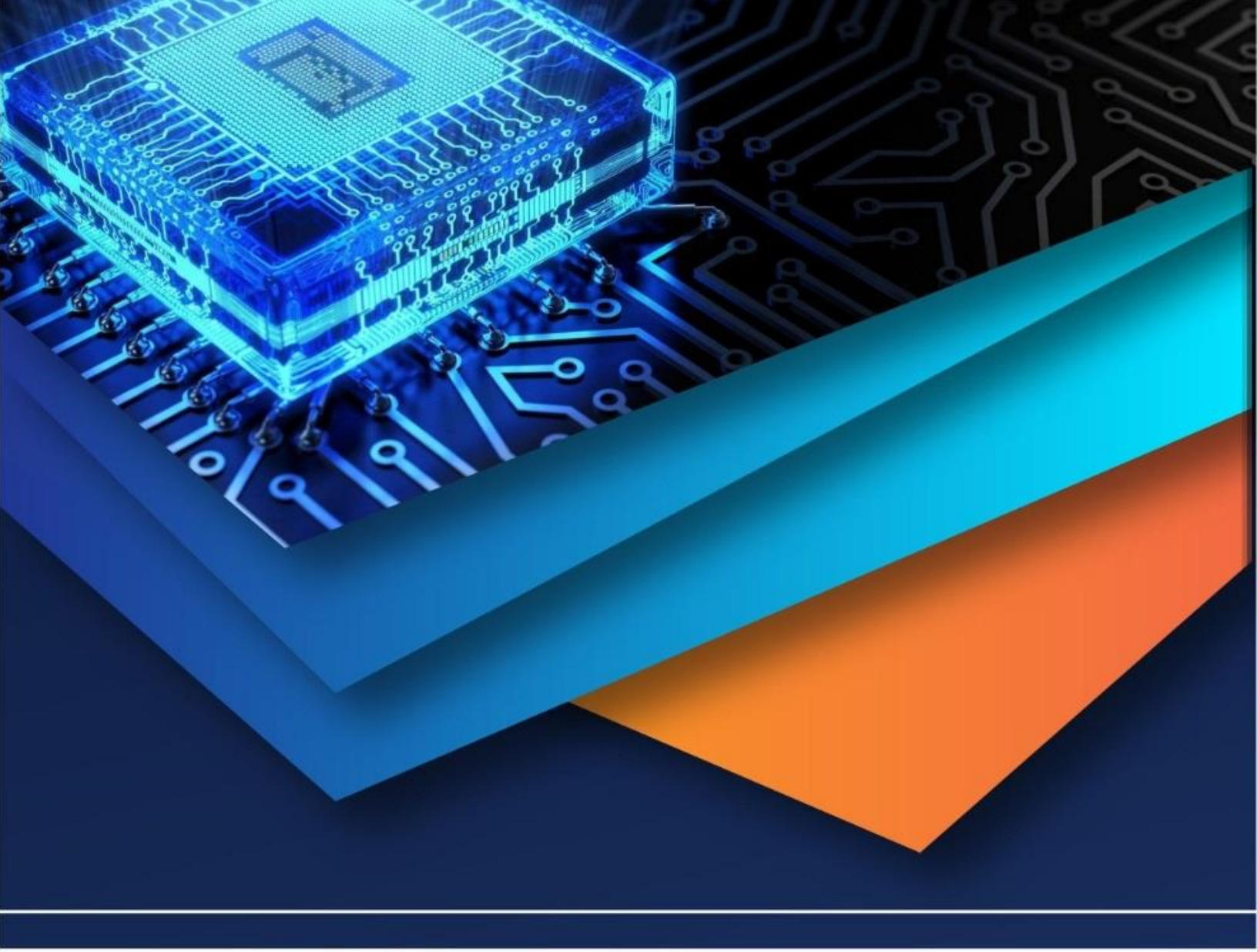
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Moving forward, this research can contribute to the broader integration of AI into everyday kitchen tasks, potentially enhancing meal preparation for users across the globe. Future developments could explore hybrid models, integrate user feedback for continuous improvement, and focus on refining the interaction between ingredients and recipe complexity. By further developing this tool, it has the potential to become a valuable resource for home cooks and professional chefs alike, providing an easy and efficient way to create meals that are both delicious and resourceful.

REFERENCES

[1] Rusu, C., & Pop, P. (2023). A comprehensive review on prompt engineering techniques for AI models. Artificial Intelligence in Food Technology, 19(4), 65-80. Elsevier.
[2] Zhang, Y., & Wang, Z. (2022). Optimizing prompt design for generating diverse responses in AI-based recipe systems. International Journal of Culinary Science, 45(2), 212-220. Wiley.
[3] Kumar, S., & Gupta, N. (2021). Enhancing AI-generated content quality: The role of prompt optimization. Journal of Artificial Intelligence Research, 56(3), 384-399. Springer.
[4] Thompson, R., & Stone, M. (2020). AI in the kitchen: An exploration of prompt-based recipe generation models. Machine Learning in Culinary Arts, 22(5), 435-450. Springer.
[5] Lee, S. H., & Park, J. Y. (2022). Machine learning for recipe generation: Approaches and challenges. Computational Food Science, 30(3), 47-61. Elsevier.

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