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Project Report

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Innovative System Design and Development I

VR-Kitchen: Risk Management Platform for Gastronomy Practitioners

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Table of Contents

Abstract

This document covers the Project Work Plan, Literature Review, Software Specification Requirements, and the Software Design Description for the project “VRKitchen: Risk Management Platform for Gastronomy Practitioners”. This project is about creating a virtual reality (VR) module that trains gastronomy students to manage major kitchen risks such as cross-contamination, burns, equipment failure, and exposure to allergens.

The students will face different realistic scenarios where they have practical experience in identifying and managing risks—preparation that is important for facing challenges in professional kitchens. In this respect, it assures that the safety and efficiency of culinary operations are guaranteed and thus becoming an important tool for chefs and culinary professionals.

1. Introduction

The VR module will immerse these students in a virtual kitchen environment where they can safely practice answering potentially hazardous situations. Each scenario is devised to draw from real-life kitchen conditions, enabling the student to engage in realistic interactions that avoid any real-life danger of personal harm. From managing fire hazards to recognizing unsafe food handling, the training will emphasize critical safety protocols and decision-making under pressure.

This project meets the call to bridge theoretical knowledge into practice through dynamic and engaging learning experiences without compromising learner engagement. Besides acquiring an advanced understanding regarding safety in the kitchen, this will equip students with the confidence to handle situations that may arise unplanned during their subsequent careers. Emphasis on risk management is all the more relevant in view of the recent heightened interest in accident-conscious professionals in both the culinary and hospitality industries.

With this, the new approach will be contributing to creating skilled and safety-minded chefs who can maintain the standards in professional kitchens. This will be a useful tool for educators, hence offering them a flexible and effective method of teaching necessary risk management competencies in a controlled, repeatable, and measurable way.

2. Project Work Plan

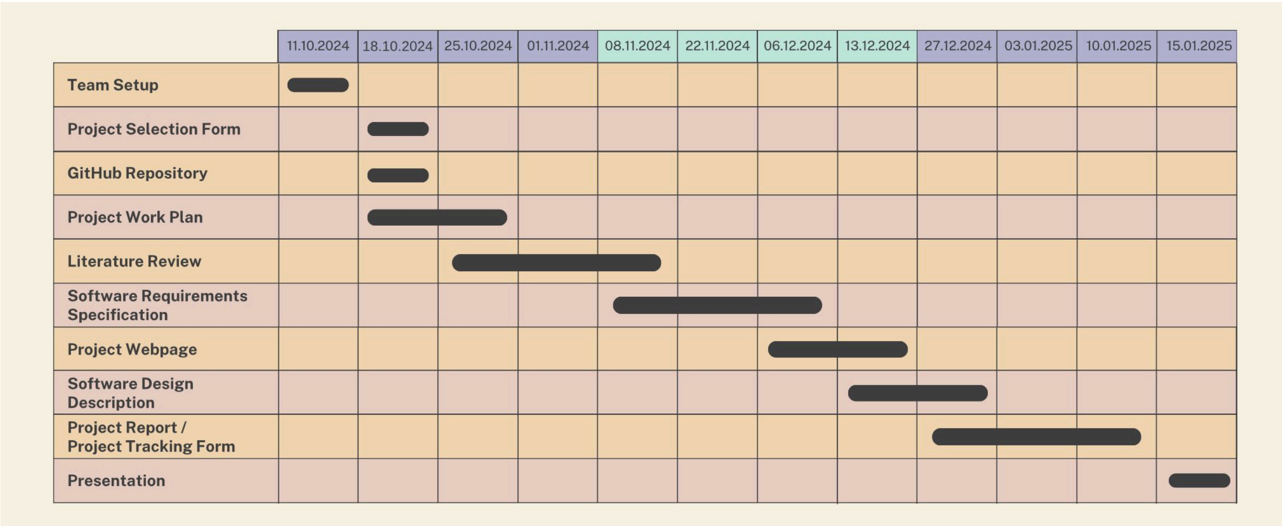

Figure 1: Project Work Plan

3. Literature Review

3.1. Introduction

Virtual reality (VR) is an evolving technology with transformative applications in education, offering immersive, hands-on simulations that enhance the learning experience by bridging the gap between theory and practice.[1] In fields requiring complex skill sets, such as culinary arts, VR can provide an invaluable platform for training and development. Cooking, a fundamental skill for gastronomy students, involves more than the creation of flavorful dishes; it encompasses a range of tasks that introduce multiple safety, health, and operational risks. Aspiring chefs must be equipped not only with the skills to craft high-quality meals but also with the knowledge to manage risks, from cross-contamination and burn prevention to equipment malfunctions and allergen cross-contact. Without adequate preparation, these risks can lead to safety hazards, health issues, and even business disruptions.

Recognizing the importance of risk management, educational institutions are exploring new ways to integrate VR technology into culinary training. VR offers an immersive environment where students can experience high-stakes scenarios in a controlled and safe setting, enabling them to develop essential skills in risk awareness and response without the dangers of a real kitchen. In recent years, VR has been used successfully across sectors—from manufacturing and engineering to healthcare and aviation—where training in a risk-free virtual environment has proven effective in building critical competencies. [2]][3]][4]] As situations in professional kitchens become increasingly complex, VR's capacity to simulate authentic, dynamic scenarios makes it an ideal tool for teaching culinary students to recognize, assess, and mitigate potential risks.

This project seeks to leverage VR technology to create a comprehensive risk management training program for gastronomy students. Through carefully designed scenarios, the VR environment will simulate common but potentially hazardous situations in a professional kitchen, such as cross-contamination incidents, allergic reactions, burn prevention, and equipment breakdowns. These scenarios will allow students to practice identifying hazards, responding quickly to potential dangers, and applying preventive measures, all within a realistic virtual kitchen that closely mirrors the environments they will encounter in their careers. By integrating this VR training module into culinary curricula, the project aims to emphasize both safety and the professional standards that are essential for risk management in the culinary field.

Ultimately, this VR-based approach to risk management training will provide gastronomy students with practical, hands-on experience that goes beyond traditional classroom learning. It will prepare them to navigate the challenges of a professional kitchen environment with confidence and efficiency, equipping them with the critical skills to address unforeseen challenges effectively. By embedding this training in their early education, the project aims to foster a new generation of chefs who are not only skilled in culinary arts but also well-prepared to uphold high standards of safety and professionalism in any kitchen setting.

3.2. Risk Management

3.2.1. Risk Management in Businesses

Risk management is a crucial part of business strategy, enabling organizations to navigate uncertainties in areas such as finance, operations, and compliance. Businesses adopt risk management to mitigate risks that could harm organizations. Through a comprehensive approach, enterprise risk management (ERM) enables firms to evaluate risks collectively and coordinate risk management initiatives with more general strategic goals. Experts argue that, compared to enterprise risk management, traditional risk management lacks the mindset and mechanisms required to understand risk as an integral part of enterprise strategy and performance.

Risk management isn't just about avoiding negative outcomes. It may also be the spark that drives the development and innovation of your company. Studies have shown that ERM positively impacts firm performance by increasing resilience and adaptability.[5] Effective risk management also prepares companies for unexpected events, such as global crises, by establishing rapid response mechanisms.[6]

In traditional business settings, risk management typically follows a structured process that includes risk identification, assessment, and response. Technologies like data analytics and machine learning, which assist in identifying risk trends and projecting possible effects, aid in this process.

Figure 2: Risk Management Lifecycle

3.2.2. Risk Management Learning Methods and Techniques

Techniques and methods for teaching risk management vary, with common approaches including case studies, simulations, and experiential learning. Case studies allow learners to analyze real or hypothetical risk scenarios, applying theoretical frameworks to make informed decisions. Simulations, on the other hand, immerse learners in high-risk situations where they can observe outcomes based on their choices in a controlled environment.[6] Research suggests that experiential learning methods, which emphasize hands-on practice, are particularly effective for understanding the complexities of risk management, as they allow learners to experience the consequences of different strategies in simulated environments.[7]

Additionally, cutting-edge techniques like machine learning (ML) and artificial intelligence (AI) are also transforming risk management training. Managers may examine large datasets, discover risk trends, and make data-driven decisions with the help of AI-driven risk assessment tools. These tools improve learning by giving learners feedback loops where they may observe the immediate effects of their risk management choices.

3.2.3. Risk Management in Kitchen

Risk management within kitchens, especially in commercial and industrial settings, is critical to ensuring food safety, worker safety, and operational efficiency. Kitchen risk management addresses hazards like fire, food contamination, equipment malfunction, and workplace injuries. A structured risk management plan in kitchens typically includes hazard identification, risk assessment, and implementation of preventive measures such as standard operating procedures (SOPs) and food safety protocols. [8]

When conducting a risk assessment in the kitchen, it is important to start by:

- Identifying the potential hazards present in the kitchen, such as sharp objects, hot surfaces, or slippery floors.
- Assessing the likelihood and severity of each identified hazard.
- Evaluating the current control measures in place to mitigate the risks.
- Determining if additional control measures are necessary to reduce the risks further.
- Prioritizing the identified risks based on their potential impact.
- Developing an action plan to address the identified risks and implement the necessary control measures.
- Regularly reviewing and updating the risk assessment as needed. [9]

Kitchens employ specific techniques, like Hazard Analysis and Critical Control Points (HACCP), to identify and manage risks in food preparation processes. HACCP involves determining critical control points where potential contamination could occur and implementing stringent checks to prevent it. Training kitchen staff on proper handling, storage, and cooking practices is essential, as human error is a significant factor in kitchen risks.

Furthermore, risk management in kitchens have many technology-based solutions nowadays such as temperature monitoring devices and automated cooking systems, which could help reduce human error. This technology integration and ongoing staff training significantly reduce risks and enhance safety in commercial kitchens. [10]

3.2.4. Other Fields

From risk management in various fields, specific methodologies have been instituted in handling each particular problem.

The complexity of global supply chains has amplified the need for effective risk management strategies to handle disruptions. Key challenges include geopolitical shifts, economic policies, and the increasing frequency of disruptions due to natural and human-made events. Studies suggest methods such as robust optimization, stochastic planning, and the incorporation of digital tools like blockchain to enhance resilience.

SCRM often involves evaluating, prioritizing, and monitoring risks across all segments, enabling firms to respond to external shocks effectively. Recent literature underscores the importance of adapting strategies to maintain stability, competitiveness, and sustainability amid changing market conditions.[11]

The integration of cybersecurity with supply chain risk management is crucial for sectors dependent on technology. A typical approach includes using standardized frameworks such as the NIST Cybersecurity Framework, which helps organizations create a cohesive strategy across departments like IT, legal, and engineering. These frameworks facilitate incident responses and establish policies to secure critical supply chain elements. Executive involvement is often critical, ensuring that security protocols align with business objectives, thus minimizing disruptions to product and service delivery.[12]

Risk management in finance is centered around mitigating financial losses due to market volatility, credit defaults, and liquidity issues. Methods include portfolio diversification, financial derivatives like options and swaps, and regulatory compliance. Recent research focuses on data-driven risk assessments that utilize machine learning for predictive analytics, helping firms make informed decisions to buffer against economic downturns.
This field faces operational risks, including equipment failure, labor shortages, and supply delays. To manage these risks, companies implement maintenance programs, diversify suppliers, and use lean manufacturing techniques to streamline production and minimize vulnerabilities. Studies emphasize a proactive approach, with risk mapping and scenario analysis as tools to prepare for disruptions.

3.3. Virtual Reality

3.3.1. History of VR

The concept of virtual reality (VR) has a long history, dating back to early ideas of simulated environments. In the 1960s, Morton Heilig pioneered the creation of the "Sensorama," a multi-sensory machine designed to immerse viewers in an environment using visual, auditory, and tactile feedback, laying the groundwork for immersive VR [13]. Ivan Sutherland's invention of the first head-mounted display (HMD), often called "the Sword of Damocles," in 1968 further advanced VR technology, albeit with very basic graphics and limited functionality due to the technology constraints of the time [14].

The 1980s and 1990s saw significant progress, driven by innovations from companies like NASA, which used VR for pilot training and simulation. In 1989, Jaron Lanier, the founder of VPL Research, popularized the term "virtual reality," bringing public attention to its potential for creating immersive digital experiences. However, the hardware at this time was often bulky, costly, and not widely accessible [14] [15].

VR technology became more practical and affordable in the 2010s with advances in computing power, graphics rendering, and sensor technology. Oculus, which launched its first consumer headset in 2012, was a game-changer, popularizing VR for gaming, training, and educational applications. Oculus' success encouraged major tech companies like Sony, HTC, and Google to develop VR solutions, making it more accessible across industries [15] [16]

Today, VR is an essential tool across various fields, including medical training, construction safety, and, increasingly, culinary education. By enabling safe simulations of real-life environments, VR helps users learn and practice skills in scenarios that would otherwise be too dangerous or costly to recreate [13] [16]. For gastronomy students, VR can offer realistic kitchen environments where they can experience and manage risks without real-world consequences, an approach especially beneficial for training in high-risk areas like allergen management and equipment handling [17].

3.3.2. VR Technology

Virtual Reality (VR) technology creates a fully immersive, computer-generated environment that users can interact with, simulating real-world experiences. This immersive quality is achieved through head-mounted displays (HMDs), spatial audio, and hand controllers, which together provide a sensory-rich experience that engages sight, sound, and motion. This makes VR a powerful tool for training, education, and skill-building across many fields, including gastronomy, safety training, and technical education. [18] [19]

In its current state, VR technology includes both hardware and software components that work together to create an engaging virtual environment. The hardware typically consists of VR headsets (such as those produced by Oculus, HTC, and Sony), which provide high-resolution 3D graphics, and motion-tracking sensors, which translate real-world movements into the virtual environment. [18] Advanced VR systems may also integrate haptic feedback, allowing users to "feel" virtual objects, enhancing the realism of the experience.

VR technology's software side relies on robust graphics processing and realistic rendering capabilities to create visually convincing worlds. These virtual environments can simulate complex scenarios that would be challenging, costly, or dangerous to reproduce in real life. For instance, VR has been particularly successful in simulating high-risk environments for safety training, where users can practice responding to hazards without facing real-world dangers. Studies show that VR-based training can improve knowledge retention, engagement, and confidence, making it an invaluable tool in educational settings.

Despite VR's growing capabilities, challenges remain. High costs and potential issues like motion sickness can limit accessibility and user comfort, especially for prolonged use. However, with continuous advancements and increasing affordability, VR is becoming more accessible and adaptable to diverse training contexts, paving the way for more widespread application in fields like gastronomy and technical education.

3.3.3. VR Usage in Education and Training

Virtual Reality (VR) has emerged as a transformative tool in education and training, offering immersive, interactive environments that enhance learning outcomes. By simulating real-life scenarios, VR enables learners to engage in hands-on experiences that would otherwise be too costly, dangerous, or difficult to recreate in physical settings. This makes VR particularly valuable for vocational training, where students can practice complex skills in a controlled environment that minimizes real-world risks.

In educational contexts, VR's immersive qualities help increase student engagement and motivation. Studies show that VR can improve both knowledge retention and comprehension, as learners are more likely to remember and understand concepts when they experience them firsthand. For example, vocational and technical training programs have successfully implemented VR to teach students skills in fields such as construction, engineering, and healthcare, where they can practice procedures and protocols in realistic yet risk-free settings. This also allows for repeated practice without the need for additional physical resources. [20]

In gastronomy and culinary education, VR's applications are expanding. Culinary students can use VR to simulate kitchen environments and practice managing common risks, such as cross-contamination, equipment malfunctions, and allergen handling. These VR simulations provide a safe space for students to hone their skills in risk management, which is essential in the culinary profession. By training in a VR environment, students gain valuable experience in handling unexpected challenges, preparing them for real-world kitchen situations where safety, precision, and professionalism are critical.

VR also offers flexibility in learning, as students can access training modules remotely, enabling distance learning and minimizing logistical constraints. This flexibility is beneficial for institutions aiming to provide consistent, standardized training across diverse locations. Additionally, VR's adaptability allows trainers to create customized learning scenarios, catering to different skill levels and learning objectives, which further enhances its effectiveness as a training tool.

Despite its advantages, VR in education and training does come with challenges, such as the high cost of VR hardware and potential issues like motion sickness for some users. However, as technology advances and becomes more affordable, these barriers are gradually diminishing. With continuous improvements, VR is expected to play an increasingly central role in education and professional training, helping students acquire practical skills in an interactive and safe environment.

Figure 3: VR and Kitchen

3.3.4. VR in Industry

Virtual Reality (VR) technology has made a significant impact across a range of industries by offering innovative solutions to complex challenges. One of the most profound applications of VR is in healthcare. Through immersive simulations, VR enables medical professionals to engage in surgical training, enhancing their skills in a controlled and risk-free environment. For instance, VR simulations can replicate intricate surgeries, allowing trainees to practice and perfect their techniques without real-life consequences. This approach not only improves skill retention but also enhances patient safety in actual procedures. Studies have indicated that VR-based training can lead to higher accuracy and efficiency among surgeons, ultimately benefiting healthcare outcomes.

Additionally, VR is being utilized for pain management and therapy. Virtual environments can help patients with pain distraction techniques, such as guided VR experiences that reduce pain perception during treatments. Chronic pain sufferers have also shown improvements through VR-mediated exercises and rehabilitation programs. By creating engaging and controlled scenarios, VR fosters adherence to rehabilitation exercises, which can be difficult in traditional settings. This application exemplifies the versatility of VR in addressing both physical and psychological aspects of patient care.

The automotive and manufacturing sectors are also harnessing VR technology. In these industries, VR facilitates product design and prototyping, reducing the need for physical mock-ups and enabling efficient collaboration across global teams. Engineers can visualize and interact with 3D models, making design iterations and testing different variables before actual production. This not only saves time and costs but also enhances the quality of the final product. Furthermore, VR training modules prepare workers for handling heavy machinery or hazardous materials by simulating real-world tasks and scenarios in a safe environment .

Education and training sectors continue to benefit significantly from VR, as well. VR makes experiential learning more accessible by providing scenarios that would otherwise be too dangerous, costly, or impractical. This is especially crucial in emergency response training, where VR can simulate disaster environments for first responders to practice crisis management without endangering lives. The growing adoption of VR across various domains underscores its potential to revolutionize traditional practices and pave the way for more immersive, interactive, and efficient processes.

3.4. Unity as a Game Engine

Unity is the most acknowledged real-time 3D development platform, really widely adopted, thanks to its ability to provide an optimal mix of flexibility, scalability, and usability. Capabilities include immersive environments, interactive simulations, and high-fidelity graphics that are very vital in VR projects. The possibility of scripting Unity with C# grants, together with the very powerful physics engines, the creation of highly interactive VR environments. This is very important in training simulations where user engagement and real interactions are believed to augment the effectiveness of any training experience. Unity's ML-Agents Toolkit brings reinforcement learning into play, enabling a development of AI that learns and adapts in response to a user's actions.

This elasticity is really important in providing training modules where the hardness or the behavior of AI agents changes with the progress of the learner, thus personalizing their experience. It also plays a part in understanding user inputs well and paving the way for intuitive interaction. Gesture recognition is one of the key AI features in Virtual Reality for letting users behave naturally-such as in the case where some hand movements or ways of body language will be important. Unity also allows gesture recognition- Integration with other AI libraries like TensorFlow and PyTorch would enable a developer to implement deep learning models that recognize certain hand or body gestures. Such an implementation may further create intuitive interaction models in which one can simply reach out, point, or make certain gestures to manipulate objects inside the VR environment. Gesture recognition in VR has been shown to improve user engagement and immersion, as it aligns with natural human movements and reduces the need for controllers or abstract inputs. This hands-on experience is particularly valuable in training simulations where physical actions are essential for skill development.

This represents great added value: Unity AI and conversational interaction in VR with NLP. With the integrated models of NLP, Unity will be able to support applications where users converse with AI-powered NPCs or follow voice-over instructions. Unity finally can handle conversational agents thanks to its support for various third-party NLP frameworks. Immediate feedback or guidance plays an important role in providing an effective learning experience, which in turn makes training simulations far more productive.

Another great plus would be that Unity has a very active developer community-a lot of resources are online. It means a person can take advantage of so many different resources while self-improving and increasing contribution to a project.

3.5. Artificial Intelligence

3.5.1. Deep Learning VR Simulations

In the context of gastronomy education, integrating deep learning with Virtual Reality (VR) technology can significantly enhance risk management training by providing highly realistic and adaptive learning experiences. Deep learning, a subset of machine learning, allows VR simulations to evolve dynamically in response to a user's actions, offering a more personalized and interactive training environment. By embedding AI-driven models into VR simulations, the system can create realistic, context-sensitive scenarios that adapt to each user's decisions in real time, offering a more nuanced and effective approach to teaching risk management skills. This deep integration of AI and VR provides a truly immersive learning experience that traditional methods simply cannot match [21].

For gastronomy students, this deep learning-powered VR environment can simulate a wide range of high-risk scenarios they are likely to encounter in a professional kitchen. These scenarios include critical situations like cross-contamination between raw and cooked foods, burns from mishandling hot equipment, allergic reactions triggered by improper food handling, and equipment malfunctions. The VR system will react dynamically based on how the student interacts with the kitchen environment—if a student fails to prevent cross-contamination, for example, the system could simulate the consequences, such as a foodborne illness or an allergic reaction. The deep learning model can also detect unsafe practices, such as improperly handling hot utensils or neglecting to follow hygiene protocols. When such unsafe actions are recognized, the system can intervene by providing real-time feedback and guiding the student toward safer practices.

The use of deep learning in VR training allows for continuous improvement and refinement of scenarios based on the user's behavior and decision-making patterns. As students repeat the training, the system learns from their actions, enhancing the training experience by progressively increasing the complexity and difficulty of risk scenarios. This personalized approach not only ensures that each student's individual learning pace is taken into account but also offers increasingly sophisticated feedback that challenges the student to sharpen their skills. Over time, the system can tailor training pathways to the specific needs of each student, helping them focus on areas where they need the most improvement. This ability to adjust and evolve ensures that gastronomy students are exposed to a broad array of risk situations and are better prepared to handle them effectively in real-world kitchen environments.

Moreover, AI-driven VR simulations also provide an invaluable tool for instructors to monitor and assess students' progress. By analyzing patterns in the students' decision-making, the system can identify weaknesses in their knowledge and behavior, helping instructors pinpoint areas where additional training is required. For instance, if a student consistently fails to identify certain hazards or risks, the system can automatically adjust the difficulty level of the simulation, making that specific risk more apparent in future training scenarios. This feedback loop helps reinforce correct behaviors and correct mistakes before they become ingrained. Instructors can also use the data gathered by the VR system to provide more targeted, personalized guidance to students based on their performance in the training environment [22].

Incorporating deep learning into VR simulations not only enhances the realism and effectiveness of the training but also ensures that students develop the necessary skills to manage risks and maintain safety in a professional kitchen setting. By exposing students to a wide variety of potential hazards in a safe, adaptive, and immersive virtual environment, the training program helps them develop the confidence and competence needed to navigate real-world challenges in the culinary world. This advanced training approach goes beyond static, traditional methods by offering a more interactive, engaging, and responsive learning experience. It better prepares students to meet the demands and complexities of a fast-paced kitchen environment, where the ability to manage risk effectively is crucial to ensuring safety, health, and business success [22].

3.5.2. Chatbots/ GPT

Integrating Chatbots and GPT-based AI within a VR training system for gastronomy education creates an immersive learning experience that not only simulates real-world environments but also provides dynamic guidance and interaction. This combination introduces a layer of personalization and interactivity previously unattainable with static, non-interactive training methods.

GPT (Generative Pre-trained Transformer) chatbots, like ChatGPT, are advanced AI-driven systems that use machine learning to understand and generate human-like text.

These models are trained on massive language datasets to capture the complexities of grammar, context, and semantics, enabling them to hold nuanced and coherent conversations with users. This functionality makes GPT-based chatbots ideal for providing real-time responses and detailed explanations, which can significantly enhance the learning experience [23]. By leveraging this deep understanding of language, GPT-based chatbots are able to simulate the role of an instructor, tutor, or assistant, which can be particularly useful in VR environments [24].

The unique capabilities of these chatbots have already made them effective in applications beyond simple Q&A. They can answer complex questions, engage users in conversations that foster deeper understanding, and adapt their responses based on previous interactions. In gastronomy education, where understanding and immediate feedback are crucial, such AI can simulate a live training environment by engaging students in conversation about their techniques, methods, or safety practices, much like a real-life mentor would [25].

Embedding GPT chatbots into VR takes this potential a step further by creating an adaptive, context-aware educational experience. In the VR-based gastronomy training system, the chatbot could interact with students as they engage in various cooking scenarios, providing immediate, context-specific guidance. For example, if a student neglects a critical safety step, such as cleaning surfaces to avoid cross-contamination, the chatbot can provide a gentle reminder and explain the consequences of such omissions, thus reinforcing safety protocols [26].

This application aligns with findings from recent studies, which indicate that integrating AI like GPT in virtual reality can significantly enhance learning retention and user engagement, especially in fields that require hands-on experience [27]. As students interact with the virtual kitchen, the chatbot can simulate real-time instructional feedback, enhancing immersion by "observing" student actions and responding accordingly. If a student mistakenly uses raw ingredients in a way that could lead to contamination, the chatbot could prompt them to reconsider their approach, mimicking real-world training conditions where instant feedback is essential for skill development.

One of the most transformative aspects of using GPT-based chatbots in VR is their ability to create personalized learning experiences. GPT models are highly adaptable, allowing them to respond based on the user's actions and learning progress. This functionality could be crucial for gastronomy students who may have varying levels of proficiency in risk management and kitchen safety. For example, as a student repeatedly encounters specific tasks or challenges, the chatbot can adjust the difficulty of the scenario, suggest advanced techniques, or introduce more complex scenarios [28].

This adaptive feedback loop is achieved through the chatbot's ability to learn from user interactions and adjust responses accordingly. Over time, the VR system, with embedded GPT, can tailor the training experience to the student's individual needs. Studies suggest that such personalized learning pathways enhance educational outcomes by focusing on areas where the student needs the most practice or reinforcement, a principle that has proven effective in other VR-based training systems [29].

In addition to enhancing the student experience, GPT-based chatbots in VR also provide valuable tools for instructors. AI-driven chatbots can track and analyze student interactions, providing data on each individual’s strengths, weaknesses, and progression. For instance, if a student consistently fails to recognize certain hazards, the system can report this information to the instructor, who can then provide additional guidance or target these areas in future training. This data-driven approach enables instructors to give personalized feedback, and it ensures that students receive comprehensive, targeted training [30].

Furthermore, this kind of integration allows students to learn independently, with the AI chatbot acting as a virtual mentor. Studies have shown that interactive learning tools can be more effective than traditional classroom-based approaches, especially for practical skills that require hands-on experience [31]. By facilitating constant, contextually relevant feedback, GPT-driven chatbots allow for self-paced learning, helping students build confidence and competence in risk management before they even step into a physical kitchen.

The immersive nature of VR, combined with the adaptive conversational abilities of GPT-based chatbots, helps to bridge the gap between theoretical learning and practical application. When students are immersed in a realistic, interactive virtual kitchen environment, the learning experience becomes more engaging and memorable. As referenced in studies on VR applications in gastronomy training, the ability to simulate high-risk situations safely allows students to experiment, make mistakes, and learn from those mistakes in a risk-free environment [32].

In conclusion, the integration of GPT-based chatbots into VR for gastronomy education introduces a dynamic layer of interaction that traditional training methods cannot match. By offering real-time guidance, personalized feedback, and adaptive learning pathways, this approach provides a comprehensive training solution that prepares students for real-world challenges. Not only does it enhance safety and risk management skills, but it also fosters critical thinking and decision-making in a controlled, immersive environment.

3.5.3. RAG LLM Systems

A large language model is a type of artificial intelligence algorithm that uses deep learning techniques and massively large data sets to understand, summarize, generate and predict new content. The term generative AI also is closely connected with LLMs, which are, in fact, a type of generative AI that has been specifically architected to help generate text-based content.[33]

Over millennia, humans developed spoken languages to communicate. Language is at the core of all forms of human and technological communications; it provides the words, semantics and grammar needed to convey ideas and concepts. In the AI world, a language model serves a similar purpose, providing a basis to communicate and generate new concepts.[33]

The first AI language models trace their roots to the earliest days of AI. The Eliza language model debuted in 1966 at MIT and is one of the earliest examples of an AI language model. All language models are first trained on a set of data, then make use of various techniques to infer relationships before ultimately generating new content based on the trained data. Language models are commonly used in natural language processing (NLP) applications where a user inputs a query in natural language to generate a result.[33]

An LLM is the evolution of the language model concept in AI that dramatically expands the data used for training and inference. In turn, it provides a massive increase in the capabilities of the AI model. While there isn't a universally accepted figure for how large the data set for training needs to be, an LLM typically has at least one billion or more parameters.[33]

To further improve large language models (LLMs) and enable them to provide accurate answers without requiring additional training, a method called Retrieval-Augmented Generation (RAG) has been developed. RAG allows users to ask LLMs specific questions on any topic, provided that a relevant dataset is available. By combining retrieval of information from external sources with the model's generative capabilities, RAG enhances the accuracy and relevance of responses.

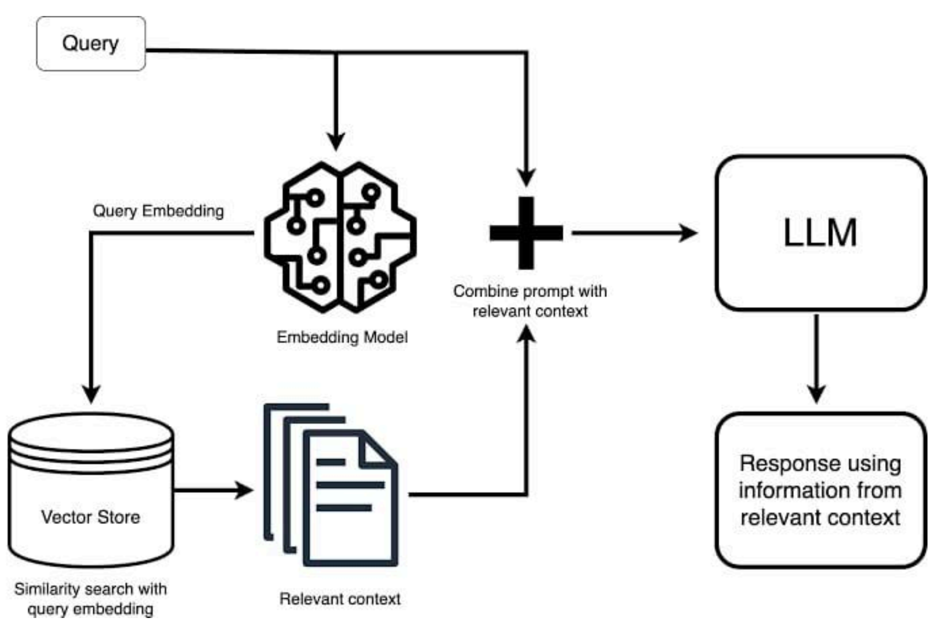

Figure 4: Rag System Overview

3.6. Related Works

As VR technology advances, its applications in training and education have become increasingly popular, particularly in high-stakes environments where real-world risks are involved. In the field of healthcare, for example, VR simulations have been employed to train medical personnel to respond to emergency situations without endangering patient lives. Studies have shown that VR can enhance both the engagement and retention of critical skills, providing a safe space for learners to practice complex procedures and make decisions under pressure [34]. This emphasis on creating realistic, risk-laden scenarios aligns closely with the needs of culinary education, where understanding risk management is fundamental to kitchen operations.

In addition to healthcare, VR has also been adopted in the fields of industrial and manufacturing training to simulate equipment handling and hazard prevention. Ford Motor Company, for instance, has utilized VR for employee training in factory settings, enabling workers to navigate safety protocols around heavy machinery before entering a live production floor. By allowing users to experience potentially dangerous scenarios in a virtual setting, VR has proven to be an effective tool for training in environments where physical safety is paramount [35].

VR's application in culinary education, specifically for risk management, is still emerging, though initial implementations have demonstrated the technology's effectiveness. A study by Chen et al. [36] explored VR as a tool for food safety training in commercial kitchens, finding that it improved learners' ability to identify cross-contamination risks and adhere to food safety regulations. The study suggests that VR could serve as an invaluable supplement to traditional culinary training, where physical risks such as burns, cuts, and contamination pose constant challenges.

Our project takes inspiration from these VR applications across various fields and builds on their success by integrating a Retrieval-Augmented Generation (RAG) system. RAG is an AI-driven approach that enhances traditional VR training by dynamically guiding users based on their actions in the simulation. When users encounter a simulated risk, such as a stovetop fire, the RAG system offers immediate, context-specific feedback and instructions, helping learners understand both preventative and responsive actions in real-time. Through this combination of VR and RAG, the project not only aims to replicate the practicalities of kitchen safety but also provides an adaptable training experience that reinforces risk management skills essential for a career in the culinary arts.

3.7. Sample Scenario

In a professional kitchen, various risks can arise due to human error, equipment malfunctions, and environmental factors. To prepare students for real-life incidents, the VR training module includes simulated scenarios that guide them step-by-step through proper responses to hazards, reinforcing essential risk management practices.

Scenario Example: Stove Fire Response

In this scenario, a student is working at a virtual stovetop, learning to cook a complex dish under simulated time constraints. Midway through the cooking process, a risk event is triggered: an oil spill on the stovetop catches fire. The VR system, powered by a Retrieval-Augmented Generation (RAG) component, immediately alerts the student to the hazard and begins providing guided instructions on handling the situation safely.

As the fire ignites, the RAG system directs the student to locate and use the fire extinguisher mounted on the kitchen wall. The VR module tracks the student's actions, offering real-time guidance on proper extinguisher technique, such as maintaining a safe distance, aiming at the base of the fire, and controlling the extinguisher spray. Each instruction is paired with explanations to reinforce the importance of each action, ensuring that the student understands both the "how" and the "why" of effective fire response.

After successfully extinguishing the fire, the system provides additional preventive information, reminding the student to maintain a clear workspace, keep flammable materials away from cooking surfaces, and monitor oil temperatures carefully. This preventive guidance, integrated throughout the scenario, helps instill best practices for avoiding similar hazards in the future.

Risk and Solution Outline:

Risk: Mishandling the stove fire, which could lead to further spreading and potential injuries.

- **Consequences**: Possible injury, equipment damage, delays in food preparation, and failure to adhere to safety standards.

Solution Controls:

- Direct instruction on fire safety protocols in the VR environment, ensuring that the student learns the correct response.
- Virtual practice with essential safety tools, such as fire extinguishers, to build familiarity and confidence.
- Preventive reminders to maintain awareness of hazards and reduce future risks.

Through these guided VR scenarios, students gain hands-on experience in handling and preventing kitchen hazards, preparing them for real-world kitchens where effective, immediate responses are essential for safety and efficiency.

3.8. Conclusion

This literature review has explored the integration of risk management with virtual reality (VR) and artificial intelligence (AI), focusing on their applications and benefits in educational settings. The review provides insights into these technologies and discusses how they can enhance training in complex, high-risk fields. Effective risk prevention is essential in industries like culinary arts, not only to protect health and safety but also to prevent costly disruptions and ensure operational efficiency. Consequently, risk management education has become increasingly important for training future professionals in identifying and managing potential hazards.

Traditional training methods often fall short in preparing individuals for real-world challenges, as they lack the immersion and adaptability that modern technologies offer. Research demonstrates that VR, especially when combined with AI, has significant positive effects on learning outcomes. AI-enhanced VR environments can provide realistic, interactive simulations that adapt to user behavior, allowing trainees to experience and respond to various risks in a controlled virtual setting. Through this approach, learners become more familiar with potential dangers and develop confidence in handling unexpected situations. Thus, incorporating VR and AI into risk management education offers a promising, innovative approach to creating highly effective, engaging, and practical training experiences tailored to industry needs.

4. Software Requirements Specification

4.1. Introduction

4.1.1. Purpose

This paper provides the specifications for the project entitled VR-Kitchen: Risk Management Platform for Gastronomy Practitioners. The proposed project will introduce virtual reality simulation that will inform students of gastronomy and practicing chefs of how they can attempt to avoid certain hazards in the kitchen. Advanced 3D virtual environments, combined with AI, will simulate the scenarios of professional kitchens for better preparation of users by identification, evaluation, and mitigation of possible risks.

This SRS document explains the system requirement, constraint, and functionality, and represents a detailed framework that guides the development process. Secondly, this document outlines the interaction between the user and the simulation in the development process as the stakeholders expect. Lastly, this SRS should be guiding the creation of an effective training tool for reinforcement in ensuring safety, efficiency, and professionalism in culinary education and practice.

4.1.2. Project Scope

VR Kitchen represents a whole new frontier in culinary training and risk management education through immersive virtual reality, supported by state-of-the-art cloud-based intelligent systems. To that end, it allows for placing a user into a virtual, interactive kitchen simulation, complemented by a range of advanced AWS-hosted [39] RAG technologies using speech-to-text that can provide real-time guidance, recipe instructions, and hazard management.

Key Features :

- **Virtual Reality Cook Simulation:** An interactive 3D virtual kitchen that is fully articulated and simulates real-life situations. Users can chop, stir, plate, and use appliances to build their practical skills while modeling common hazardous events, such as liquid spills, fires, and malfunctioning equipment that allow users to learn to mitigate risks.

- **RAG System:** AWS cloud services have also been utilized by RAG for the delivery of answers to the immediate facts any user would request. This enables step-by-step recipe instructions, context-aware safety procedures, and responses tailored for user interactions in order to achieve better learning and hazard responses.

- **Speech-to-Text Functionality:** With the power of Amazon Transcribe, the system will be listening to every word he/she says for hands-free execution. Anything can be asked, from recipes to safety advice or any particular situation one finds himself/herself in. Therefore, this makes the operation smooth and fast during training sessions.

Project Objectives:

- **Improved Learning Experience:** This platform offers an interactive, hands-on environment for training; therefore, the divide between theoretical knowledge and practical implementation has been bridged.

- **Real-Time Support:** Integrating VR simulations with the RAG system will let users receive right on time and precise support concerning cooking techniques and risk management.

- **Accessibility and Flexibility:** The use of Speech-to-Text and scalability of AWS services make this platform usable for diverse audiences and flexible to adapt for a wide range of training needs.

Target Audiences: The target audiences are gastronomy students-students undergoing culinary education, which includes practical training in a controlled and risk-free environment.

System Roles:

- **VR User:** The person interacting with the VR kitchen and performing cooking activities while learning to identify and react to hazards in continuous improvement through real-time feedback.

- **Admin:** It provides a secured interface for the configuration of the simulation, customization of the scenario, monitoring of the participants' progress, and management of the AWS RAG system.

The VR-Kitchen Platform was developed to meet the latest needs of gastronomic training through state-of-the-art VR simulations combined with cloud-based support; this way, gastronomic practitioners will be assured to acquire those critical competencies enabling them to perform safely and efficiently in a professional kitchen.

4.1.3. Glossary

Term	Definition
Participant	The user interacts with the VR simulation environment to perform tasks, learn cooking techniques, and practice risk management strategies. [40]
Virtual Environment	A computer-generated 3D kitchen environment that replicates real-world professional kitchens, including tools, appliances, and scenarios.
Virtual Reality (VR)	A computer-simulated immersive environment that allows users to interact with and manipulate objects as if they were in a real-world setting.[37]
Unity	A cross-platform game engine used to develop the VR-Kitchen's interactive virtual environment, including 3D graphics and dynamic simulations.
Meta Quest 3	A VR headset used to access the VR-Kitchen platform, providing immersive experiences through high-resolution displays, motion tracking, and hand controls.
RAG (Retrieval Augmented Generation) System	An LLM-based system that retrieves and synthesizes information from a knowledge base to provide real-time, context-aware guidance on recipes, safety protocols, and hazard responses during the VR simulation.

AWS (Amazon Web Services)	The cloud platform hosting the RAG system and supporting other backend functionalities, including real-time information retrieval and data management.
Stakeholders	Individuals or entities involved in the project, including gastronomy students, culinary professionals, educational institutions, developers, and administrators.

4.1.4. Overview of the Document

This document represents the SRS for VR-Kitchen, the risk management platform for the industry of gastronomy practitioners. It first introduces the purpose of the project and its scope, defining some key terms so that some basis can be laid for the understanding of the system. Further, it goes into details on the technical and functional aspects of the project by stating its objectives and components.

Requirements specifications are given in two different ways, considering different audiences. The informal requirements set the background and give a top-level view on what the platform can offer. The technical specification targets the developers concerning the development of the system in more detail and with preciseness.

4.2. Overall Description

4.2.1. Product Perspective

The project focuses on the enhancement of safety training in kitchens using advanced technologies, such as VR and AI. This virtual kitchen helps the user interactively and more immersed in how to prepare a meal and react in case of any danger.[41] While integrating the AI, it provided real-time guidance, explanation, and advice on how to solve every problem at hand, hence turning the learning process of thSis very system highly dynamic and engaging. This can be done as an interdisciplinary project that balances technology use with practical safety training to make learning fun.

4.2.2. Development Methodology

Improvements or developments to this project will be based on the Agile methodology [38], meaning it will allow incremental improvements and support rapid prototyping. It develops the core system using Unity, hence providing an interactive virtual kitchen environment to be experienced using a Meta Quest 3 VR headset. This VR platform serves as an interactive and spatially aware environment where one can cook while learning all about safety and risk in a very controlled and safe manner.

The model enhances this, particularly by adding the element of AI through RAG-which incorporates both IR and model generation to yield personalized, context-sensitive recommendations. This methodology will, in turn, enable the extraction of relevant safety information from a large knowledge repository to provide real-time adaptive feedback on user interaction. This program leverages a cloud computing scalability framework provided by AWS, hence its AI capability in handling large data sets, which guarantees speed and reliability. For example, AWS tools such as SageMaker make it easier to train and deploy machine learning models so the system is flexible in integrating new scenarios and content.

4.2.3. User Characteristics

Major users of the system are those who seek to increase their knowledge on kitchen safety and they include:

- Amateurs:Individuals who are inexperienced in culinary practices and seek to acquire fundamental knowledge regarding kitchen safety.
- Professionals:Culinary professionals and students seeking to enhance their proficiency in hazard management.
- Educators and Trainers:Organizations or individuals providing training on safety issues to the industry.

It is envisioned that the end-users would have a very limited technical background; hence, it has been made more intuitive, user-friendly, clear in instructions, and entertaining.

4.2.4. Constraints

The project operates under the following constraints:

- Hardware Requirements: The system demands the Meta Quest 3 VR headset, supported by the appropriate computing device.
- Development Tools:Primary development will be performed in Unity, along with libraries for the integration of AI, which requires skilled people in both directions.

- Performance Optimization: Smooth performance in the entire virtual reality, along with realistic interactions and responsiveness of AI, becomes highly critical.
- User Safety:This is a potentially hazardous activity-for example, motion sickness or falling-considering the kind of physical interaction that VR implies, and it needs to be tested and calibrated as such.

4.3. Requirements Specification

4.3.1. External Interface Requirements

4.3.1.1. User Interface

- **VR Environment:** The interface will feature an immersive virtual kitchen where users interact with objects (e.g., tools, ingredients) and the virtual chef through natural VR gestures and voice commands.
- **Menu System:** A simple menu accessible within the VR environment for settings, help, and session management.
- **Input Methods:**Users actions will be taken via VR devices controllers.
- **Feedback Mechanisms**: Visual cues (e.g., highlighted objects) and audio feedback (e.g., chef's voice) will guide users during interactions.

4.3.1.2. Hardware Interface

- **VR Headsets:** The application will be developed on meta quest 3.
- **Controllers:** VR controllers for interaction, with support for haptic feedback.
- **Cloud Connectivity:** Devices must connect to the internet to communicate with the rag server.

4.3.1.3. Software Interface

- **RAG API:** The VR client communicates with the cloud-hosted RAG server via a REST or WebSocket API to process user queries and return responses.
- **Game Engine:** Built using a VR-compatible game engine (Unity) that handles rendering, physics, and interaction logic.
- **Authentication:** Integration with an authentication system to ensure users are verified before sending queries to the RAG server.

4.3.1.4. System Interface

- **Cloud Infrastructure:** The RAG server operates on a cloud platform, handling user requests and managing the knowledge base.
- **Database:** The knowledge base resides in a structured database accessible by the RAG server for query synthesis.
- **Session Management:** The system maintains active user sessions, ensuring that data like progress or preferences are available during gameplay.

4.3.2. Functional Requirements

4.3.2.1. Use Case Diagram

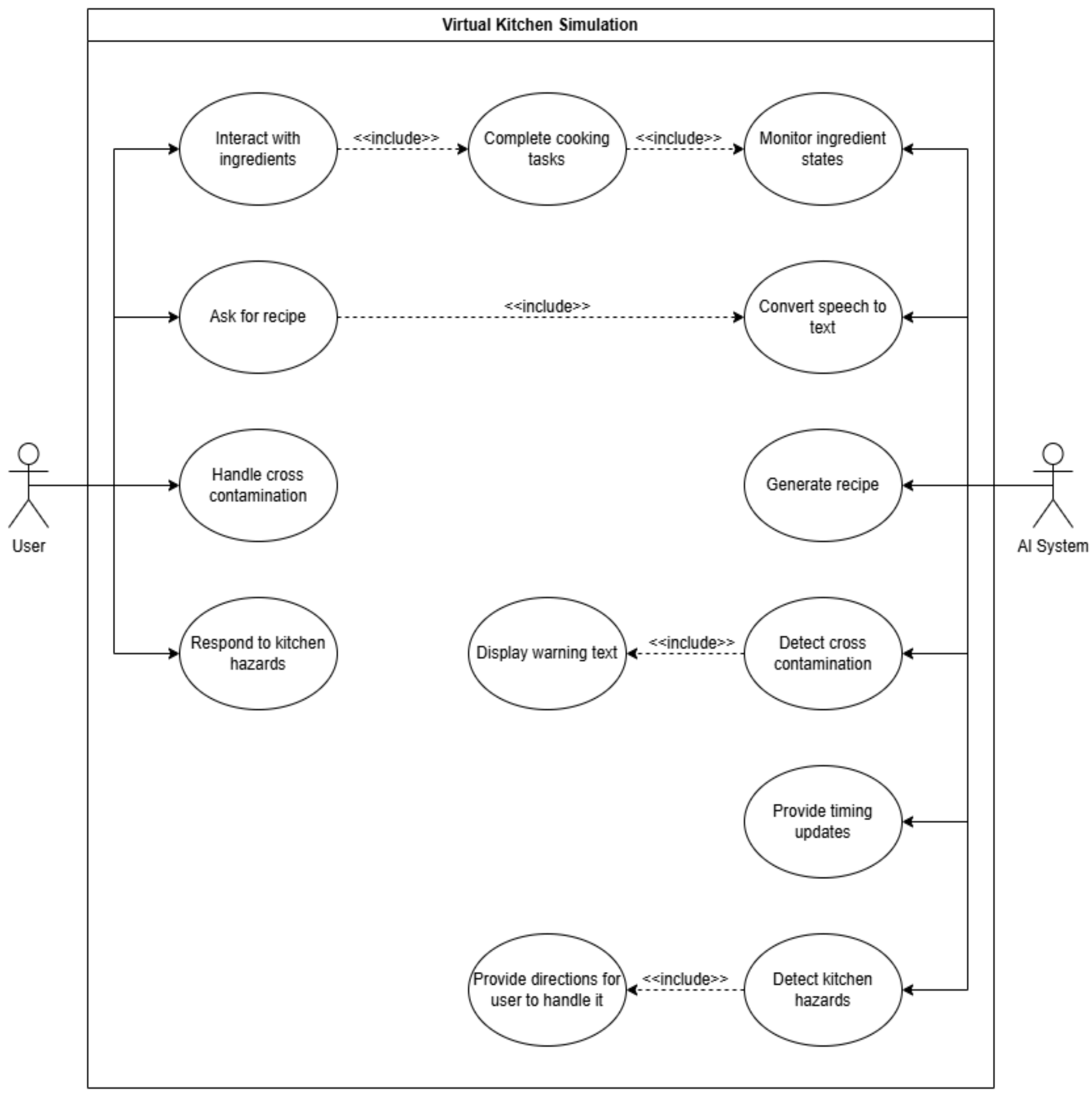

Figure 5: Use Case Diagram of VR Kitchen

4.3.2.2. Use Cases

Field	Description
Use Case Number	Use Case 1
Use Case Name	Interaction with Ingredients
Actor	User
Description	The user interacts with ingredients in the virtual kitchen by cutting, carrying, and cooking them, following real-world culinary techniques and safety protocols.
Precondition	The simulation is running, and the user has selected ingredients from the pantry.
Scenario	1. The user selects an ingredient from the pantry or refrigerator. 2. The user places the ingredient on a cutting board. 3. The user uses VR tools such as knives to chop or peel the ingredient. 4. The user carries the ingredient to a workstation or appliance. 5. The AI system offers instructions on cooking techniques, temperatures, or timings.
Postcondition	The ingredient is prepared and ready for the next cooking step.
Expectation	1. The user selects the wrong ingredient. 2. The user mishandles a tool. For example, drops a knife or the food

Field	Description
Use Case Number	Use Case 2
Use Case Name	Responding to Kitchen Hazards
Actor	AI System, User
Description	The user identifies and resolves kitchen hazards with real-time guidance and instructions provided by the AI system, ensuring effective risk management while enhancing user skills.
Precondition	The simulation is running, a kitchen hazard scenario has been triggered, and the AI system is actively monitoring the environment.
Scenario	1. The AI system detects a hazard (e.g., liquid spill, malfunctioning appliance, or fire) using virtual sensors and alerts the user with visual and audio cues. 2. The system provides step-by-step instructions to the user on how to handle the hazard. 3. The user selects the appropriate tools or takes the necessary actions to resolve the hazard (e.g., mopping a spill, turning off malfunctioning equipment, or extinguishing a fire). 4. The system evaluates the user's actions and provides feedback for improvement.
Postcondition	The hazard is resolved, and the kitchen returns to a safe state, with the user gaining knowledge and confidence in risk management.

Expectation	1. The user fails to notice or respond to the hazard in a timely manner. 2. The user selects incorrect actions despite AI instructions, resulting in escalation of the hazard.

Field	Description
Use Case Number	Use Case 3
Use Case Name	Practicing Fire Safety
Actor	AI System, User
Description	The user identifies and manages fire-related risks in the kitchen with AI-provided safety instructions.
Precondition	The simulation is running, and a fire scenario has been triggered.
Scenario	1. The AI system detects a fire and alerts the user with visual and audio signals. 2. The AI provides guidance on identifying the fire source and selecting the appropriate safety tool. 3. The user selects the correct tool like fire extinguisher and follows AI instructions to extinguish the fire. 4. The system evaluates the user's actions and provides feedback for improvement.
Postcondition	The fire is extinguished, and the kitchen is safe for continued operations.
Expectation	1. The user selects an incorrect tool or fails to extinguish the fire effectively.

Field	**Description**
Use Case Number	Use Case 4
Use Case Name	Managing Cross-Contamination Risks
Actor	AI System, User
Description	The user learns to prevent cross-contamination by handling and storing ingredients safely, guided by AI-provided best practices.
Precondition	The simulation is running, and a cross-contamination scenario is active.
Scenario	1. The AI system alerts the user to potential risks. For example, using the same knife or cutting board for raw chicken and vegetables without cleaning in between. 2. The system provides instructions on sanitizing tools and surfaces. 3. The user follows the instructions to safely handle and store ingredients. 4. The system evaluates the user's actions and offers corrective feedback if needed.
Postcondition	Ingredients are handled and stored correctly, reducing contamination risks.
Expectation	1. The user fails to follow safety guidelines. 2. Cross-contamination occurs due to improper handling.

Field	Description
Use Case Number	Use Case 5
Use Case Name	Time Management in Cooking
Actor	AI System, User
Description	The user manages time effectively while performing multiple cooking tasks, guided by the AI system.
Precondition	The simulation is running, and a multi-step recipe with time constraints has been selected.
Scenario	1. The AI system breaks down the recipe into manageable steps with time allocations. 2. The user begins tasks such as boiling water, chopping vegetables. 3. The AI system provides reminders and progress updates as tasks progress. 4. The user completes all tasks within the given time frame.
Postcondition	The recipe is completed on time, and the user learns to manage overlapping tasks.
Expectation	1. The user misses critical steps or exceeds the time limit

Field	Description
Use Case Number	Use Case 6
Use Case Name	Ingredients Changing State (Cooked, Frozen)
Actor	AI System, User
Description	The user observes and controls ingredient transformations.
Precondition	The simulation is running, and an ingredient is being processed.
Scenario	1. The AI system guides the user on placing an ingredient in an appliance. 2. The user monitors the transformation. For instance, cooking progress, freezing and so on. 3. The system alerts the user when the desired state is achieved.
Postcondition	The ingredient reaches the correct state, ready for the next step.
Expectation	1. The user overcooks or undercooks the ingredient.

Field	**Description**
Use Case Number	Use Case 7
Use Case Name	Speech-to-Text
Actor	AI System, User
Description	The user interacts with the system using voice commands, and the AI provides real-time guidance based on user queries.
Precondition	The simulation is running, and the speech-to-text system is active
Scenario	1. The user gives a voice command. For example, "What is the next step in the recipe?" 2. The AI system processes the command and provides an appropriate response. 3. The user follows the guidance provided.
Postcondition	The user receives the requested information or assistance.
Expectation	1. Voice command not recognized due to noise or unclear speech.

Field	Description
Use Case Number	Use Case 8
Use Case Name	Recipe Explanation
Actor	AI System, User
Description	The user follows a recipe with AI provided step by step guidance.
Precondition	The simulation is running, and a recipe has been selected.
Scenario	1. The user selects or inputs a recipe. 2. The AI system breaks the recipe into manageable steps. 3. The user completes each step as guided by the system. 4. The system provides feedback on the completed recipe.
Postcondition	The recipe is completed successfully.
Expectation	1. The user skips steps or provides incomplete inputs.

4.3.3. Performance Requirements

4.3.3.1. System Responsiveness

- Virtual chef responses should occur within 2 seconds on average, with a maximum delay of up to 6 seconds.
- User interaction latency (e.g., grabbing tools) must be under 200 to 400 milliseconds.
- Combined end-to-end latency should remain stable for small-scale usage.

4.3.3.2. VR Rendering

- Maintain a frame rate of at least 60 FPS(Frame Per Second) desired.
- Load assets within 5 seconds (e.g., kitchen tools, environment elements) during updates.
- Ensure basic rendering transitions for user-initiated actions, such as ingredient selection.

4.3.3.3. Scalability and Network

- Support up to 10 concurrent users scalable up to 25.
- Operates with 10 Mbps and tolerates packet loss rate %1 on average, maximum %3.

4.3.3.4. Reliability and Security

- Guarantee 90% uptime with failover within 1 minute.
- Users must authenticate through the vr kitchen app to send RAG queries; external requests are rejected.
- User authentication should complete within 10 seconds.

4.3.4. Software System Attributes

4.3.4.1. Reliability

- The VR-Kitchen system should not hang or crash at any moment during training.
- The platform should manage small-scale failures, like connectivity loss, without having huge data loss.
- Both speech-to-text and RAG functionalities should have a minimum accuracy of 95% for real-time response.
- User interactions and progress need to be tracked and stored securely.

- The performance of the VR environment shall not degrade under dynamic scenarios.

4.3.4.2. Availability

- The system should be accessible at all times, not to delay the start of a training session.
- The cloud-based RAG system must be up 24/7, guiding and responding to the emergence of any hazards in the virtual session.
- Scheduled downtime, for system updates or maintenance, must be an opportunity to be timely communicated to users, minimizing disruptions in service.
- It should fit perfectly on supported devices-such as Meta Quest 3-and always be connected to the RAG system: at least stably, with fallbacks if the cloud services are disrupted.

4.3.4.3. Maintainability

- The system should be modular, allowing easy updates and bug fixes.
- The RAG knowledge base and VR scenarios should be updatable without significant downtime.
- Clear and up-to-date documentation should be available for troubleshooting and development.

4.3.4.4. Portability

- The VR-Kitchen platform is to be executed on different VR headsets with minor adaptations, such as the Meta Quest 3 and others.
- The application should work in full within the limits of devices and operating systems supported by Unity.
- The RAG system on the cloud must be web-accessible from any device, ensuring cross-platform functionality.

4.3.4.5. Scalability

- The concept of the VR-Kitchen shouldn't break down when continuously adding users but instead allow for multiple parallel sessions.
- The system should allow for the easy addition of new training modules, hazard scenarios, or recipe updates as the platform grows.
- The cloud-based RAG system must allow for scaling, with more data, queries, and users without impacting response times and overall availability.

4.3.4.6. Usability

- The VR-Kitchen should have an easy-to-use interface with which the users can move and interact easily inside the virtual kitchen environment.
- Training sessions should be user-friendly, with clear explanations and easy access to guidance through the RAG system.
- The speech-to-text functionality should be responsive and accurate, allowing users to communicate naturally with the system.
- The simulation platform that should be engaging, interactive, easily accessible, and enjoyable to learn through by any person at any level of skill.

4.3.5. Safety Requirements

Considering the engaging characteristics of this virtual reality, users' safety while interacting in the virtual kitchen must be one of the top priorities.

- Clear Space of Play: The user of the equipment needs to have a free and open area to play to avoid any accidents or hurt incidents. The equipment needs to provide 2 meters x 2 meters minimum clear space.
- Boundary notifications: These would include warnings on virtual boundaries, which can notify users approaching an edge of the playing area through illuminations and pending lights amongst other sounds signifying possible collision.
- Ergonomic Guidelines: Make sure the VR headset fits and is adjusted properly to the specifications of each user and does not cause strain or discomfort. Provide guidelines related to posture to avoid physical strain during operations.
- Time Constraints and Break Notifications: Design the system notifications to remind users to take periodic breaks-say every 20 minutes-to avoid eye strain and other kinds of discomforts resulting from VR.

5. Software Design Description

5.1. Introduction

5.1.1. Purpose

The document is to provide an overview of the software architecture, components, and functionality involved in the VR safety training system. This will help the developers and testers for clarity in implementation so as not to lose the interest of the project at stake. A correlation of AI, VR, and cloud-based services has to ensure that the system remains scalable, user-friendly, and secure.

5.1.2. Scope

This is a VR Safety Training System aimed at amateur cooks, professional chefs, and culinary students who want to enhance their knowledge in kitchen safety. The software simulates real-world kitchen environments where users can interact with both virtual objects and AI assistants. Key features include:

- VR immersive environment to prepare a meal and identify hazards.
- AI-powered real-time feedback and guidance via Retrieval Augmented Generation
- Scalable cloud infrastructure to hold safety guidelines and avail AI capabilities.
- An intuitive user interface that bridges the technical proficiency gap among end users.
- The system will be deployed on the Meta Quest 3 VR headset, relying on Unity for development and AWS for backend support.

5.1.3. Definitions And Acronyms, Abbreviations

- **VR:** Virtual Reality – A simulated environment allowing immersive user interaction.
- **AI:** Artificial Intelligence – The capability of a machine to imitate intelligent human behavior.
- **RAG:** Retrieval Augmented Generation – A hybrid AI model combining information retrieval with generative AI.
- **AWS:** Amazon Web Services – A cloud platform providing scalable computing and storage solutions.
- **Unity:** A game engine used for creating 3D and VR applications.
- **Meta Quest 3:** A VR headset used to deliver the immersive experience.

5.1.4. Motivation

Safety in the kitchen is a very important yet poorly taught subject when teaching people to cook. Most kitchen accidents occur simply because such factors were either unknown, not taught, or because such factors were not recognized. Traditional ways of safety training are usually boring and less effective in learning. Using VR and AI, this project tries to change how safety in kitchens is taught—traditional paradigms shift with this system. For instance, the realistic hands-on training capability in immersive simulations, combined with personalized tutoring by AI, really enables this system. This greatly enhances safety awareness, plus the practical skills that are directly usable in real kitchen situations.

5.2. System Architecture

5.2.1. Design Approach

5.2.1.1. Class Diagram

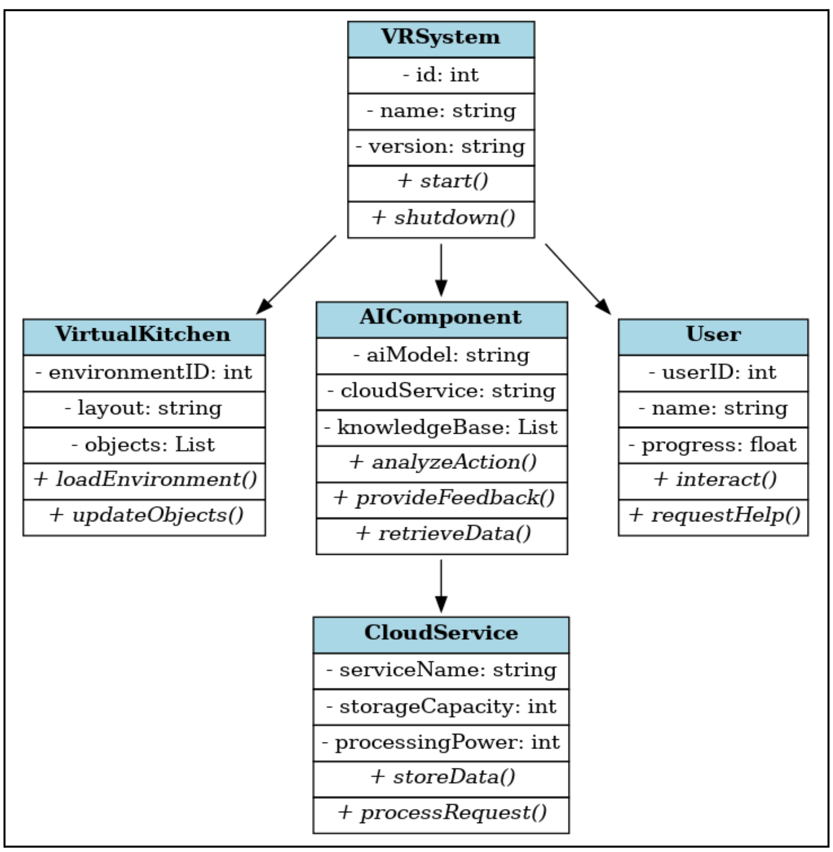

Figure 6: Class Diagram

5.2.1.2. Activity Diagram

5.2.1.2.1. Cooking Scenario Simulation

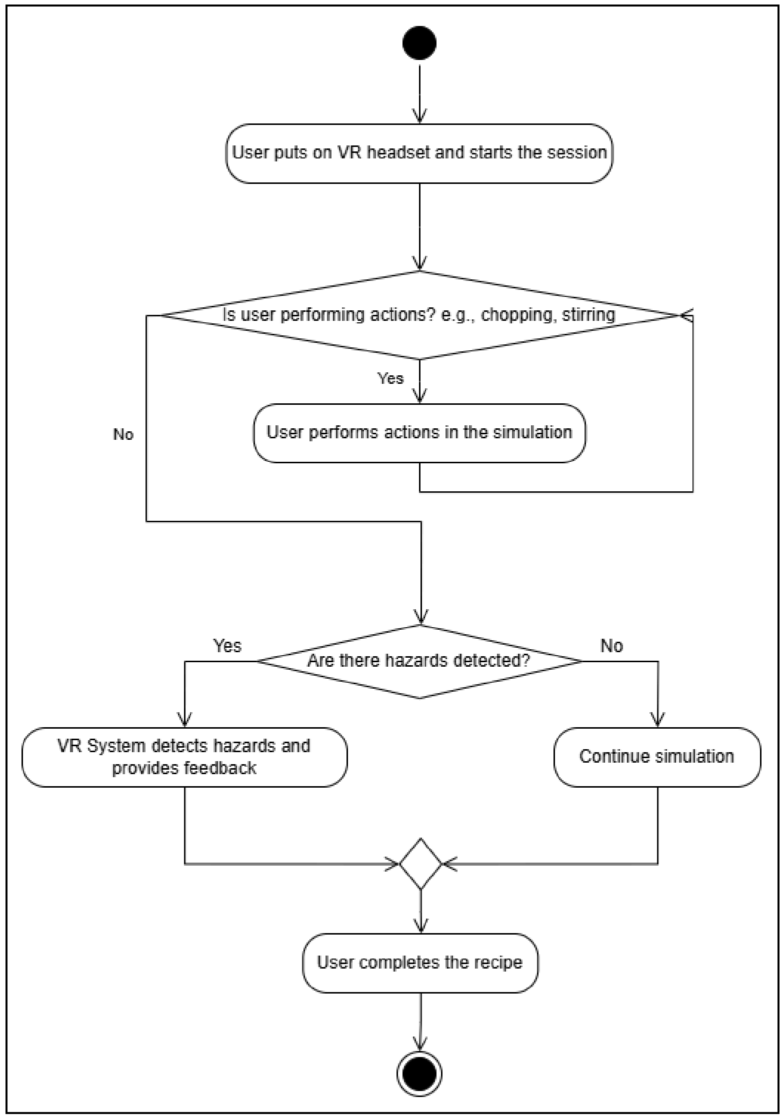

Figure 7: Cooking Scenario Simulation Activity Diagram

5.2.1.2.2. Hazard Detection and Feedback

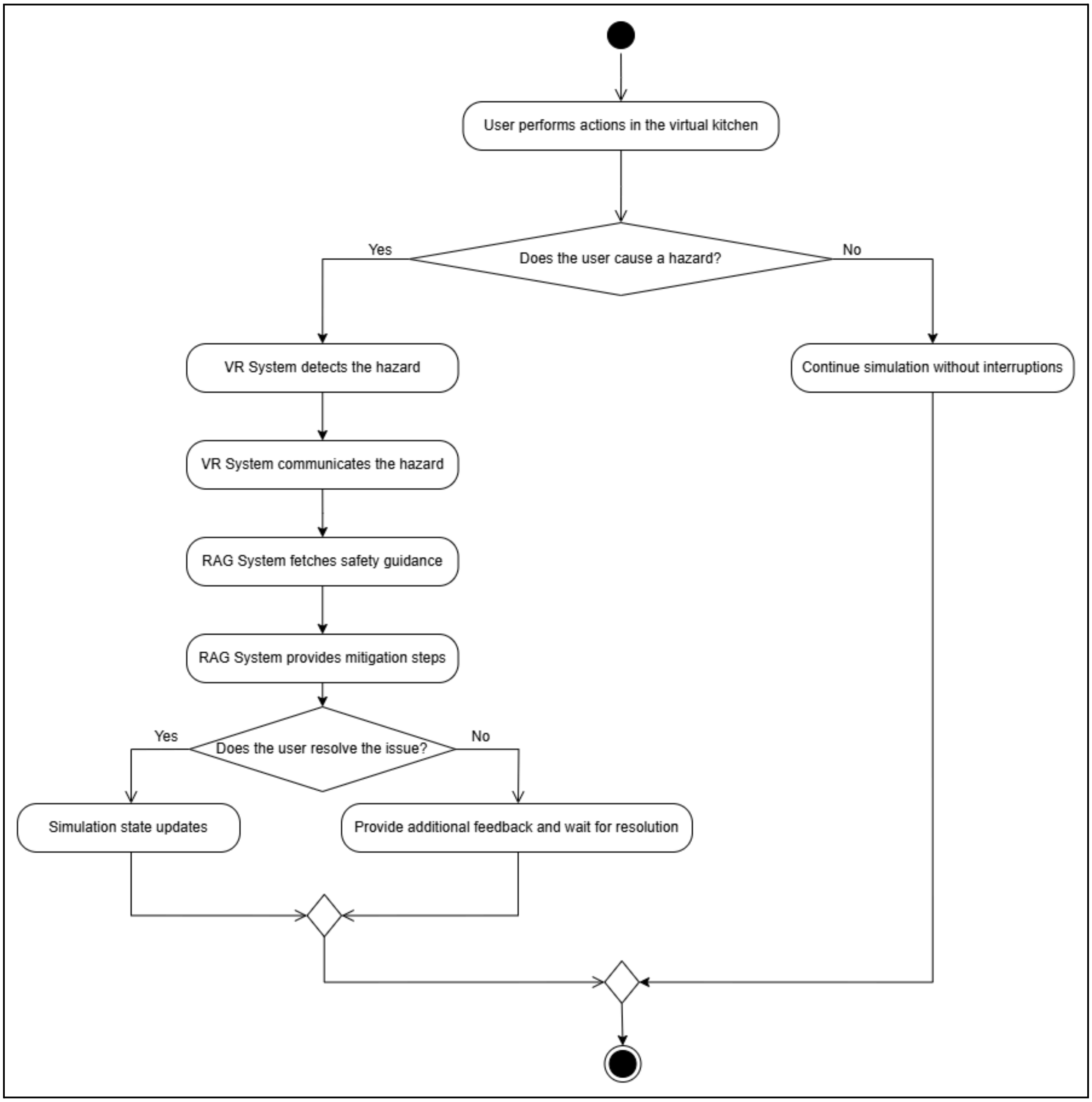

Figure 8: Hazard Detection and Feedback Activity Diagram

5.2.1.2.3. Speech-to-Text and Query Handling

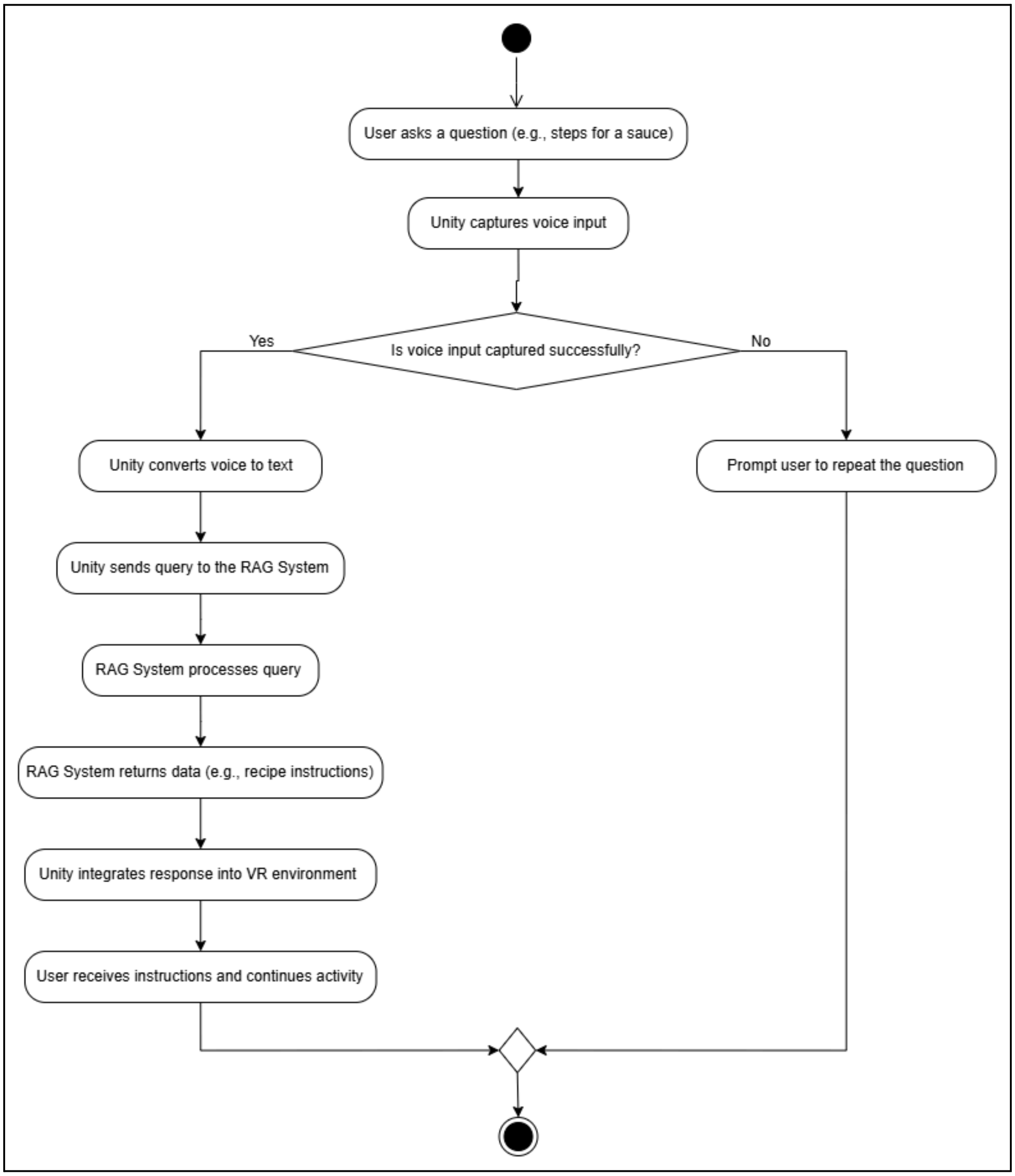

Figure 9: Speech-to-Text and Query Handling Activity Diagram

5.2.1.2.4. Progress Monitoring and Feedback

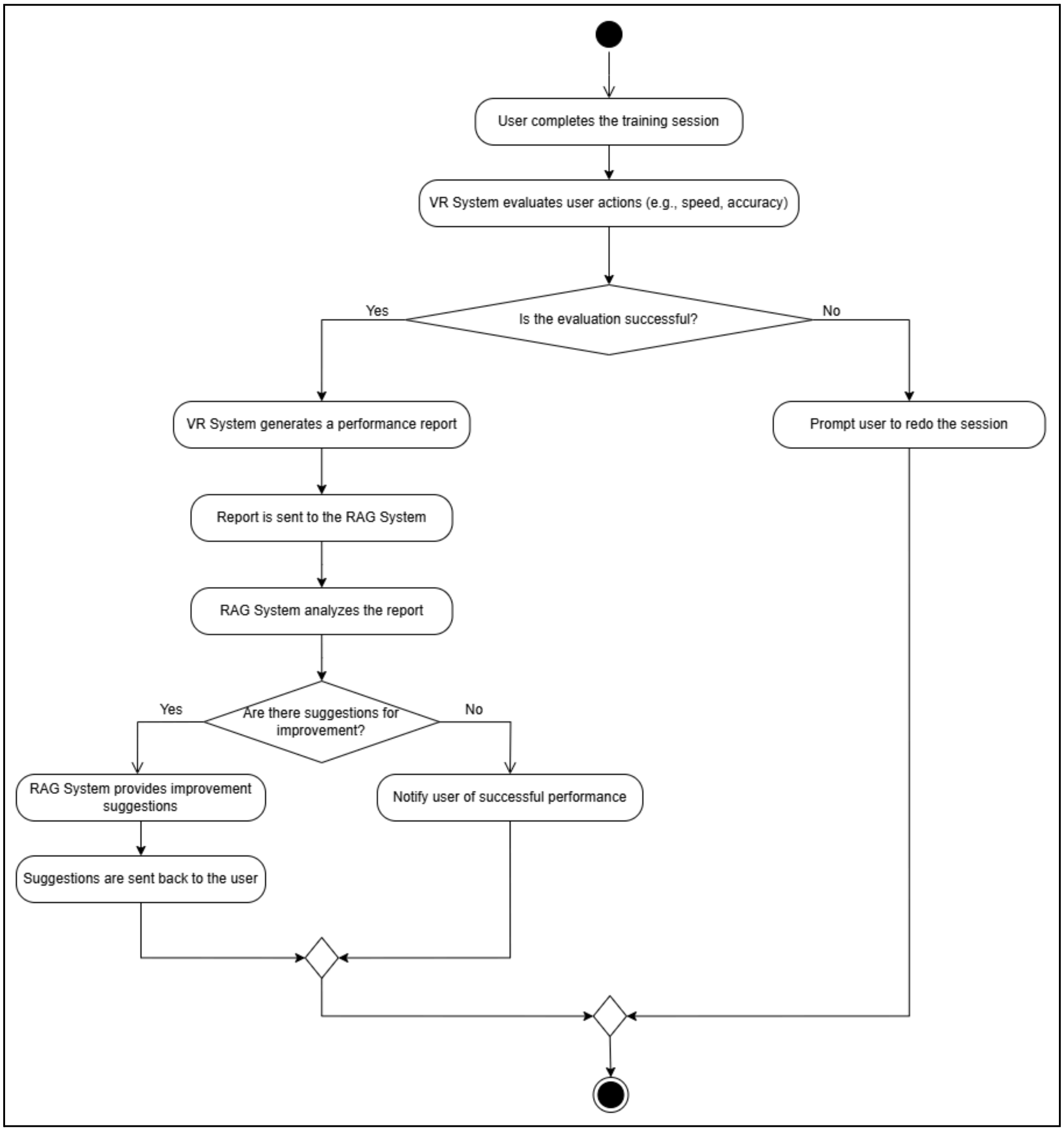

Figure 10: Progress Monitoring and Feedback Activity Diagram

5.2.1.3. Sequence Diagram

5.2.1.3.1. Cooking Scenario Simulation

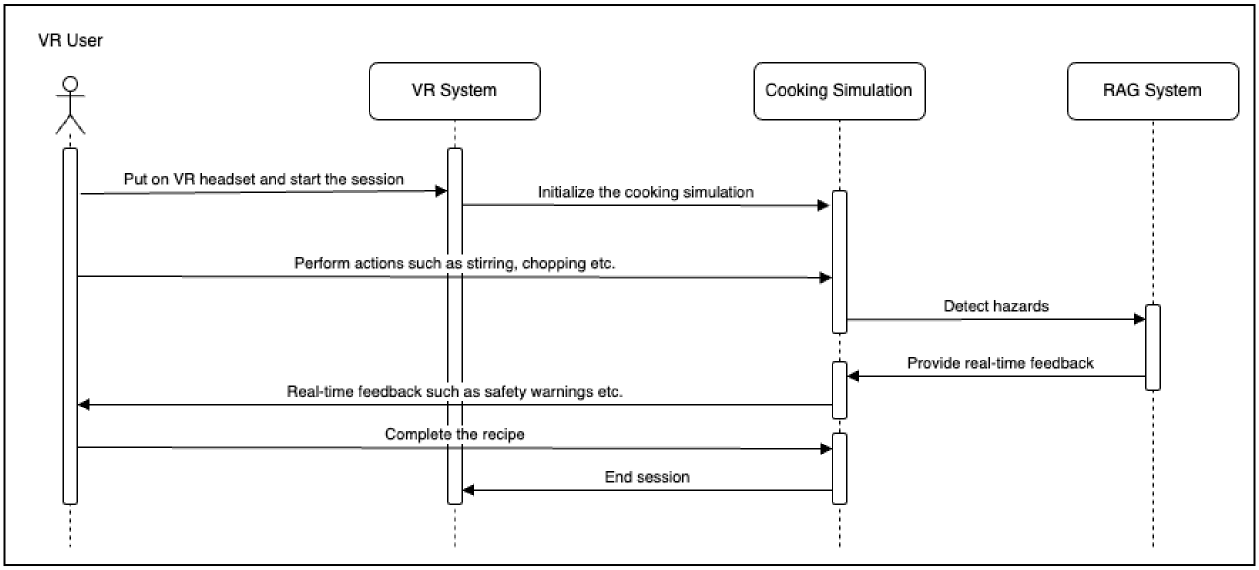

Figure 11: Cooking Scenario Simulation Sequence Diagram

5.2.1.3.2. Hazard Detection and Feedback

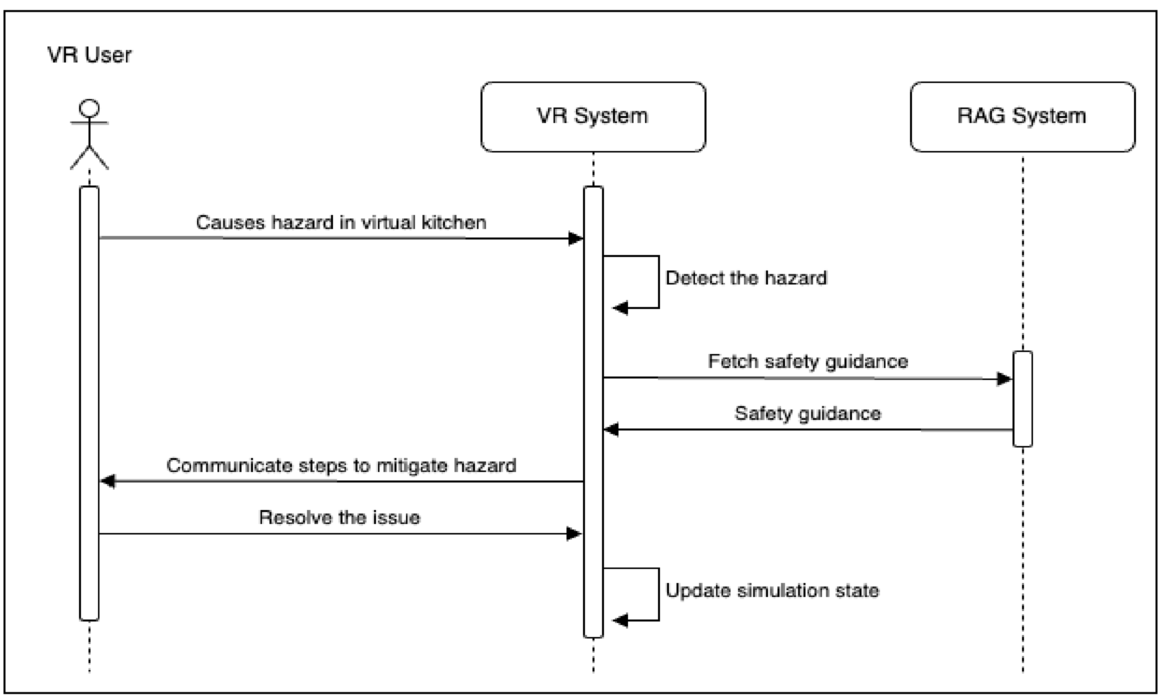

Figure 12: Hazard Detection and Feedback Sequence Diagram

5.2.1.3.3. Speech-to-Text and Query Handling

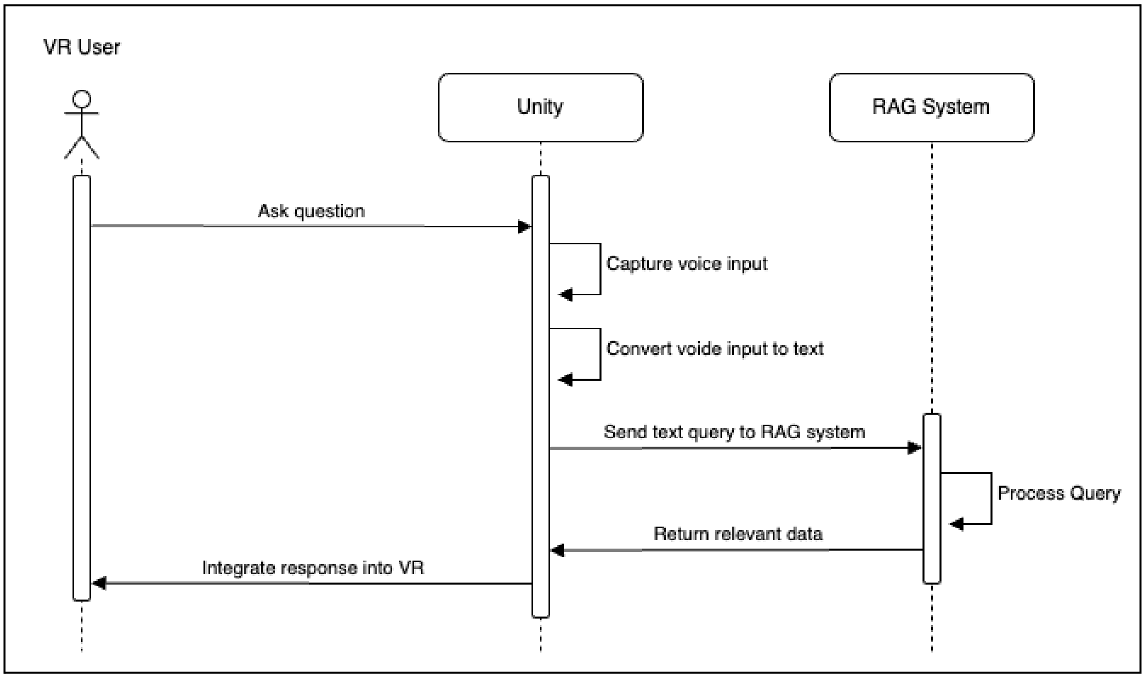

Figure 13: Speech-to-Text and Query Handling Sequence Diagram

5.2.1.3.4. Progress Monitoring and Feedback

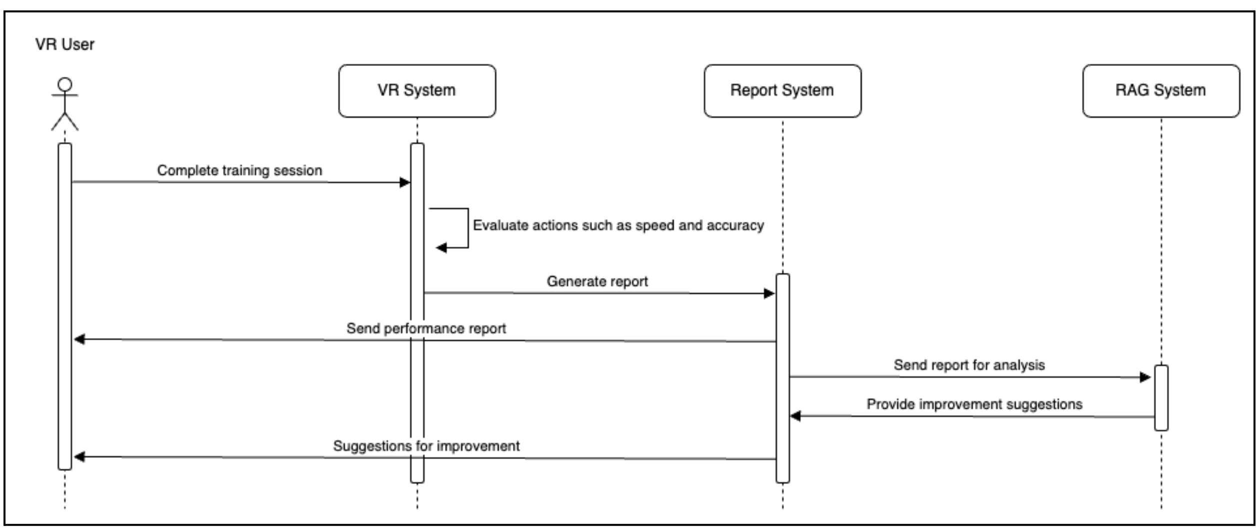

Figure 14: Progress Monitoring and Feedback Sequence Diagram

5.2.1.4. Data Flow Diagram

5.2.1.4.1. Context Diagram

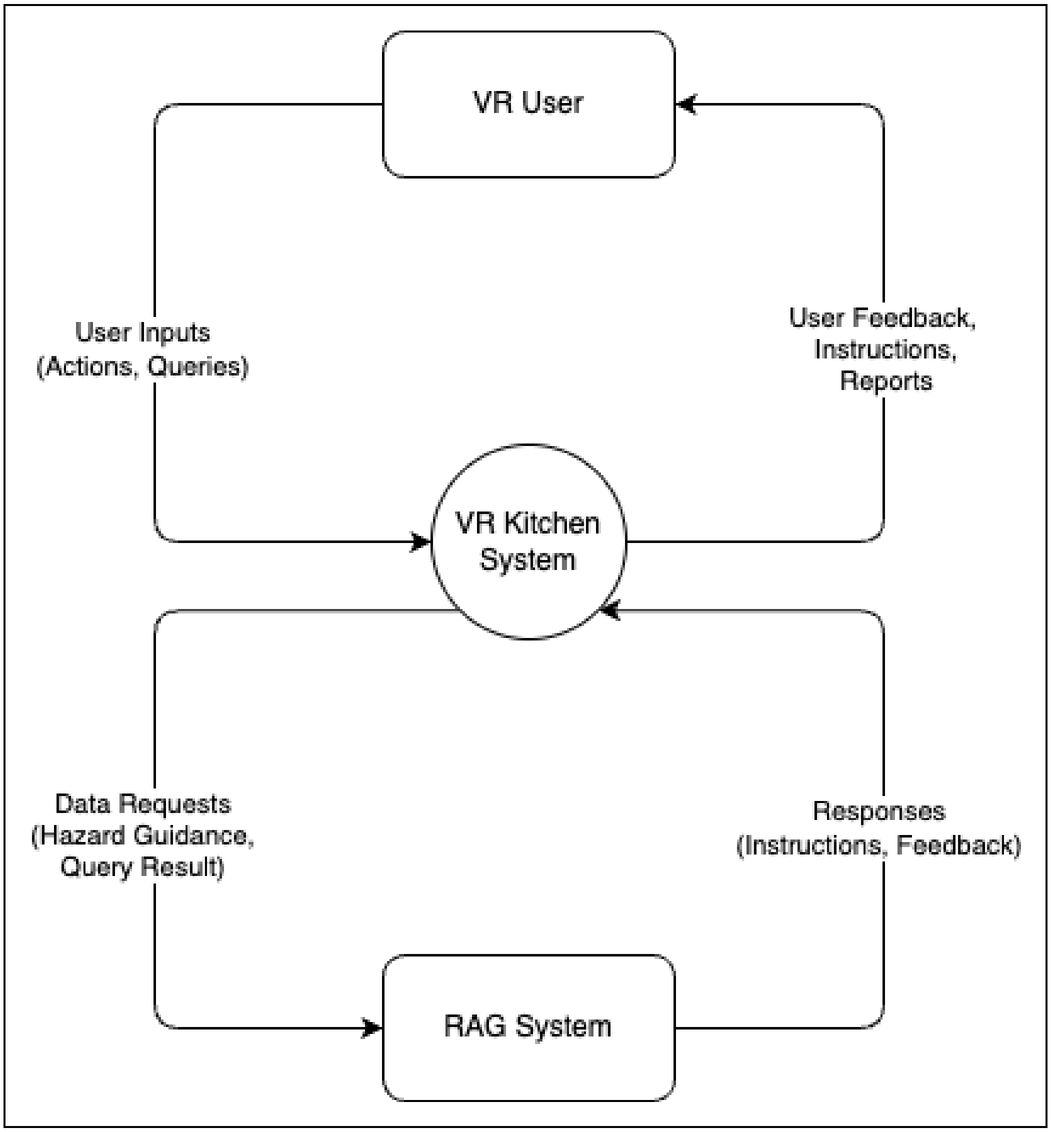

Figure 15: Context Diagram

5.2.1.4.2. Level 1 DFDs

5.2.1.4.2.1. Cooking Scenario Simulation

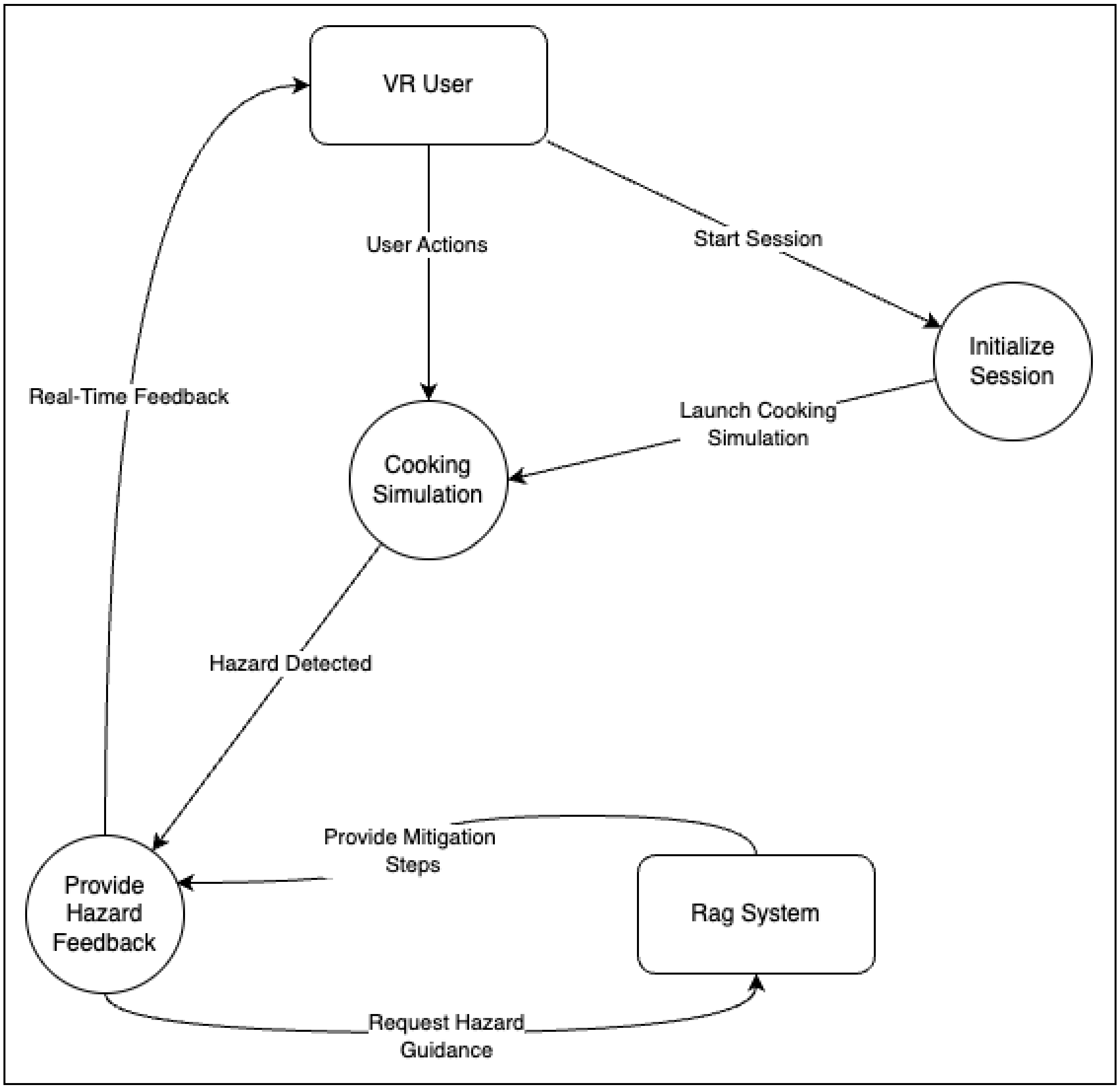

Figure 16: Cooking Scenario Simulation Level I DFD

5.2.1.4.2.2. Hazard Detection and Feedback

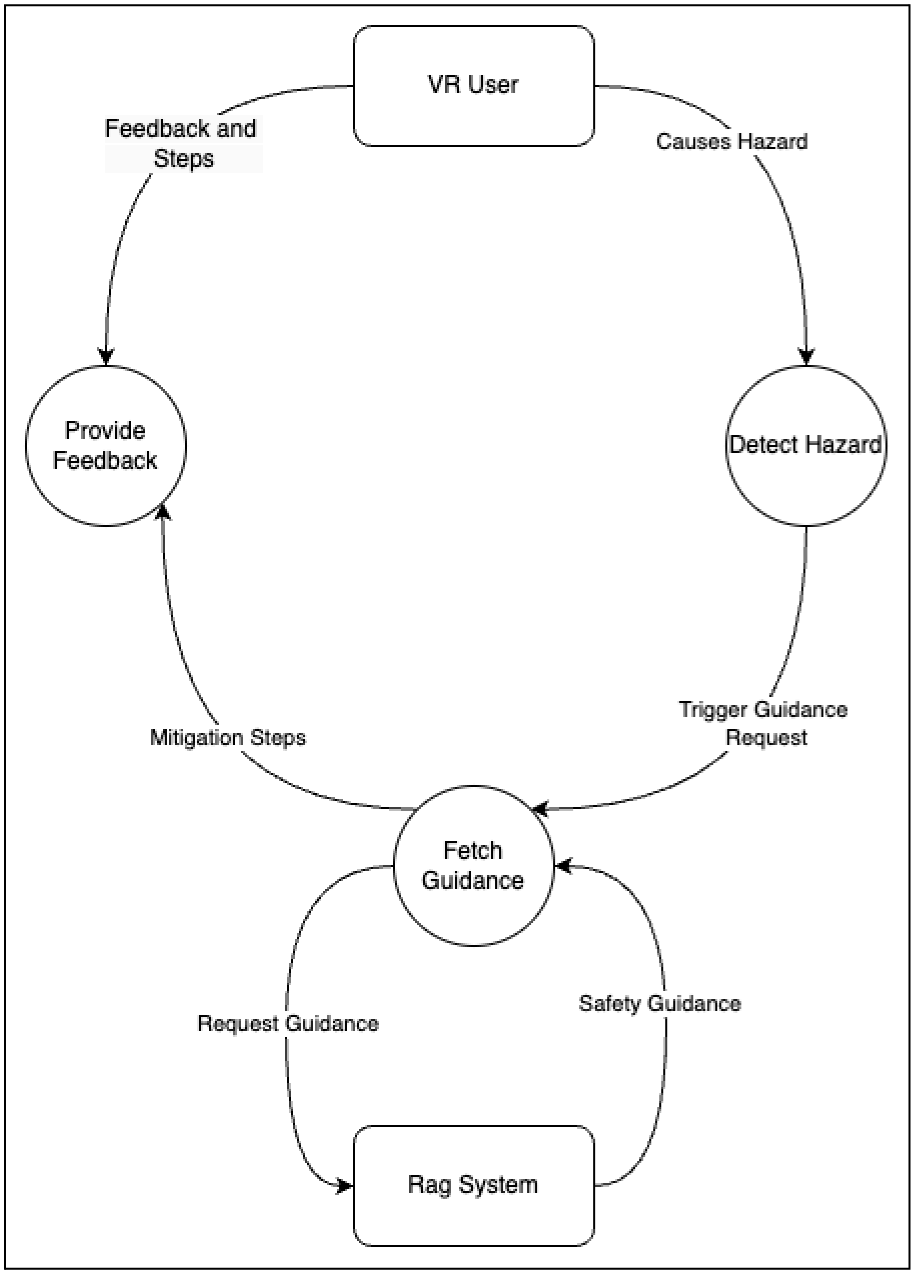

Figure 17: Hazard Detection and Feedback Level I DFD

5.2.1.4.2.3. Speech-to-Text and Query Handling

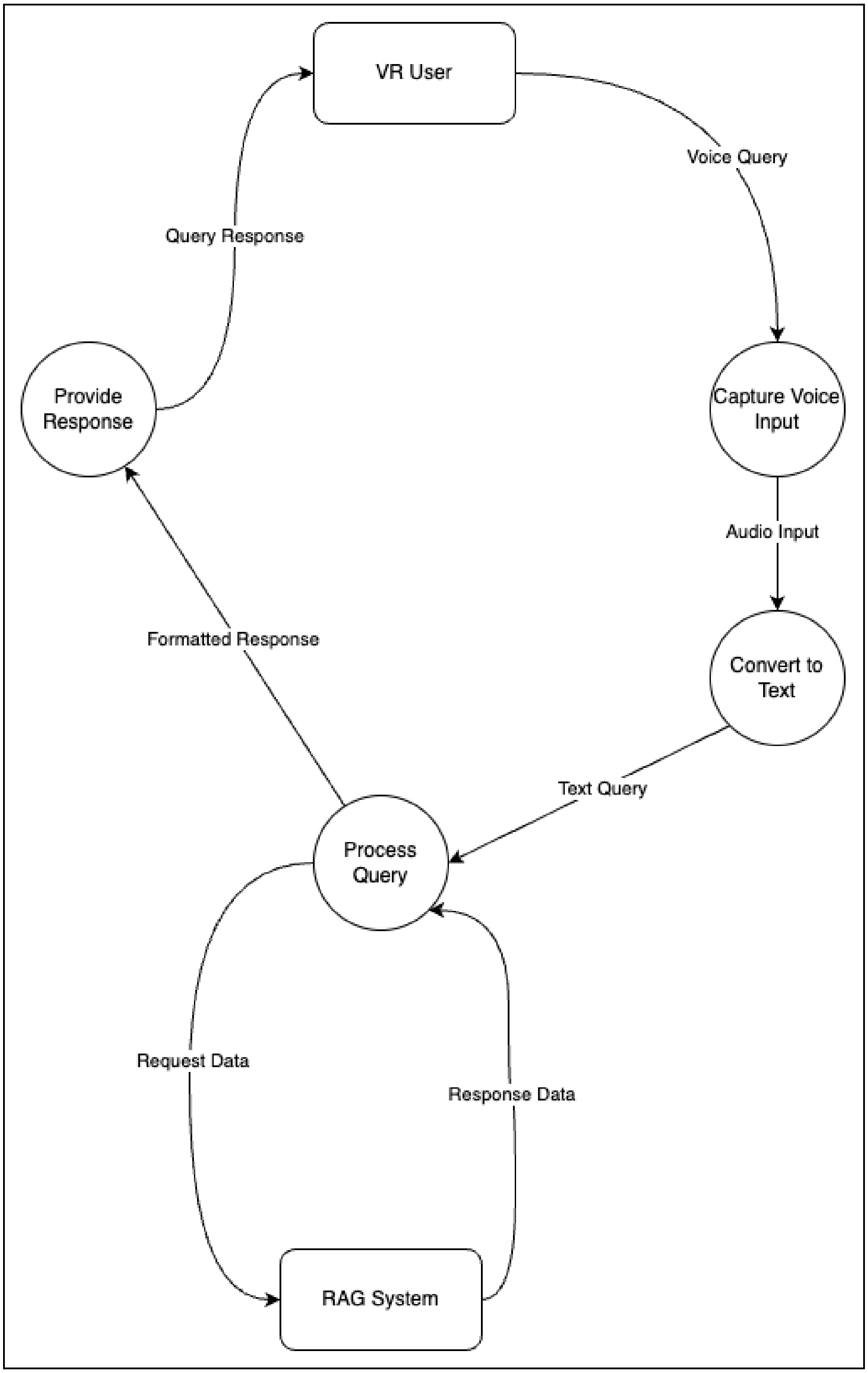

Figure 18: Speech-to-Text and Query Handling Level I DFD

5.2.1.4.2.4. Progress Monitoring and Feedback

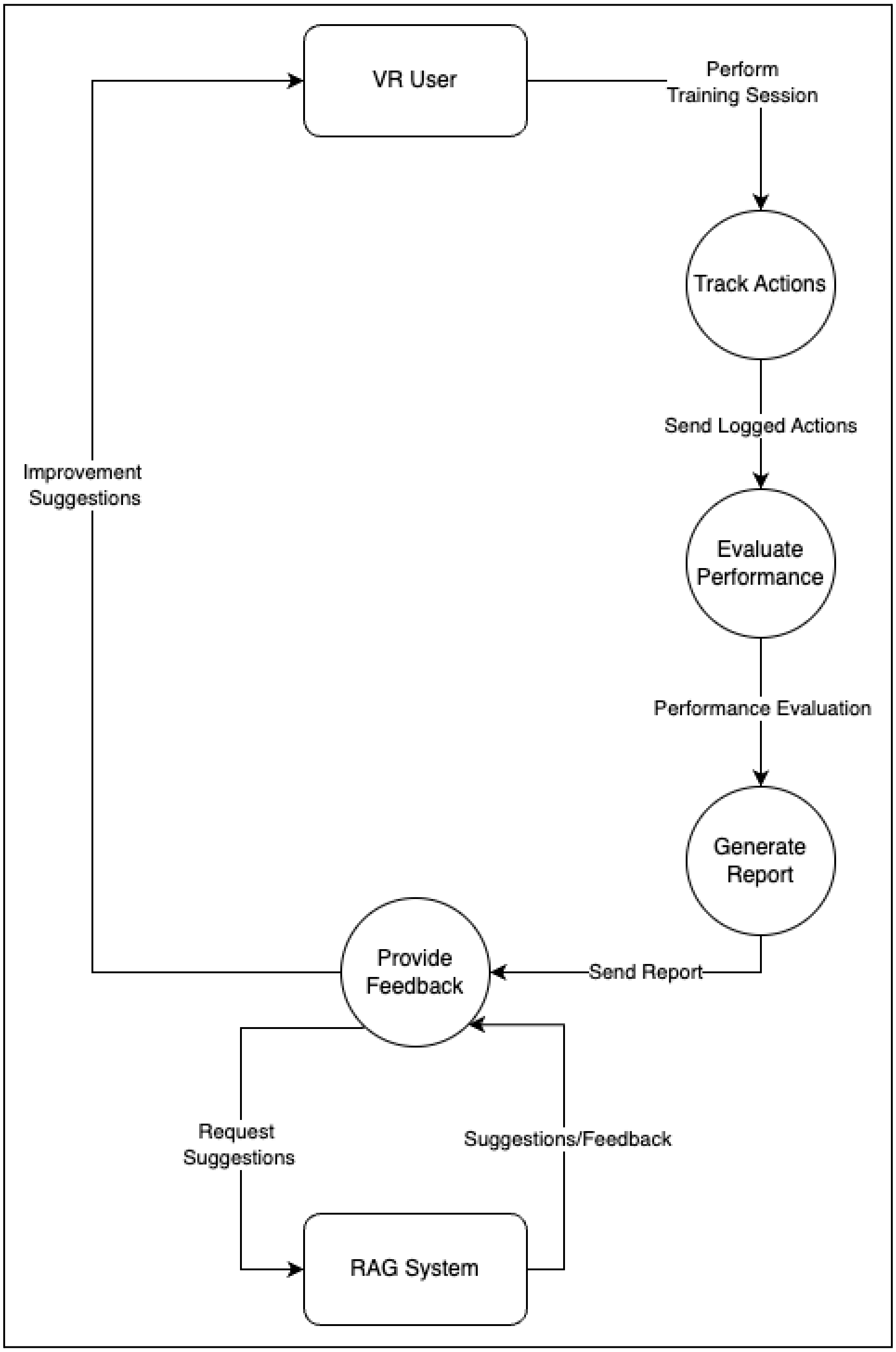

Figure 19: Progress Monitoring and Feedback Level I DFD

5.2.2. Decomposition Description

5.2.2.1. Main Modules and Subsystems

Virtual Kitchen Environment Module

- Controls the presentation layer, providing real 3D of a kitchen in which users can manipulate utilities, appliances, and ingredients.
- Becomes the physical space for the making of recipes and risk scenarios.

Risk Simulation Module

- Constructs at runtime and controls risk scenarios such as fire or injury based on user actions or pre-set triggers.
- Guarantees realism and variability of the occurrence of risk events within the skills test of problem solving.

Speech-to-Text RAG System Module

- Processes user speech inputs; when necessary, provides context-sensitive guidance during risk scenarios.
- Looks for relevant safety instructions in the knowledge base and provides clear, actionable feedback.

User Interaction Module

- Processes user inputs by VR controllers or hand-tracking devices.
- Provides an easy and natural user experience: reacting through vision and hearing to user gestures.

Performance Monitoring and Evaluation Module

- Logs users' activities, evaluates their response to risk scenarios, and monitors general progress.
- Provides feedback to users to improve their understanding and practice of the Safety Protocol.

System Management Module

- Deals with back-end operations such as data storage, configuration management, and error handling.
- Maintains the stability and scalability of the system.

5.2.2.2. Component and Module Relationships

- The Virtual Kitchen Environment Module will interact with the Risk Simulation Module to introduce hazards during the cooking process.
- Risk Simulation Module: It would communicate with the Speech-to-Text RAG System Module for guidance when there is a risk.
- User Interaction Module: This module will allow users to interact with the software, present their choices, and feed input to the Virtual Kitchen Environment Module and the Risk Simulation Module.
- Performance Monitoring and Evaluation Module: It gathers data from all other modules to monitor user performance and build feedback.
- System Management Module: It makes sure that module-module communication is running smoothly by persisting data consistently and managing changes in system configuration.

5.2.2.3. Functions and Responsibilities

1. **Virtual Kitchen Environment Module**
    - Emulates a professionally equipped kitchen with thoroughly detailed 3D models, along with realistic physics.
    - Used as the host for both creation and risk management scenarios.

2. **Risk Simulation Module**
    - Triggers and controls dynamic scenarios of risks, including outbreak of fire or malfunctioning of equipment.
    - Observes the development of risks and the reaction of the user.

3. **Speech-to-Text RAG System Module**
    - Translates what a user says to text.
    - Fetches relevant safety instructions and context-aware guidance.
    - Guarantees that users receive timely, actionable feedback.

4. **User Interaction Module**
    - Handles user interactions either by using VR controllers or hand tracking.
    - Shows intuitive interfaces together with mechanisms to provide feedback in order to increase usability.

5. **Performance Monitoring and Evaluation Module**
    - Tracks user action while performing cooking tasks and during risk scenarios.
    - Analyze the performance of users based on their response times and adherence to safety protocols.
    - Generate feedback supporting the building of skills.

6. **System Management Module**
    - Guarantees proper storage of data, configuration settings, and error handling.
    - Supports system scalability easily with new scenario and feature integration.

5.2.2.4. System Hierarchy

1. **Virtual Kitchen Environment Module**
    - Is the very highest order, serving as the main user interface and area of interaction.

2. **Risk Simulation Module**
    - Collaborates with the Virtual Kitchen Environment to introduce hazards and observe responses.

3. **Speech-to-Text RAG System Module**
    - Operates independently but can always guide when invoked.

4. **User Interaction Module**
    - The module provides support for the different forms of input and output of the user interactively and integrates the information with other modules.

5. **Performance Monitoring and Evaluation Module**
    - Gathers and evaluates information from all the above modules to provide feedback.

6. **System Management Module**
    - Ensures that the back-end operations are performing correctly and keeps the system stable.

5.2.2.5. Dependencies and Boundaries

- Virtual Kitchen Environment Module: This module depends on the Risk Simulation Module in introducing hazards when creating a certain recipe.
- Risk Simulation Module: This module relies on the Speech-to-Text RAG System Module to provide instructions during an emergency.
- User Interaction Module: This module relies on the Virtual Kitchen Environment Module to render responses to every user action.
- Performance Monitoring and Evaluation Module: This module relies on input from all other modules to evaluate user performance.
- Each of these modules has well-bounded boundaries with specific responsibilities for modularity and ease of maintenance.

5.2.2.6. Technologies and Tools Used

1. **Virtual Kitchen Environment Module**
   - Unity-3D for simulation and interaction
2. **Risk Simulation Module**
   - C# scripts and event-driven logic and Unity physics engine
3. **Speech-to-Text RAG System Module**
   - Speech recognition API and Retrieval-Augmented Generation for Natural Language Processing and Guidance
4. **User Interaction Module**
   - Uses input through VR-specific SDKs such as Meta XR Interaction.
5. **Performance Monitoring and Evaluation Module**
   - Utilizes the Data Analytics Frameworks logging and evaluation of user actions.
6. **System Management Module**
   - Cloud Storage Solutions ensure scalability, and hence management of data is effortless.

5.2.3. Design Rationale

The overall architectural approach in designing this VR kitchen training environment has been driven by the need for an immersive, interactive, and effective learning environment for gastronomy students to master the skills of addressing kitchen risks. The following provides the design rationale for the architecture and functionalities of the system.

1. **Realistic and Contextual Simulation**

   The system is designed to simulate the complexity and dynamism of a professional kitchen. It includes high-precision 3D models of instruments, apparatus, and foodstuffs and physics-based interactions, emulating the real world. With such a highly realistic and contextual experience, students can learn by practicing in a virtual environment that challenges them with situations similar to real-world kitchen work. Due to this realistic value, trainees should face fewer problems in the transition between training in virtual reality and real life.

2. **Risk-Centered Educational Approach**

   One of the main focuses of the project is to train students on how to identify, evaluate, and handle risks which may occur in a kitchen. The addition of risk scenarios-fire, injury, and equipment failures-trains the students to act swiftly yet safely. These are dynamically integrated into the process of recipe making, and a variety of routine tasks can be interrupted by some unexpected situations to test the knowledge and decision-making processes of the student.

3. **The Use of the RAG Speech-to-Text**

   The intelligent functionality within the project is facilitated at its core by the RAG system and comes with speech-to-text functionality. The possibility of the user to interact with the content and ask for advice-such as what to do in case of a fire-is reacted to through speech-to-text functionality. This gives advice based on context through a set of step-by-step instructions. In this way, students get clear, actionable advice just when they need it the most. They get reinforcement in their theoretical and practical knowledge of safety procedures at work.

4. **Immersion through Gamification**

   To keep the user engaged, the project incorporates gamified elements, taking inspiration from popular titles such as Cooking Simulator VR. It gets the students to perform specific tasks, including the preparation of recipes, the use of various kitchen tools, and time management, while exposing them to possible hazards. This mixture of game and training will keep the session enjoyable and interactive, and will help the user stay focused and motivated during the session.

5. **Accessibility and Intuitive User Interaction**

   Speech-to-text and voice-based interaction have been used deliberately to make the interaction simple. In the heat of the moment-a fire or an injury, for example-the student will be able to ask questions naturally, instead of finding their way through complex menus or remembering keybindings. This ensures that the system is accessible to a wide category of users, irrespective of previous technical experience, with minimal distraction in critical moments.

6. **Support for Educational Objectives**

   The project fits very well into the purposes of gastronomy education, as it would provide a scalable, flexible, and cost-effective way to train. Due to the fact that the system virtualizes risks, all the dangers and logistical problems of real training are avoided. In such a way, the student can repeat and experiment with just the process of building confidence and competence.

7. **Inculcation of Risk Awareness and Critical Thinking**

   The integration of unplanned risk situations nurtures the proactive attitude of the student. The critical thinking and problem-solving skills in real kitchens are acquired by going through and solving the hazard in the virtual kitchen. The realistic learning installs not just knowledge of safety protocols but also engages in the practical implementation in real situations.

8. **Scalability and Future Proofing**

   Applying modular design principles, easy expansion to more risk scenarios, tools, or recipes is possible later on. The scalability developed for this makes the system extendable in respect to the evolution of gastronomy education needs and creates opportunities for module integrations or integrations of other training technologies.

It combines realism, interactivity, and finally, access to produce an environment supportive of the overall objective of the project: to prepare gastronomy students to deal with kitchen risks confidently and competently. This design rationale provides evidence of dedication to creating a useful and influential training tool for culinary education.

5.3. Data Design

This section describes the data design of the VR-Kitchen platform by describing both the current file-based system and the vector database approach for data management and retrieval. Although the project does not use any relational database, this section also describes a hypothetical design that could be followed for future scaling.

5.3.1. Entity-Relationship Diagram (ERD)

The current system processes data stored as PDF documents in a file directory and generates chunked text representations for retrieval. In the future, these data entities can be mapped into a relational database structure. The proposed ERD includes the following entities:

1. **Document:** Represents the uploaded PDF files containing training or reference materials.

   - **Attributes:**
     - **DocumentID:** A unique identifier for each document (e.g., a UUID).
     - **SourcePath:** The file path where the document is stored in the system.
     - **UploadDate:** The date and time when the document was added to the system.
     - **Title:** Optional descriptive title of the document for better organization.

2. **Chunk:** Represents sections of text extracted from the documents.

    - **Attributes:**
        - **ChunkID:** A unique identifier for each text chunk.
        - **PageNumber:** The page number from which the chunk was extracted.
        - **Content:** The text content of the chunk.
        - **EmbeddingVector:** The vector representation of the text used for similarity search.
        - **Metadata:** Key-value pairs containing additional details, such as the source document's name or category.

    - **Relationships:**
        - A **Document** contains multiple Chunks.

3. **Query:** Tracks user interactions with the system by storing user questions and the system's responses.

    - **Attributes:**
        - **QueryID:** A unique identifier for each query.
        - **QueryText:** The text of the user's query.
        - **ResponseText:** The system's generated answer to the query.
        - **Timestamp:** The date and time when the query was executed.
        - **UserFeedback:** Optional feedback provided by the user regarding the query response.

    - **Relationships:**
        - A **Query** retrieves data from one or more **Chunks**.

4. **User Interaction (Optional)**

    - **Attributes:**
        - **UserID:** The unique identifier for the user.
        - **QueryID:** The associated query's identifier.
        - **Action:** The action performed by the user (e.g., submitting a query, skipping, providing feedback).

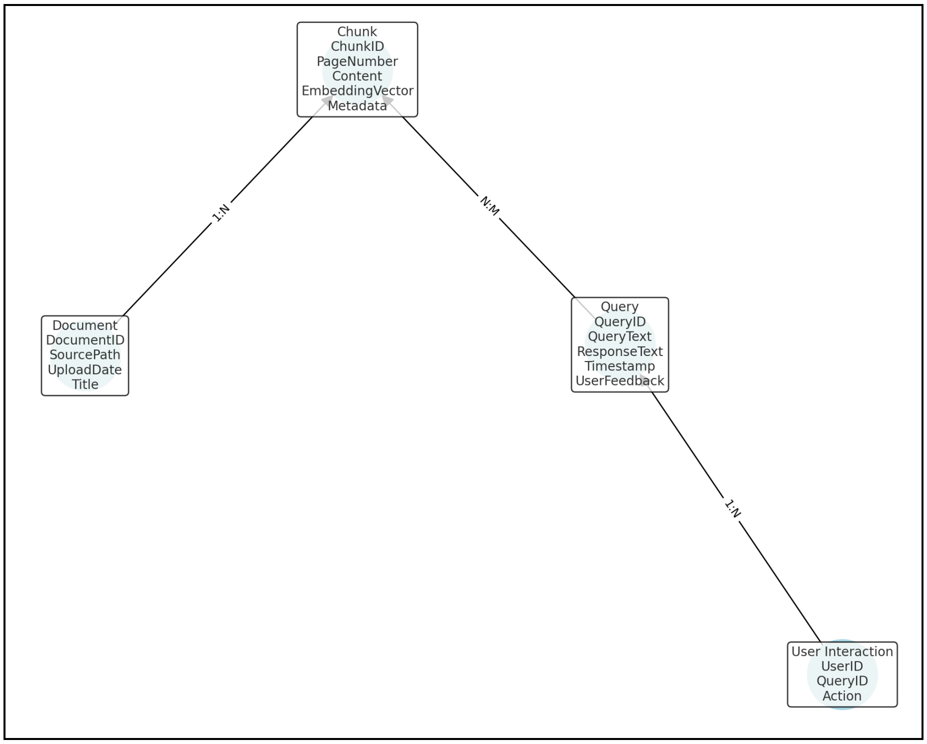

Figure 20: Entity-Relationship Diagram

5.3.2. Data Storage Design

Currently, the VR-Kitchen system uses file-based storage along with a vector database for faster execution of fetch and process queries over data. Structured and used in the following manner:

1. **File Based Storage:**

    - Purpose: The storage folder /src/data/source/ contains PDFs related to training scenarios, recipes, safety guidelines, and other instructional materials.
    - Data Organization: Files are organized by source and can include subcategories for easy retrieval and management. For example, recipes and safety guidelines.
    - Advantages: This approach makes the initial development simpler, and the dataset can then be easily updated manually.

2. **Vector Database (Chroma DB):**

    - Purpose: Chroma is used to store vector embeddings of text chunks, enabling similarity-based searches.
    - Structure: Each chunk is stored along with metadata (e.g., SourcePath, PageNumber) and its embedding vector. The embedding vector is

generated using a function (AWS Bedrock) that converts text into a numerical format for semantic comparison.

- Use Cases: When a user submits a query, the vector database is queried for similar embeddings, and the most relevant chunks are retrieved to generate responses.

5.3.3. Data Pipeline

The data pipeline consists of several stages, from document ingestion to retrieval as follows:

1. **Data Ingestion:**

   - PDF documents are ingested using the *PyPDFDirectoryLoader* utility, which scans the specified directory and extracts text from each document.
   - Metadata, such as the file name and page numbers, is collected during this stage.

2. **Data Processing:**

   - Extracted text is divided into manageable chunks using the *RecursiveCharacterTextSplitter.*
   - Parameters:
     - Chunk Size: 600 characters to balance information density and efficiency.
     - Chunk Overlap: 120 characters to maintain context continuity between adjacent chunks.
   - Metadata (e.g., source path, page number, and chunk index) is added to each chunk.

3. **Vector Storage:**

   - Each text chunk is passed through an embedding function *(get_embedding_function)*, which generates a high-dimensional vector representation.
   - These embeddings, along with metadata, are stored in the Chroma vector database.
   -

4. **Query Handling:**

   - When a user submits a query, the system performs a similarity search against the stored embeddings.

- Relevant chunks are retrieved and combined into a coherent context, which is passed to the RAG system to generate a response.

5.3.4. Future Database Plans

To ensure scalability and support additional functionalities, the following database architecture can be implemented in the future:

1. **Relational Database:**
    - **Purpose:** Store structured data, such as document metadata, query logs, and user feedback.
    - **Benefits:**
        - **i.** Provides support for advanced queries (e.g., retrieving queries by date or user feedback).
        - **ii.** Facilitates analytics on user interaction and system performance.
2. **Vector Database:**
    - **Purpose:** Continue managing embeddings for semantic searches.
    - **Benefits:**
        - i. Maintains efficient similarity-based retrieval.
        - ii. Seamlessly integrates with relational databases for combined metadata and content searches.
3. **Integration Plan:**
    - **Linking Metadata:** The relational database can store metadata that points to corresponding records in the vector database.
    - **Hybrid Queries:** Implement APIs that enable combined queries, such as fetching documents by user feedback and retrieving related content embeddings.

The VR-Kitchen system currently employs a robust file-based and vector-database approach, which is optimized for the initial phase of development. However, the system is designed with scalability in mind, allowing for seamless integration of relational databases in the future. This design ensures that the platform can efficiently handle increasing data volume and complexity as the project grows.

5.4. User Interface Design

1. Welcome Page

Figure 21: Welcome Page of the Application

Welcome page for the simulations interface where the user can change the settings about the simulation or start the unique experience.

2. **Resume Page**

Figure 22: Resume Page of the Application

The interface for the resume page where users can pause the simulation or quit the game and also change the settings like welcome page.

3. In Game Environment

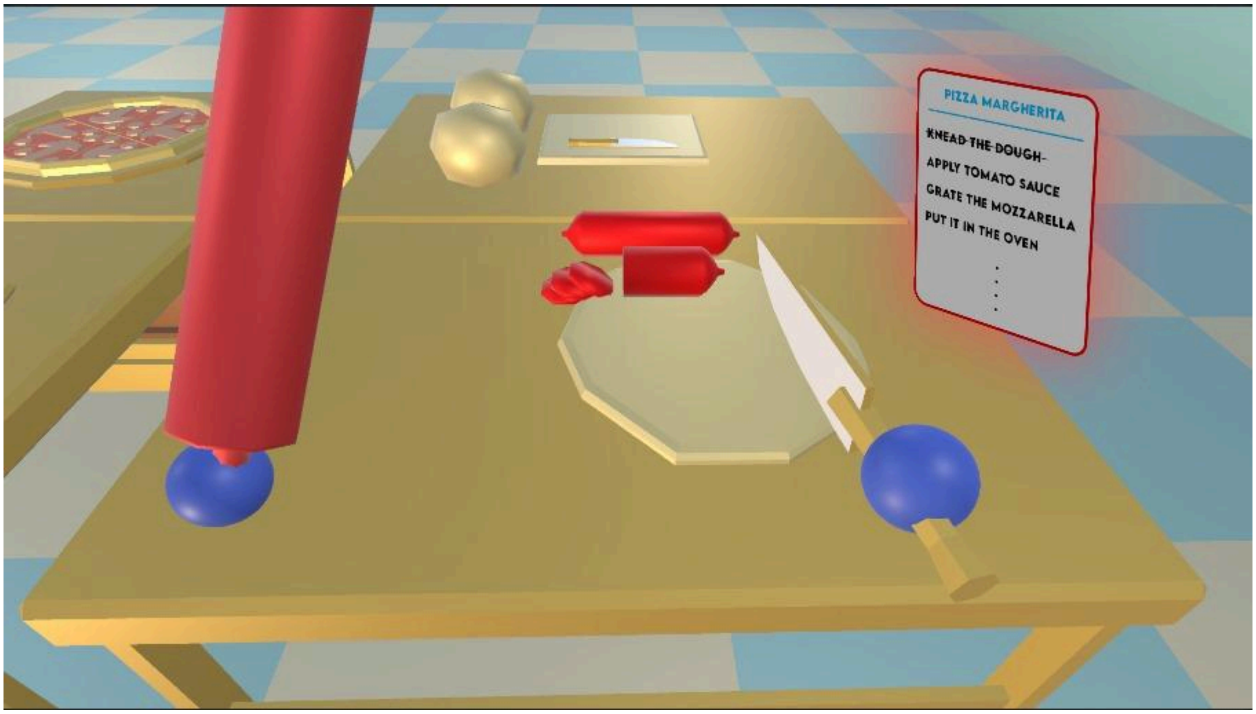

Figure 23: In Game Environment of the Application I

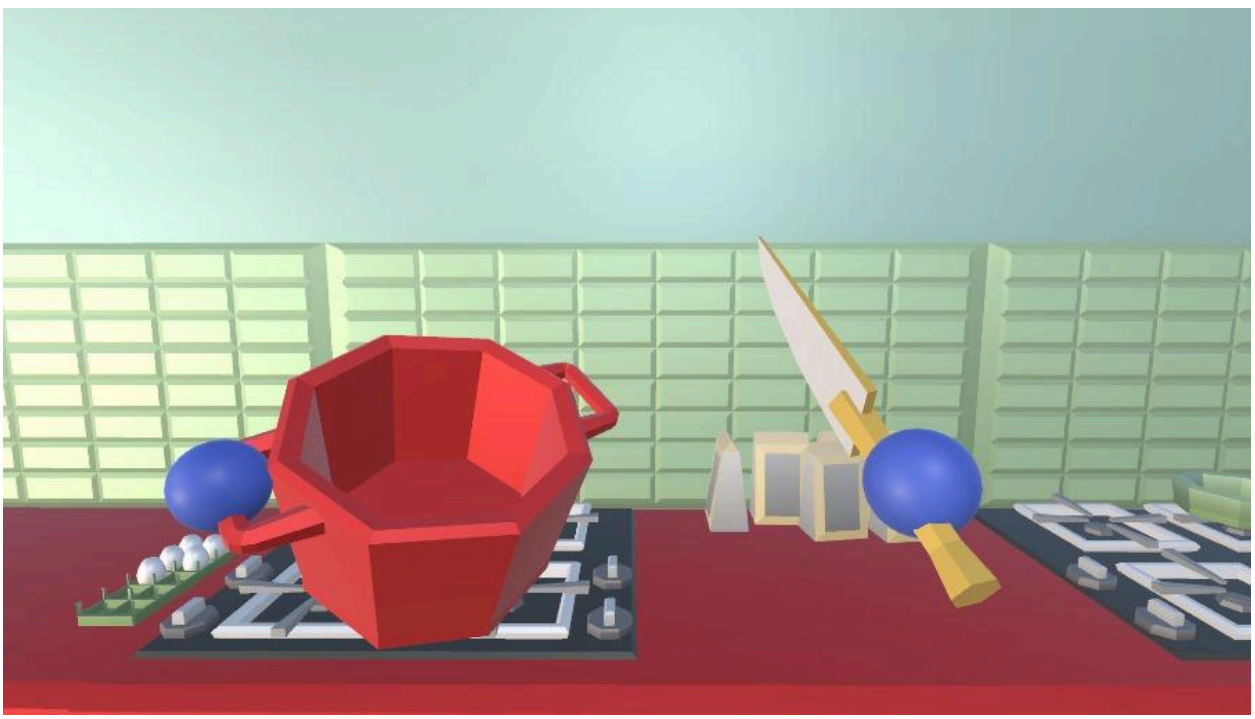

Figure 24: In Game Environment of the Application II

How basic interactions with the objects like cutting and holding look from the eyes of the user.

Figure 25: In Game Environment of the Application III

Example kitchen design where the user will experience the simulation.

6. Conclusion & Discussion

The VR-Kitchen project demonstrates proof of concept in using virtual reality and artificial intelligence to advance the training of culinary professionals on risk management. The platform enables users to practice safely in the identification of hazards and response within realistic kitchen scenarios, hence closing the gap between theory and practice. AI-driven feedback provides users with personalized guidance, helping them feel confident and competent in maintaining kitchen safety.

However, accessibility and cost may challenge the widespread adoption of the technology, especially in the case of smaller institutions. Future development should focus on reducing these barriers by way of more affordable VR solutions or possibly desktop-compatible versions. Furthermore, expanding the range of simulated scenarios to include different culinary practices could broaden the platform's appeal and inclusivity.

Overall, VR-Kitchen exemplifies how integrating advanced technologies into vocational training can transform safety education in the culinary industry and beyond.

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