Kitchen Assistant for Active Ageing at Home

Computer and Informatics Project Course

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Summary

The rise in life expectancy and decline in birth rates are contributing to the aging of populations in developed countries worldwide. Consequently, there will be a significant increase in the senior population in our society in the coming years, emphasizing the need to enhance their well-being and quality of life. Unfortunately, seniors often require more healthcare attention than the rest of the population, leading to frequent visits to the doctor or expensive medical consultations. These factors can keep elders from seeking regular medical care and receiving appropriate treatment, potentially leading to undetected health issues and more complex and costly treatments.

Leveraging recent technological innovations, particularly in smart home devices and assistive technologies, holds promise for addressing these challenges.

This project focuses on developing a proof of concept “Kitchen Assistant for Active Ageing at Home”, an assistant aimed at empowering seniors to maintain an independent and healthy lifestyle. Through the use of User Centered Design and continuous feedback from the target audience, this prototype is now able to provide step-by-step cooking guidance and pantry management features, supporting older people in their daily activities while promoting their well-being and reducing reliance on external assistance.

Acknowledgements

This project was a collaborative effort among us students, our supervisors, and the teachers on this module. Each of them played a crucial role in developing this assistant. To the teachers of this module, we want to express our gratitude for your patience, guidance, experience, and constructive criticism. Each and every one of these factors greatly contributed to the success of the project we are now delivering.

To our supervisors, who welcomed us from day one and provided structure and yet gave us the creative freedom to pursue our own ideas paving the way to the beautiful outcome that this project became, we sincerely appreciate your support.

Lastly, we would like to thank all our family members and friends who supported us throughout this journey. Your kindness and affection meant a lot to us.

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1 Introduction

In recent years, Europe has witnessed significant demographic changes, with the growth of the senior population [1]. This trend is due to an increase in average life expectancy and society's emphasis on career advancement, resulting in smaller families. As a result, this older adults increasingly require specialized care to maintain quality of life, as they face challenges associated with age-related health issues.

Currently, Portugal is among the leading European countries with a high proportion of individuals aged 65 and over [2], accounting for almost a quarter of the total population [3]. This percentage is expected to continue to rise, highlighting the urgent demand for tailored senior care solutions. This demographic shift [1] poses a significant challenge to health systems, social services, and families.

The choice of fewer children, driven by factors such as education, career aspirations, and economic stability, has allowed younger generations to adopt more independent lifestyles.

For seniors, maintaining an active and independent lifestyle is of utmost importance. They are more susceptible to various diseases and their physical and physiological abilities deteriorate slowly. Thus, it becomes important to promote activities that facilitate healthy aging. Research consistently reveals the positive effects of physical activity on reducing chronic disease risk [4], improving psychological well-being [5], and improving overall cognitive function [6].

Technology is still important in this paradigm shift. Innovations in healthcare technology, especially those focused on everyday tasks, are transforming the support and care for older adults.

Moreover, the concept of smart homes has gained significant traction in Portugal [7], potentially offering a comprehensive solution for elderly care. These technologically advanced residences are equipped with an

array of sensors, monitors, and assistive devices that enhance safety, security, and comfort for seniors. Smart homes can automate tasks such as lighting, temperature control, and even provide fall detection capabilities. This integrated approach fosters a sense of independence while simultaneously providing a safety net for unforeseen events. The adoption of assistive technology in daily life gives seniors independence and self-reliance.

These innovations not only improve their quality of life, but also reduce dependence on caregivers and reduce strain on health care systems [8]. By harnessing the power of technology, we can usher in a new era of senior care that prioritizes dignity, independence, and overall well-being, especially in Portugal where the aging population is a major concern.

1.1 Context

This project was developed at the University of Aveiro, as part of the Computer Engineering and Informatics Project course. In the scope of CASA VIVA+, a proof of concept being developed at the University of Aveiro, with companies such as OLI and the Rovisco Pais Rehabilitation Center as partners. The concept aims to understand the role of a Smart Home in the active development of an older population. Having this in mind, the idea of a kitchen assistant was born allowing older adults to maintain their independence in the day-to-day tasks related to the preparation of meals, being mindful of the pantry stock available in their homes and reminding them when products are near their expiration date.

1.2 Motivation

The motivation for this work was to take advantage of the use of technology, including smartphones, tablets, and voice assistance devices, to:

- **Help seniors be more independent** – Provide help throughout the cooking process, with step-by-step instructions on meal preparation, through voice guidance and visual display as well.
- **Combat the lack of intuitive and proactive assistance** – There are few to no equipment that is developed with the older population in mind. Equipment that tackle their needs and problems, such as forgetfulness and moving at their own pace.
- **The need for unified system** – Alerts when the commonly used products are not available in the pantry or when a product expiration date is near the end.

Having all these challenges present, the common goal seems obvious to improve the quality of life of the senior generation.

It is not hard to imagine that in the future most households will have top-tier technology. By then, people will have a better grasp of what complements their life, making the day-to-day chores a breeze. As people

grow older, physical limitations start to appear and, by that time, we hope this project will be fully operational, making these problems a thing of the past.

1.3 Goals

The goal of this project was to create a prototype of an assistant to integrate the larger project called CASA VIVA+, which aims to design, technically develop, and validate innovative solutions for monitoring of data related to the health and well-being of an individual. More specifically, CASA VIVA+ aims to develop technological solutions that facilitate the continuous monitoring of physiological parameters in a convenient and non-intrusive manner, while also detecting deviations with potential clinical importance. Therefore, the primary goals to develop the assistant were to address these crucial areas: supporting older adults living independently with meal preparation through visual cues (display) and providing unified, natural language interaction via voice. Additionally, the assistant aims to offer proactive alerts and information, such as managing stock and tracking expiration dates of pantry items, to further enhance the independence and well-being of seniors.

1.4 Document Structure

This document is structured as follows. Chapter 2 describes the *State of the Art*, including *Related Work* and *Technologies*, followed by a *Discussion* of their relevance. Chapter 3 presents the *Personas, Scenarios, and Requirements*, detailing the creation of personas, the methodology and results of the *Structured Survey*, and the identification of key scenarios and requirements. Chapter 4 provides an in-depth look at the *Kitchen Assistant*, describing the *System Architecture, Implementation* including *Tools and Technologies, Setup and Configuration*, and an examination of the *Modules and Components*, focusing on Key Algorithms and Data Structures. Chapter 5 evaluates the system with users, detailing the *Sample, Method, Results and Discussion* of the usability tests conducted. Chapter 6 presents the *Conclusions and Future Work*, summarizing the findings and proposing future directions. Chapter 7 lists the References used, and Chapter 8 includes the Appendix with supplementary materials such as the complete survey and additional data.

2 State of the Art

To better understand which methodology to use, and what tools and technologies are necessary to develop our solution, we sought to find out about existing projects, their technologies, and the development process. To do this, we used Google Scholar by searching for keywords that fit our theme. Each group member was tasked with finding two articles and after reading them, reporting the technologies and the keywords used to an Excel document. This way, we ensured there were no repeated articles, and we could gather the most data to make the most sensible choice.

There was a significant list of possibilities, but we wanted to focus on the latest technologies, with the oldest article being from the year 2014. Out of the ten selected articles, we compiled a list of potential technologies to use, which include voice assistants and smart devices, communication and network technologies, sensors, and hardware, and finally, artificial intelligence, machine learning, and robotics. *Figure 1* shows the selected technologies grouped, by their respective fields of interest, while *Table 1* includes the articles found, their year of origin, and the keywords that led to their discovery.

2.1 Related Work

To acquire all the related work, we conducted a comprehensive search on Google Scholar to gather relevant academic papers, utilizing specific keywords (*Smart + Kitchen, Virtual + Assistant + Kitchen, Smart + Kitchen + Elderly + people, Food + Product + Management, Kitchen Assistant + Voice Commands, Voice Assistant + Ageing, Kitchen + Elderly + IoT, Conversational + Assistant + Kitchen*) related to our research topic. This search allowed us to access a range of papers that are pertinent to our project.

The papers obtained through our search are presented in *Table 1.* It is important to note that we focused on selecting papers from the last 10 years to ensure the relevance and currency of the information. This approach helps mitigate the risk of relying on outdated technologies and ensures that our project is informed by the most recent advancements and insights in the field.

Name	Year	Voice assistant	Portuguese Language
An Augmented Reality Virtual Assistant to Help Mild Cognitive Impaired Users in Cooking a System Able to Recognize the User Status and Personalize the Support [9]	2018	No	
Application of Artificial Intelligence in Smart Kitchen [10]	2018	Yes	Yes
An Adaptive smart system to foster disable and elderly people in kitchen-related task [11]	2016	Yes	No
Smart kitchen cabinet for aware home [12]	2012	No	
A Futuristic kitchen assistant – Powered by AI and Robotics [13]	2014	No	
Assistant for supporting the elderly staying at home [14]	2022	Yes	Yes
Appropriation and practices of working with voice assistants in the kitchen [15]	2019	Yes	Yes
Development and comparison of customized voice-assistant systems for independent living older adults [16]	2019	Yes	Yes
Commercial ICT Smart Solutions for the elderly: State of the art and future challenges in the smart furniture sector [17]	2020	Yes	Yes
"Phantom Friend" or "Just a Box with information": Personification and Ontological Categorization of smart speaker-based voice assistant by older adults [18]	2019	Yes	Yes

Table 1 - Related Work found searching for the keywords using Google Scholar

2.2 Technologies

From the articles mentioned in ***Error! Reference source not found.***, we meticulously extracted the technologies utilized in each study. This extraction process was crucial in identifying the common technologies employed in similar research endeavors as well as any unique or innovative technologies that could potentially be incorporated into our project.
By analyzing the technologies used in the related works *(Figure 1),* we can gain valuable insights and make informed decisions regarding the technological components of our solution.

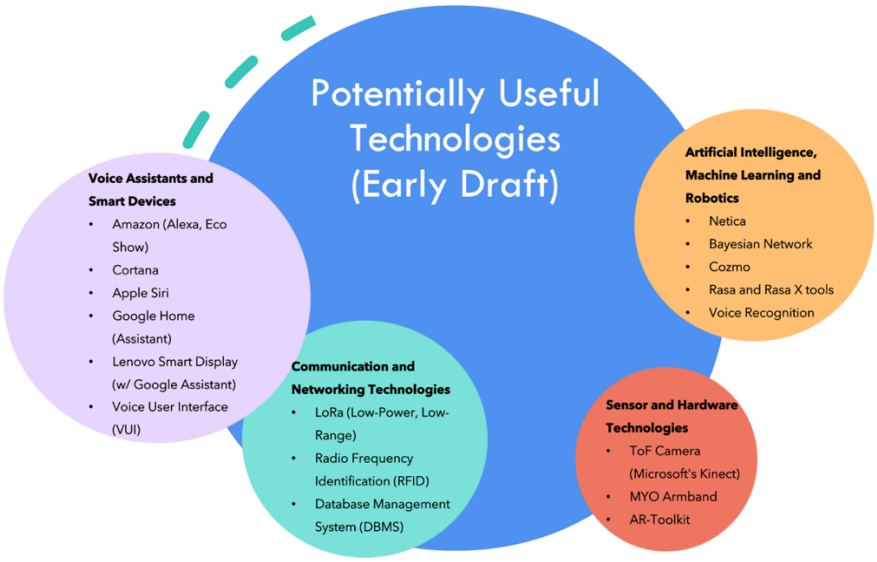

Figure 1 – Technologies Used by Related Works, divided into four sections

2.3 Discussion

After understanding each of the articles, their objectives, their goals, and also their solutions, we have selected three that stood out the most to us and were closest to our own project:

1. **An adaptive smart system to foster disabled and elderly people in kitchen-related tasks:**

   The system focuses on intelligent kitchen interaction, providing support for various disabilities. It features an adaptable user interface that guides food preparation and controls kitchen appliances. The target users include individuals with mild to moderate dementia and slight motor impairments.

2. **Assistive technology for healthy ageing for the elderly: an intelligent multimodal kitchen-terminal:**

   This technology is developed to serve as a multimodal assistant specifically designed for the elderly. Its primary goal is to assess and support individual nutritional intake.

3. **Assistente para apoio a idosos em casa (Assistant to support the elderly at home):**

   Concentrates on a personal assistant for the elderly, enhancing communication with people and devices.

Comparing the three articles above (selected from ***Error! Reference source not found.***) to our project, a common goal emerges: *enhancing the lives of senior individuals through intelligent kitchen assistance*.

These initiatives universally employ technology to aid the older people, whether it's via advising on food preparation, assessing nutritional needs, or offering general support for aging comfortably at home.

Our project distinguishes itself from similar initiatives by offering a comprehensive suite of functionalities specifically designed to address the multifaceted needs of older individuals in a kitchen environment. While the selected articles focus on various aspects of intelligent kitchen assistance, our project integrates these features into a unified system, enhancing both functionality and user experience. Here is a comparison highlighting the key differences in functionality:

- **Compared to article one ours:**
    - **Integration**: Combines step-by-step cooking instructions with effective pantry management
    - **Technological Advancements**: Uses barcode scanning for accurate inventory tracking
    - **Safety Features**: Includes alerts for product expiration dates, ensuring food safety
- **Compared to article two ours:**
    - **Breadth of Support:** Goes beyond nutritional monitoring to include comprehensive cooking guidance and pantry management
    - **User Convenience:** Simplifies shopping by allowing users to create detailed shopping lists
- **Compared to article three ours:**
    - **Specificity:** Focuses specifically on kitchen-related tasks, providing detailed and actionable guidance for meal preparation
    - **Comprehensive Management:** Manages pantry inventory and provides timely reminders for expiration dates
    - **Enhanced Interaction:** Facilitates a smart home environment with practical, everyday functionality that ensures independence and convenience

What sets our project apart is its comprehensive approach. We integrate step-by-step cooking instructions with effective pantry management, facilitated by barcode scanning technology. Additionally, our system includes alerts for expiration dates, ensuring both safety and convenience. This comprehensive approach is further enhanced by our focus on creating a smart home environment, which is in line with the broader objective of utilizing technology to foster active and independent living for the aging population.

3 Personas, Scenarios, and Requirements

For our research project, we employed a User-Centered Design (UCD) approach [19], which places the users at the forefront of the development process, ensuring that the solution is tailored to their needs, preferences, and contexts. The UCD approach involves several iterative stages, including user research, design, prototyping, and testing, with continuous user feedback sought at each stage to refine and improve the solution [19].

As part of our user research, we conducted a structured survey consisting of 15 questions, including fixed-response, quantitative, and open-ended questions. The survey was distributed to 11 individuals, with the sample population carefully selected based on age, gender, and living situation to match our target audience. The responses were then analyzed to extract valuable insights and identify key scenarios that will inform the design and development of our solution.

Furthermore, we have defined two personas that represent our target audience, each with distinct characteristics, needs, and contexts. Based on the survey results and personas, we identified four key scenarios that will serve as the foundation for our solution. Based on those scenarios, we defined both functional and non-functional requirements to guide the development process and ensure that the solution meets the needs of our users while also adhering to technical and quality standards.

In conclusion, the UCD [19] approach, coupled with the structured survey, personas, scenarios, and requirements, has provided a solid foundation for our project. This comprehensive approach ensures that we are well-equipped to develop a solution that is not only functional and effective but also truly user-centric, addressing the unique needs and preferences of our target audience.

3.1 Personas

Mr. Mário

Mr. Mário, a 71-year-old, lives in a serene seaside community where he enjoys a peaceful life post-retirement. He faces health challenges common in his age group, including hypertension, high cholesterol, and obesity, along with limited mobility due to arthritis.

Figure 2 - Mr. Mário

Technologically, he finds himself at a distance from the rapidly evolving digital world. His interactions with modern digital interfaces and small mobile devices are often challenging, leading him to prefer simple and intuitive technology.

Mr. Mário's hobbies, which include fishing and carpentry, reflect his love for activities that offer relaxation and a sense of accomplishment. Recently, he has also started exploring basic culinary skills, adding another enjoyable activity to his leisurely days. In essence, Mr. Mário values independence and ease in his interactions with technology. Products and services designed for him should be straightforward, accessible, and supportive of his lifestyle, enhancing his day-to-day experiences while respecting his need for simplicity and functionality.

GOALS FOR PRODUCT USE:

- Achieve culinary independence with easy-to-follow voice-guided recipes.
- Support memory with clear, repetitive auditory prompts and display.
- Overcome technological barriers with a simple, intuitive interface.
- Manage pantry inventory with timely expiration and stock alerts.
- Adapt recipes to meet dietary restrictions and health requirements.

Mrs. Maria

At 73, Mrs. Maria lives alone in a rural area, supported by healthcare providers due to her health and mobility challenges. She faces daily struggles with motor disabilities that affect her coordination and balance, and she is partially deaf with weakened vision. Managing chronic conditions like hypertension and diabetes, along with cognitive challenges, particularly memory lapses, is an integral part of her routine.

Figure 3 - Mrs. Maria

Communication is a hurdle for Mrs. Maria, as she often finds it difficult to interpret and express written messages. Her lifestyle necessitates assistance with daily routines and tasks, making her dependent on her support network for both social interaction and practical help. In her interactions with technology, Mrs. Maria values simplicity and accessibility. Products and services designed for her should be straightforward and supportive, enhancing her independence and quality of life while accommodating her specific needs and limitations.

GOALS FOR PRODUCT USE:

- Achieve autonomy in cooking with voice-guided, easy-to-follow recipes.
- Support memory with consistent auditory cues and visual prompts on the display.
- Manage pantry inventory efficiently with alerts for expiring products and items running low.

3.2 Structured Survey

Before starting the implementation phase, we conducted this survey, by asking the participants about hypothetical scenarios and for them to classify them according to preference. Using the results obtained to further improve the scenarios.

3.2.1 Sample

The survey targeted a sample of 11 participants, chosen specifically to align with our project's focus on the senior population. The age distribution of participants, illustrated in *Figure 4* indicates that the sample effectively covers the target range, thereby reinforcing the relevance of our study. Additionally, the survey examined demographic variables such as gender and living arrangements.

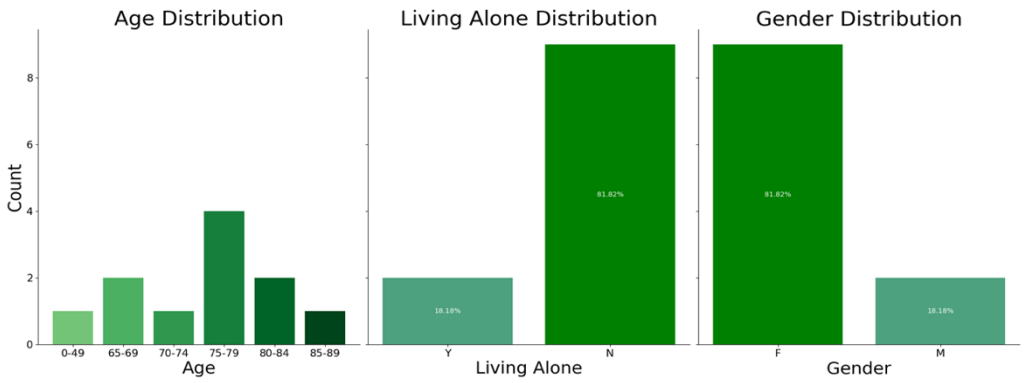

Figure 4 - On the left, it is displayed the Age distribution's Histogram of the survey, where it can be seen that most participants are between 75-79 years old. The middle histogram shows the distribution of Living Alone (Y – live alone, N – Not live alone), showing that the majority of the participants does not live alone. On the right, the Histogram represents gender distribution (F – Female, M – Male), where most participants are Females.

3.2.2 Method

The survey included 15 questions aimed at understanding the needs and preferences of older individuals regarding kitchen assistance technology. These questions were categorized into close-ended, quantitative and open-ended formats. The fixed-response questions evaluated participants reactions to specific scenarios relevant to our research, while quantitative questions measured perceived usefulness of various functionalities. Open-ended questions allowed for detailed qualitative insights, which were systematically analyzed through tokenization and frequency analysis. The complete survey is provided in the appendix for those interested in further details.

3.2.3 Results and Discussion

The answers to the fixed-response questions were analyzed to assess participants reactions to proposed scenarios *(Figure 5).* The analysis confirmed that the scenarios were widely accepted, leading to the identification of scenarios.

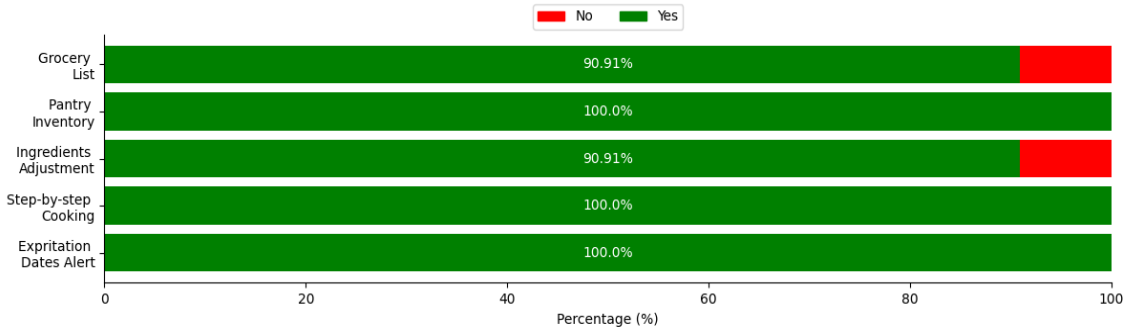

Figure 5 - Stacked Bar Chart displaying the fixed questions done within the Structured Survey scope, where the acceptance of the proposed scenarios (grocery List, Pantry Inventory, Ingredients Adjustment, Step-by-step cooking and Expiration Dates Alert) is obvious.

The analysis of the answers to the quantitative questions *(Figure 6)* highlighted participants perceived usefulness of various functionalities. This visualization revealed that participants unanimously agreed on potential benefits of a virtual kitchen assistant and food inventory system with expiration alerts. However, there was a notable dispersion in responses to questions related to "Assistant for Disabled" and "Diet Restrictions" indicating the need for clearer question formulation and consideration.

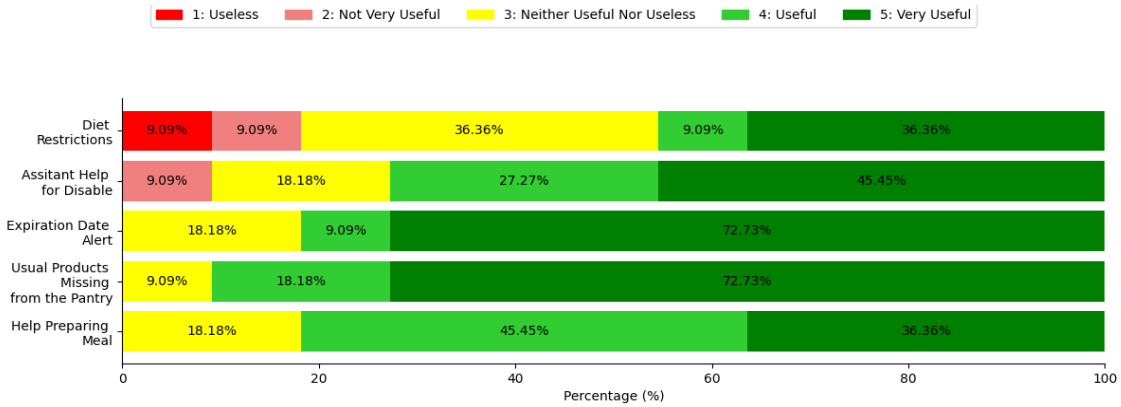

Figure 6 - Stacked bar Chart of the Quantitative Questions where the usefulness of the various proposed functionalities is depicted

From the data, we realized some functionalities got negative feedback, making us redefine the previous scenarios. The analysis of the answers to the open-ended questions gave us the following insights:

- TRUSTWORTHY: indicating no significant security concerns among users.
- VOICE and DISPLAY: suggesting a preference for a hybrid interface combining voice and display functionalities.
- MEAL-PREPARATION, MISE EN PLACE and COOKING TIMES: emphasize the need for comprehensive meal preparations guidance.
- GROCERY LIST: highlights the importance for a feature of compiling missing grocery items.

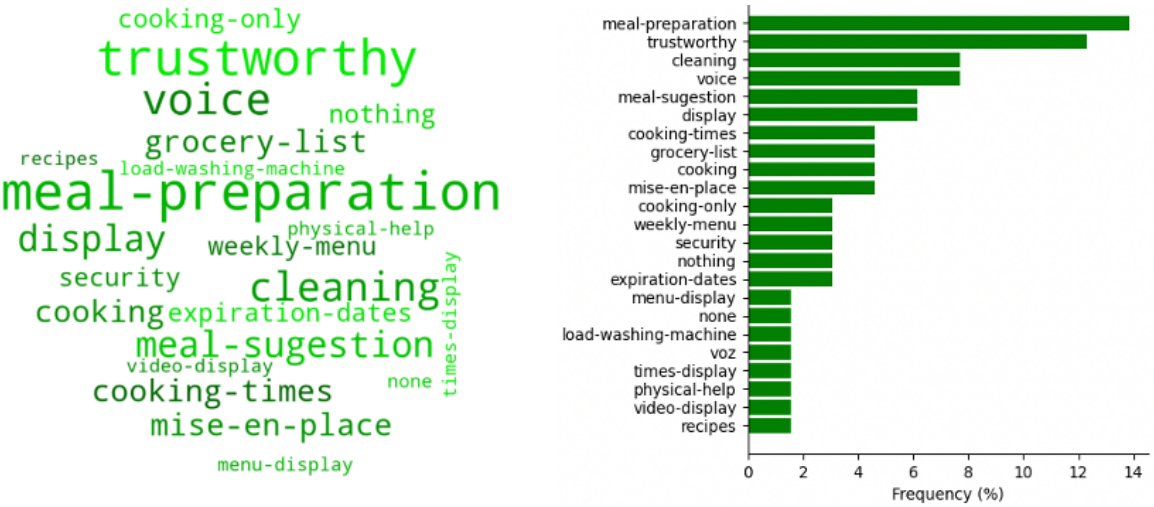

Figure 7 - On the left a Word Cloud with the tokenization of phrases given by the participants, On the right the Histogram of the token's Frequencies. On these representations are shown the participants' frequent spoken words

From the results on *Figure 7*, we can draw several conclusions that, when aligned with the defined personas, will allow us to establish the following scenarios:

1. Add a product to the pantry.
2. Generate an inventory list detailing available products and those that are missing.
3. Send alerts for products approaching their expiration dates.
4. Provide step-by-step assistance in preparing a recipe, including adjustments based on the number of people.

Furthermore, we have determined that the implementation of the Virtual Assistant must be hybrid, incorporating both voice and display functionalities to optimize user interaction. More importantly, the study indicates that there are no significant security concerns among users regarding the Virtual Assistant.

3.3 Scenarios

Initially, the project relied on direct observations and experiences to create scenarios (*Appendix A)*. Later, to improve accuracy, these scenarios were updated after a thorough analysis of survey data, survey which can be found in *Appendix B*. By combining firsthand knowledge with empirical evidence, the scenarios reflect the needs and preferences of the target audience more accurately, as revealed on the ***Error! Reference source not found.***.

Scenario 1: Add a Product to the Pantry

Mr. Mário activates the kitchen assistant using a voice command.
He requests the assistant to add something to the pantry stock.
He informs the Assistant by speech about the product he wants to add to the pantry. The assistant asks for additional details, such as quantity and expiration date, and then confirms the addition. The product is added to the pantry stock and the information is displayed on the screen.

Mr. Mário: Viva!
Kitchen Assistant: Bom dia, Sr. Mário! Como posso ajudar na cozinha hoje?
Mr. Mário: Adiciona feijão preto ao stock da despensa.
Kitchen Assistant: Claro, com prazer. Pode informar-me a quantidade de feijão preto a adicionar?
Mr. Mário: Adiciona um pacote de 500 gramas.
Kitchen Assistant: Perfeito. E a data de validade do feijão preto?
Mr. Mário: A validade é até 31 de dezembro de 2024.
Kitchen Assistant: Excelente. Estou a adicionar um pacote de 500 gramas de feijão preto com validade até 31 de dezembro de 2024 ao stock da despensa. Está correto?
Mr. Mário: Sim.
Kitchen Assistant: Feito! Feijão preto adicionado à despensa. Há mais alguma coisa em que possa ajudar?
Mr. Mário: Não, obrigado. Isso é tudo por agora.
Kitchen Assistant: Se precisar de mais alguma coisa, estarei aqui. Tenha um bom dia, Sr. Mário!

Scenario 2: Generate an Inventory List

Mrs. Maria activates the kitchen assistant using a voice command. She requests the assistant to generate an inventory list. The assistant analyses the pantry and creates a list of available products.
The list is displayed on the screen and can also be sent to the user's mobile phone.

Mrs. Maria: Viva!
Kitchen Assistant: Bom dia, Dona Maria! Como posso ajudar na cozinha hoje?
Mrs. Maria: Gera uma lista de inventário da despensa.
Kitchen Assistant: Claro, um momento enquanto analiso o stock da despensa.

Kitchen Assistant: Pronto! Gostaria de ver no ecrã ou prefere que envie por email?
Mrs. Maria: Mostra no ecrã.
Kitchen Assistant: Excelente. Estou a mostrar a lista no ecrã, lista que mostra todos os itens disponíveis e dentro da validade.
Mrs. Maria: Obrigada.
Kitchen Assistant: Se precisar de mais alguma coisa, estarei aqui. Tenha um bom dia, Dona Maria

Scenario 3*: Send Alerts for Expiring Products*

The kitchen assistant periodically checks the expiration dates of products in the pantry stock.
If a product is approaching its expiration date the assistant sends an alert to the user
The alert is displayed on the screen and can also be sent to the user's mobile phone.
The user can then take necessary action, such as consuming or discarding the product.

Kitchen Assistant: Bom dia, Dona Maria! Tem um produto a expirar o prazo de validade.
Mrs. Maria: O que se passa?
Kitchen Assistant: Detetei que o pacote de natas na despensa está prestes a expirar a validade. A data final de validade é daqui a 3 dias.
Mrs. Maria: Ok, Obrigada.
Kitchen Assistant: Foi enviado um alerta para o seu email com esta informação, para que possa tomar as ações necessárias
Mrs. Maria: OK, obrigada por me manteres atualizada.
Kitchen Assistant: Se precisar de mais alguma coisa, estarei aqui. Tenha um bom dia, Dona Maria!

Scenario 4: Provide Step-by-Step Assistance in Preparing Recipe

Mr. Mário activates the kitchen assistant using a voice command. He requests the assistant to aid in preparing a recipe.
The assistant asks for the recipe name and the number of people to be served.
The assistant checks the pantry stock to ensure all required ingredients are available.
An ingredient is missing, the assistant notifies the user and suggests alternatives or the option to add the missing ingredient to the shopping list.
The assistant provides step-by-step instructions, adjusting the ingredient quantities as needed.
The instructions are displayed on the screen and delivered through natural voice.
The user follows the instructions to prepare the recipe.

Mr. Mário: Viva!
Kitchen Assistant: Bom dia, Sr. Mário! Como posso ajudar na cozinha hoje?
Mr. Mário: Gostaria de preparar uma receita.
Kitchen Assistant: Claro, qual é a receita e para quantas pessoas é?
Mr. Mário: Quero fazer lasanha para quatro pessoas.
Kitchen Assistant: Excelente. Vou verificar se tem todos os ingredientes necessários.
Kitchen Assistant: Parece que tem quase tudo, mas está sem queijo mozzarela.
Mr. Mário: Oh, isso é um problema.
Kitchen Assistant: Posso sugerir uma alternativa, como queijo cheddar, ou adicionar mozzarela à sua lista de compras.
Mr. Mário: Adiciona, mas no entretanto vamos usar cheddar.
Kitchen Assistant: Perfeito, vou ajustar a receita para usar queijo cheddar. Vamos começar com o primeiro passo. Pré-Aqueça o forno a 180º Celsius. Depois de ter feito este primeiro passo diga 'CONFIRMO' para prosseguir para o próximo passo.
Mr. Mário: Confirmo!
Kitchen Assistant: Agora, vamos preparar o molho. Vou guiá-lo através de cada etapa.
[continues with the preparations of the recipe waiting on each step for the confirmation from Mr.Mário to get the next step]
Kitchen Assistant: Finalizado! Pode retirar a lasanha do forno e está pronta a servir.
Mr. Mário: Perfeito, obrigado.
Kitchen Assistant: Quer adicionar à lista de compras os ingredientes que usou nesta receita?
Mr. Mário: Sim por favor.
Kitchen Assistant: Lista de compras atualizada.
Kitchen Assistant: Se precisar de mais alguma coisa, estarei aqui. Tenha um bom dia, Sr. Mário!

3.4 Requirements

When building a product or undertaking a project, it is crucial to keep requirements analysis in mind. In the development process, the team should determine what the product is meant to achieve. These objectives are termed "functional specifications", and identifying them is part of the requirement gathering phase. These requirements should be measurable, detailed, and directly contribute to the final product. It is essential to also consider what the users want, ensuring that the result is as transparent and aligned with user expectations as possible. The process we followed to extract the requirements from the scenarios is depicted in *Figure 8.*

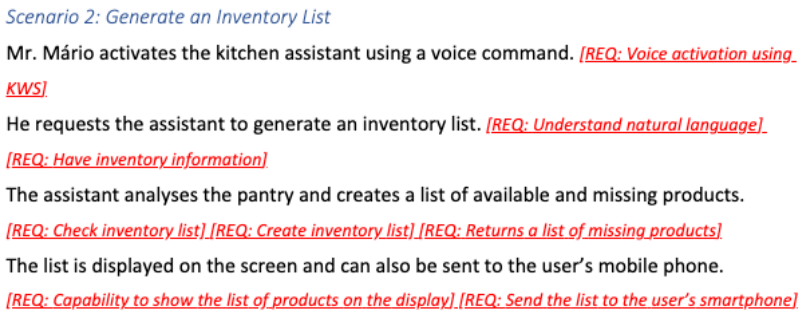

Figure 8 - Requirements Extraction Example, extracting one or more requirements from each interaction between User and Assistant

Therefore, we decided to attribute a priority to each requirement to access the order of the implementation, as shown in Table 2.

Functional	Non-Functional	Interaction
Add products to stock (P0) Retain information about the product quantity (P0) See the recipe information (P0) Create alerts when products are closer to the expiration date(P1) Return a list with the missing products (P1)	Have a database where the product inventory (P0) Have a recipe database (P0) Barcode scanner technology (P1)	Understand natural language (P1) Voice activation with key words(P1) Give information through voice (P1) Ability to show information on display (P2) Capacity to give alerts and lists (P1)

Table 2 - Table of Requirements Extracted from the Scenarios with P0 - MAX priority, P1 – MEDIUM priority and P2 – MIN priority

4 Kitchen Assistant

This chapter details the design, architecture, and implementation of the Kitchen Assistant system. It begins with an overview of the modular system architecture, enabling the integration of interaction forms and enhancements. The current implementation supports voice, keyboard, and barcode interactions.

We then cover the implementation phases, including development environment, key algorithms, and technologies used. Each system component is explained in terms of function and role within the system.

The chapter concludes with a discussion on cloud services, pantry database, key algorithms and data structures.

4.1 System Architecture

The architecture *(Figure 9),* collaboratively developed by the group with guidance from the supervisors, was designed with modularity in mind. This modular approach ensures that additional forms of interaction with the assistant can be seamlessly integrated as needed or identified as beneficial enhancements.

Given that the project was developed and executed on a laptop, the input devices include the computer's webcam, which functions as a barcode scanner, and the microphone for capturing voice inputs. Respectively, the output devices consist of speakers, which deliver auditory feedback, and the laptop display, which visually shows information.

The following tables illustrate and describe various modules. We believe this format enhances comprehension and visually correlates each module with its corresponding component in the system's architecture by color coding.

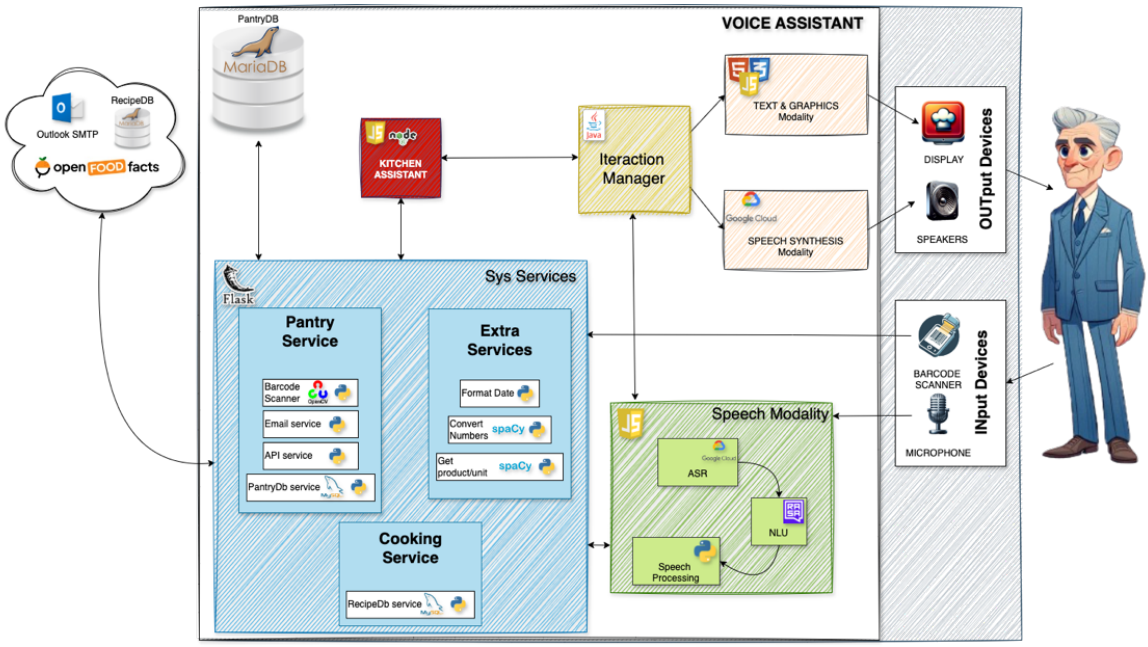

Figure 9 - Assistant's Architecture, where is depicted the modularity of the system. Another modality can easily be added to the system connecting it with the Interaction Manager

Speech Modality	FUNCTION	DESCRIPTION
Automatic Speech Recognition (ASR)	Converts voice to text	Captures and transcribes spoken commands from users, enabling the conversion of voice input into text

Natural Language Understanding (NLU)	Identify user intentions	Analyzes the text produced by ASR and processed by Speech Processing, to recognized predefined entities and user intents requires TRAINING
Speech Processing	Processes Data from NLU	Prepares the text generated by ASR for more straightforward interpretation by the NLU module

Table 3 - Speech Modality brief description

Speech Synthesis Modality	FUNCTION	DESCRIPTION
Text to Speech (TTS)	Converts text into spoken words	Transform textual content into audible speech, enabling system to communicate verbally with users

Table 4 - Speech Synthesis Modality brief description

Text & Graphics Modality	FUNCTION	DESCRIPTION
Display Management Module	Manages all content displayed on the user interface	Oversees the display of all visual content on the interface, ensuring that both text and graphics are shown accurately

Table 5 - Text & Graphics Modality brief description

Interaction Manager	FUNCTION	DESCRIPTION
Information Processing Module	Handles and processes all information, directing to appropriate modules	Manages the flow of information within the system, ensuring data is correctly processed and routed to the relevant modules for further action

Table 6 - Interaction Manager brief description

Kitchen Assistant	FUNCTION	DESCRIPTION
Service Selection Module	Choose the assistant's actions based on user requests/intention	Selects and activates the necessary services from the system's available resources in response to user intentions extracted by the Speech Modality

Table 7 - Kitchen Assistant brief description

Sys Services	FUNCTION	DESCRIPTION
COOKING SERVICE: Eases cooking by offering detailed, sequential instructions for recipe preparation.		
RecipeDb Service	Connects with RecipeDb and interacts with it	Connects with RecipeDb and interacts with it Interfaces, with RecipeDb to retrieve and manage recipe data

PANTRY SERVICE:

Oversees the inventory of pantry items, handling their addition, removal, and status updates.

Barcode Scanner	Connects with the laptop webcam and interprets barcode data	Utilizes the webcam to scan and decode barcodes, facilitating the identification of pantry items
Email Service	Creates and sends emails to users	Generates email content and dispatches it to users, providing notifications, such as, shopping lists and expiration alerts
API Service	Connects with OpenFoodFacts to retrieve product information based on barcode data	Works with the OpenFoodFacts API to obtain detailed information about products using the barcode's EAN number
PantryDb Service	Connects with the local PantryDb and interacts with it	Connects with the local PantryDb to manage pantry inventory data

EXTRA SERVICES:

Offers supplementary functionalities to process and manage data effectively.

Format Date	Formats dates into a format accepted by MySQL	Converts date representations into a format compatible with MySQL databases
Convert Numbers	Converts extended representations of numbers into digits	Transforms written-out numbers into their numeric digit forms
Get Product/Unit	Extracts product or unit information from a sentence	Identifies and extracts relevant product or unit details from textual input

Table 8 - Sys Services like Extra Services, Pantry Service and Cooking Service and the small modules brief descriptions

Pantry Database	FUNCTION	DESCRIPTION
PantryDb	A comprehensive database containing various items, accessible for shopping and grocery lists	A local database that manages pantry inventory, allowing the addition, removal, and monitoring of products to ensure the creation of shopping and grocery lists

Table 9 - Pantry Database brief description

Cloud Services	FUNCTION	DESCRIPTION
RecipeDb	Provides a comprehensive repository containing a wide variety of recipes	A critical database for cooking assistance, offering users an extensive selection of culinary options and step-by-step guidance for recipe preparations
OpenFoodFacts API	Provides detailed information about food items based on barcode data	Enhances inventory management capabilities by retrieving nutritional information, ingredients, and other relevant details about food products using barcode data
Outlook SMTP	Facilitates the sending of shopping lists and expiration date alerts to users	Ensures users remain informed and up-to-date by automatically generating and sending emails that include shopping lists and notifications of product expiration dates

Table 10 - Cloud Services brief description

Although the clouds services are currently implemented to operate locally within the scope of this project, they are architecturally prepared to transition to online services, enabling broader accessibility and scalability.

4.2 Implementation

This section provides an overview on the implementation of the different stages of the kitchen assistant. We will focus mainly on the development environment, implementation details, key algorithms and data structure, ending this chapter with the main challenges and solutions we faced in this particular part.

Programming Languages

Frameworks

Software

4.2.1 Tools and Technologies

Depicted below, are the icons to the software we used in the system development and documentation. Followed by the programming languages, some frameworks, and on *Table 11* a list of the libraries used.

Libraries	
Requests	A simple and elegant HTTP library for Python, used for making HTTP requests
OpenCv	An open-source computer vision and machine learning software library, used for image and video analysis
Pyzbar	A library for reading one-dimensional barcodes and QR codes from images
Mysql.connector	A Python library for connecting to and interacting with MySQL databases
symPy	A Python library for symbolic mathematics and algebraic manipulation
Matplot.lib	A plotting library in Python used for creating static, interactive, and animated visualizations
NumPy	A fundamental package for numerical computation in Python, providing support for arrays and matrices
Smtplib	A Python library for sending emails using the Simple Mail Transfer Protocol (SMTP)
Email_validator	A library for validating email addresses in Python
Spacy	An open-source library for advanced natural language processing in Python

Table 11 - List of Tools and Technologies used on this project and a brief description of each library installed

4.2.2 Setup and Configuration

To implement the system, the following software and libraries must be installed:

- **Java 21**: For application development and execution
- **Node.js**: For server-side scripting
- **Miniconda**: For managing Python environments and dependencies
- **Doxygen**: For generating project documentation
- **Flask**: For developing the server
- **Requests**: For handling HTTP requests
- **OpenCV**: For image and video analysis
- **pyzbar**: For barcode reading functionalities
- **NumPy**: For numerical computations
- **email_validator**: For validating email addresses
- **SpaCy**: For natural language processing
- **mysql.connector**: For connecting Python with MySQL databases
- **MariaDB**: For managing relational databases

After installing the required software, we needed to create the databases **PantryDb** and **RecipesDb**. The next step was to configure the **nlu.yml** file, for Rasa to define the training data necessary for recognizing user intentions. Before training Rasa, we needed to make sure that the Rasa environment is activated. Once activated, we would train the Rasa model using the **nlu.yml** file to enable accurate interpretation of user speech.

4.3 Modules and Components

Along this section, we will dive into the technical specifications and methodologies employed in the development of our Kitchen Assistant system. We will explore the key modules and components that make the backbone of the system, highlighting their roles and interactions.

Sys Services

/Pantry Services

/PantryDb service

This module, essential to manage pantry items, provides the following core functionalities:

- **Database Connection**: Establishes a connection to the MariaDB database
- **Stock Management**: Functions for inserting, removing, and retrieving stock items, along with their quantities and expiration dates
- **Unit Conversion**: Converts quantities between different units of measure using predefined conversion factors

- **Grocery List Management**: Manages a separate grocery list, allowing the addition, removal, and display of grocery items

/Pantry Services
/Barcode Scanner

The module analyzes and decodes barcodes from the image shown in the webcam. By using the capabilities of the OpenCV and Pyzbar libraries to process and interpret barcode data, returning the decoded information as strings.

- **Conversion and Decoding**: Begins by decoding the base64-encoded string to bytes. These bytes are then converted into a NumPy array, which is subsequently decoded into an image using OpenCV's **imdecode** function
- **Barcode Detection**: The decoded image is analyzed using the Pyzbar library to detect and decode any barcodes presented. If a barcode is found, its data is extracted and returned as a string.
- **Error Handling**: The function includes error handling to catch and report any exceptions that occur during the image decoding or barcode detection process, printing error messages to aid in diagnostics

/Pantry Services
/Email Service

The module provides a function to send emails through an SMTP server, allowing the inclusion of HTML content in the email body. It also validates the sender's and recipient's email addresses using the **email-validator** library to ensure they are correctly formatted.

- **Email Validation**: The function begins by validating the sender's and recipient's email addresses using the **email-validator** library. This step ensures that the email addresses obey to standard formats and are likely to be valid
- **Email Composition**: If the email addresses are valid, the function creates an email message using the **EmailMessage** class from the **email** module, allowing the inclusion of HTML content in the email body
- **SMTP Connection and Security**: The function establishes a connection to the specified SMTP server, secures the connection using TLS, and then sends the email

/Pantry Services
/API Service

The module provides a function to perform HTTP GET requests to the Open Food Facts API using product's barcode. The primary function, **get_product_name**, processes the API response to extract and return essential product information.

- **API Request**: The function constructs the URL for the API request using the provided barcode and performs an HTTP GET request to the Open Food Facts API
- **Response Handling**: If the request is successful and the product is found in the database, the function extracts the product name, quantity, and image URL from the API response. If the product is not found or if an error occurs, appropriate messages are printed in the console
- **Error Handling**: The function includes error handling to catch and report any exceptions that occur during the API request, ensuring that issues can be diagnosed and addressed effectively

Sys Services
/Extra Services

The **Extra Services Module** provides a suite of algorithms that support core functionalities such as converting units of measurement, parsing date formats, and processing natural language inputs. These services are essential for maintaining the system's flexibility and accuracy in handling various data types. You can see more about this algorithms in the subsection 5.3.

Sys Services
/Cooking Services
/RecipeDb service

This module provides a set of functions to access and manipulate data stored in the recipe database. This module utilizes the **mysql.connector** library to connect to and perform queries on a MariaDB database providing the following core functionalities:

- **Database Connection**: Establishes a connection to the MariaDB database
- **Recipe Retrieval**: Retrieves all available recipes from the database, returning a list of dictionaries containing the name, number of servings, and cooking time for each recipe
- **Ingredient Retrieval**: Retrieves the ingredients of a recipe given its ID, returning a list of ingredients with their names, quantities, and units
- **Tool Retrieval**: Retrieves the tools used in a recipe given its ID, returning a list of tools
- **Recipe Search by Tag**: Retrieves the IDs of recipes associated with a specific tag
- **Random Recipe Selection**: Randomly selects a recipe from the database and returns its ID
- **Recipe Instruction Retrieval**: Functions to retrieve the next, previous, and current instructions for a given recipe step, respectively
- **Image URL Retrieval**: Retrieves the URL of the image from a given recipe ID

Speech Modality
/NLU

The **NLU Module** is essential for natural language understanding in the system, enabling the assistant to interpret and respond to user queries effectively. The **NLU Module** uses Rasa's capabilities to handle diverse user interactions by defining intents, entities, and example phrases. This module ensures that the assistant can understand and respond to various queries related to recipes, pantry management, and general interactions.
Key intents and some Examples:

1. **Recipe-Related Intents**
    a. Ask for All Recipes

```
# Ask for all recipes
- intent: ask_all_recipes
  examples: |
    - Quais são as receitas disponíveis
    - Mostra-me as receitas disponíveis
    - Quais são as receitas
    - Quais são as receitas que tens
    - Quais são as receitas que sabes
    - Quais são as receitas que conheces
```

*Figure 10 - Example of an intent definition, in this case **ask_all_recipes** and the examples used*

2. **Pantry Management Intents**
    a. Check for a Specific Ingredient in the Pantry

```
# check if a ingredient is in the pantry
- intent: ask_specific_pantry
  examples: |
    - Tenho [ovos](ingrediente) na despensa
    - Tenho [ovos](ingrediente)
    - Confirma se tenho [ovos](ingrediente)
    - Confirma se tenho [ovos](ingrediente) na despensa
    - Verifica se tenho [ovos](ingrediente)
    - Verifica se tenho [ovos](ingrediente) na despensa
```

Figure 11 - Example of an intent definition, in this case with the entities between () and the examples between []

3. **Regex Expression to extract Entities Values**
    a. Regex: data

```
# regex to extract the expiration date - simplistic way only validating the number of digits
- regex: data
  examples: |
    - \d{1,2}/\d{1,2}\s\d{4}
    - \d{1,2}/\d{1,2}/\d{4}
    - \d{1,2}\sde\s(?:Janeiro|Fevereiro|Março|Abril|Maio|Junho|Julho|Agosto|Setembro|Outubro|Novembro|Dezembro)\sde\s\d{4}
```

Figure 12 - Example of a regex extraction, in this case for data entity, with 3 regular expressions to catch different cases

4. **Lookup Tables to extract Entities values**

    a. Lookup: unidade

```
# lookup table for the entity "unidade"
- lookup: unidade
  examples: |
    - l
    - ml
    - cl
    - dl
```

*Figure 13 - Example of a lookup extraction for entity **unidade**, where are listed all possible examples*

Speech Modality /Speech Processing

The **Speech Processing Module** is designed to enhance the raw text extracted from the Automatic Speech Recognition (ASR) system, making it easier for the Natural Language Understanding (NLU) module, powered by Rasa, to interpret. This module interacts with the **SYS Services**, specifically the **EXTRA Services**, to perform various text processing tasks such as formatting dates, converting numeric words to digits, and handling units of measurement.

Text & Graphics Modality

The **Text & Graphics Modality Module** is responsible for managing and transforming the visual and textual elements of the user interface. This module handles the presentation of recipes, images, tools, pantry lists, barcode scanning, and the textual representation of the Assistant's interactions assuring that the interface is visually appealing and functionality effective.

Kitchen Assistant

The **Kitchen Assistant Module** is the core component responsible for orchestrating various tasks and functionalities within the system. It handles user interactions, processes commands, and coordinates between different services to provide a seamless experience, ensuring that user requests are processed accurately and efficiently. It manages commands related to recipes, pantry inventory, shopping lists, and more, using asynchronous functions to handle tasks concurrently. As the ***"BRAIN"*** of the assistant, the Kitchen Assistant Module interprets the user's intentions, which have been pre-processed by the IM

module, and **takes appropriate actions** to assist the user. This central role ensures that the assistant can respond to a wide range of queries and tasks, making it an indispensable part of the system. To perform this action Kitchen Assistant uses all the **Sys Services** as needed.

4.3.1 Key Algorithms and Data Structures

Managing a kitchen inventory system involves a lot of details, from converting units of measurement to identifying ingredients and parsing dates accurately. This sub-chapter explores the essential algorithms and data structures that make these tasks easier and more reliable.

Algorithms:

Conversion Algorithm for Units of Measure

In the context of this project, it is imperative to handle various units of measure efficiently, particularly when dealing with ingredients and inventory items in a kitchen setting. The conversion algorithm presented here is designed to help with the conversion between different units of volume and weight, ensuring accurate and consistent measurements.

The **conversion algorithm**, is designed to convert quantities between different units using the Conversion Factors Dictionary. It ensures accurate conversions through the following steps:

1. **Normalization of Units**: Converts input units to lowercase and removes plural forms for consistency
2. **Direct Conversion**: Attempts an immediate conversion using the dictionary
3. **Recursive Conversion**: If a direct conversion is not possible, recursively searches for an intermediary unit to complete the conversion
4. **Cycle Prevention**: Tracks visited units to avoid infinite loops
5. **Error Handling**: Raises a **ValueError** if no valid conversion path is found

The algorithm ensures that both direct and indirect conversions are handled seamlessly, maintaining accuracy and efficiency in unit conversions.

Ingredient Identification Algorithm

The **Ingredient Identification Algorithm**, encapsulated in the **get_ingredient** function, is designed to process a sentence to identify and return the mentioned ingredient. This algorithm leverages the SpaCy natural language processing (NLP) model to tokenize and lemmatize the input text, enabling accurate identification of ingredients based on a predefined list of food items.

The algorithm operates as follows:

1. **Sentence Processing**: The input sentence is processed using SpaCy to convert the text to lowercase, tokenize it, and generate lemmas
2. **List Conversion to Lemmas**: The predefined list of food items (**food_list**) is converted to lemmas to ensure accurate matching, even when the ingredients are mentioned in different grammatical forms
3. **Multi-Word Unit Check**: The algorithm first checks for multi-word ingredients within the sentence, ensuring that complex ingredient names are accurately identified

4. **Single-Word Unit Check**: If no multi-word ingredients are found, the algorithm then checks for single-word ingredients by comparing both the lemmatized tokens and the original text against the predefined list

Unit Identification Algorithm

The **Unit Identification Algorithm**, implemented in the **get_unit** function, processes a sentence to identify and return the mentioned unit of measure. This algorithm checks for both multi-word and single-word units within the sentence, ensuring comprehensive identification of measurement units based on a predefined list (**unit_list**).
The algorithm operates as follows:

1. **Sentence Splitting**: The input sentence is split into individual words
2. **Multi-Word Unit Check**: The algorithm first checks for the presence of multi-word units in the sentence to ensure that complex unit names are accurately identified
3. **Single-Word Unit Check**: If no multi-word units are found, the algorithm then checks for single-word units within the split words, ensuring that all potential units are considered

Numeric Phrase Extraction and Conversion Algorithm

The **Numeric Phrase Extraction and Conversion Algorithm**, implemented in the **extract_and_convert_numeric_phrases** function, extracts numeric phrases from a sentence and converts them into their respective numerical values and unit abbreviations.
The algorithm operates as follows:

1. **Sentence Splitting**: Split the input sentence into individual words
2. **Initialization**: Initialize lists to store converted words and numeric phrases
3. **Iteration and Processing**: Iterate over each word:
    - Accumulate words representing numbers in a temporary list
    - Convert numeric phrases to digits and append them to the result
    - Convert units using the **convert_units** function
4. **Final Check**: Ensure that any remaining numeric phrase is converted at the end
5. **Result Construction**: Join the converted words into a final string

Date Parsing Algorithm

The **Date Parsing Algorithm**, encapsulated in the **parse_date** function, is designed to analyze a date string in various formats in Portuguese and convert it to the ISO 8601 format (YYYY-MM-DD). This algorithm ensures consistent date representation, which is crucial for data processing and storage.
The algorithm operates as follows:

1. **Initialization**: The function begins by iterating over predefined date patterns stored in the **date_patterns** dictionary, which maps regular expression patterns to their corresponding date formats
2. **Pattern Matching**: For each pattern, the function uses the **re.match** method to check if the **date_string** matches the current pattern
3. **Date Extraction and Conversion**:
    - If the pattern matches and the format is "DD/MM/YYYY" or "DD/MM YYYY", the function extracts the day, month, and year components. It then creates a **datetime** object and converts it to the ISO 8601 format

- If the format is "DD de Month de YYYY", the function extracts the day, month name, and year. It uses the **month_to_number** dictionary to convert the month name to its corresponding numerical value. If successful, it creates a **datetime** object and converts it to the ISO 8601 format

Error Handling: If the **date_string** does not match any predefined pattern, the function returns "Invalid date format".

Data Structures:

Dictionaries		
Conversion_factors	***Numbers_dict***	***Uni_dict***
The conversion_factors data structure is a dictionary that includes predefined conversion rates between common units of volume and weight. These factors are primarily based on the density of water, allowing straightforward conversions between units such as liters, milliliters, grams, and kilograms. Additionally, the dictionary includes non-standard units often encountered in culinary contexts, such as "cups," "tablespoons," "teaspoons," and "cans."	The **numbers_dict** data structure is a dictionary that serves as a mapping between the textual representation of numbers and their corresponding numerical values. Supporting conversions from text to numerical data. This is particularly useful in interpreting user input where quantities are specified in words rather than digits.	The **uni_dict** data structure is a dictionary that maps various unit names to their standardized abbreviations. This dictionary supports the normalization of unit names, enabling consistent and accurate interpretation across different contexts. By standardizing unit names, the system can efficiently manage and convert between different units of measure.

Table 12 - Overview of Dictionaries used in the Kitchen Assistant System, including conversion factors, numerical mappings, and standardized unit names

Lists			
Unit_list	***Food_list***	***Plant_products***	***Animal_products***
The unit_list data structure is a list that encapsulates various units of measure used in culinary contexts. This list includes standard units such as liters (l), milliliters (ml), grams (g), and kilograms (kg), as well as more specific units like tablespoons (colher de sopa), teaspoons (colher de chá), and non-standard units like cans (lata) and bottles (garrafa). The inclusion of such a wide range of units ensures that the system can accurately interpret and convert measurements across diverse recipes and inventory items.	The food_list data structure is an extensive collection (list) of food items categorized into different groups such as seafood, meats, dairy, vegetables, fruits, grains, herbs and spices, nuts, and oils and other miscellaneous items. This categorization facilitates efficient management and retrieval of food items within the system.	The plant_products data structure is a list that includes a wide variety of vegetables and fruits. This list ensures that the system can accurately categorize and manage plant-based ingredients.	The animal_products data structure is a list that encompasses a broad range of seafood, meats, and dairy products. This list enables the system to effectively handle and categorize animal-based ingredients.

Table 13 - Lists utilized in the Kitchen Assistant System, detailing various units of measure, food items, plant products, and animal products for efficient management and retrieval

Date_patterns
The date_patterns data structure is a dictionary that maps regular expression patterns to specific date formats. This dictionary is used in the date parsing algorithm to identify and convert dates from various textual representations into the standardized ISO 8601 format (YYYY-MM-DD). Each pattern corresponds to a common date format in Portuguese, ensuring that the system can handle diverse date inputs accurately. The patterns included in the dictionary are designed to match the following formats:
1. DD/MM YYYY: "day/month year" (e.g., "24/3 2045")
2. DD/MM/YYYY: "day/month/year" (e.g., "21/05/2024")
3. DD de Month de YYYY: "day of month of year" (e.g., "21 de Maio de 2030")
4. DD de Month YYYY: "day of month year" (e.g., "21 de Maio 2030")
5. DD Month de YYYY: "day month of year" (e.g., "21 Maio de 2030")
6. DD Month YYYY: "day month year" (e.g., "21 Maio 2030")

Table 14 - Overview of the date_patterns dictionary, which includes multiple regular expressions designed to accurately parse and convert various Portuguese date formats into the standardized ISO 8601 format (YYYY-MM-DD)

5 Evaluation with Users

This chapter will consist of the processes and the results of the tests conducted during the development of this project - usability and acceptance survey – including the analysis of the main obtained results.

This took place in an advanced stage of the assistant, after the implementation was completely done according to our plan. The process and the results are presented in the following sections.

After completing the implementation phase, it was important to test the assistant with its intended focus group and gather their opinion to help improve it.

5.1 Sample

To conduct this evaluation, we gathered a group whose ages where between 53 and 85 years old and in average 73 years old (*Figure 14*). All the participants were Portuguese; therefore, all instructions were written in the native language. Regarding their technology knowledge (*Figure 14*) more than half classified themselves as beginners, the first of four possible options: beginner, intermediate, advanced and expert. In the health department is important to state that the bigger share did not possess crippling disabilities.

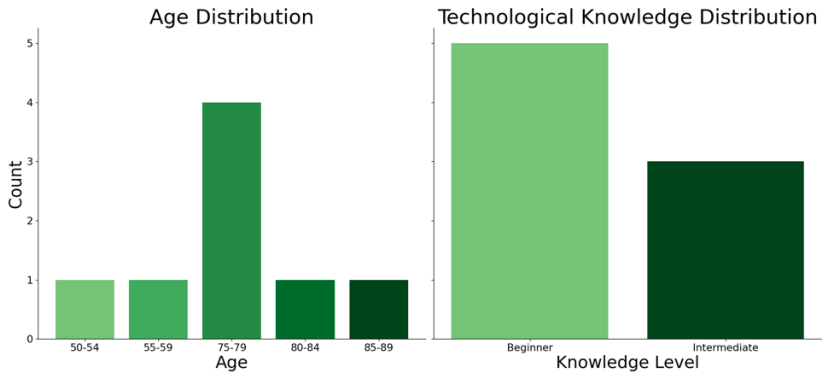

Figure 14 - The Histogram representing the Technological Knowledge of the participants on the left clarifies the bigger part of them are beginners in what comes to the use of technology; The right graphic illustrates the Age distribution of the participants, being the average age user 73 years old

5.2 Method

At the beginning of the survey:

1. Participants were provided with an informed consent form (*Appendix D*) which explained the project's context, primary objective, and emphasized the voluntary nature of their participation. It also assured them that their personal data would be secure and completely anonymous.
2. We then detailed the tasks they would be performing, reassuring them that any difficulties encountered would be due to flaws in the user interface, not their own performance. We emphasized that their feedback was essential for identifying the most significant changes needed to improve the system [20]. Each session was done in the presence of at least one group member.
3. Before moving on to the tasks (listed in *Table 15),* we compiled the assistant's main capabilities into a PowerPoint slide (Appendix C). We presented this information neutrally and clarified any doubts before proceeding.
4. The survey comprised a series of questions designed to evaluate the acceptance of the Assistant. The System Usability Scale [21](SUS) evaluation was conducted based on the tasks outlined in *Table 15*, utilizing the specific formula (*Equation 1*) for calculation.
5. After completing the tasks, participants were asked to fill out a questionnaire to provide their insights, as well as open-ended questions. We encouraged them to be as honest as possible in their feedback, as their candid input was vital for making meaningful improvements to the prototype.

Task 1	*Ask the assistant for a mousse recipe, follow the recipe through and after the first two steps, ask the assistant to repeat the last one. Keep moving forward in the recipe to the end.*
Task 2	*Add the two* products *displayed before you to the pantry. After that, ask the assistant to remove one of them and confirm the stock.*
Task 3	*Ask the assistant if it has rice in stock, if not, ask him to add it to the shopping list. Ask the assistant to send you an email with the shopping list.*

Table 15 - Table with the given tasks for the participants of the Usability and Acceptance Survey. SUS evaluation will depend on this interaction with the assistant.

$$SUS\ Score = 2.5(\sum_{ODD}(x-1) + \sum_{EVEN}(5-x))$$

Equation 1 - Equation to calculate the SUS SCORE

5.3 Results and Discussion

Based on the answers given, the calculated SUS score is **51**, which falls below the acceptable threshold, as seen in the SUS scoring (*Figure 15*) indicating that significant improvements are necessary to meet usability standards.

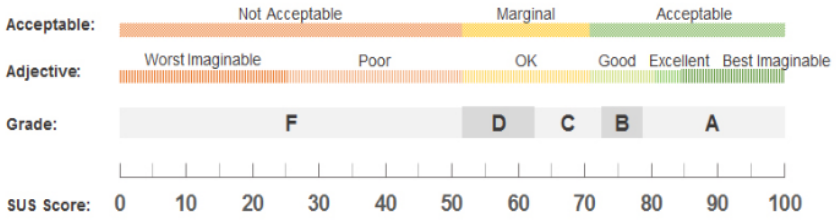

Figure 15 - SUS SCORE Scale, showing acceptability, adjective ratings, and letter grades for SUS scores from 0 to 100.

As illustrated in *Figure 16,* the responses to the SUS questions provide a comprehensive view of user feedback regarding the Assistant. The color-coded bars represent the deviation of median responses from the ideal scores, with green indicating responses close to the ideal and red highlighting significant deviations. The questions (Q2, Q4, Q7, Q8, Q9, and Q10) are of particular concern, as they indicate a substantial divergence from the desired responses. These questions should be prioritized for further research and improvement to enhance overall user satisfaction. By focusing on the problematic questions identified in red, we can make targeted enhancements that are likely to yield a higher overall SUS score and better user experience. This targeted approach to addressing usability concerns is crucial for iterative design and user-centered development.

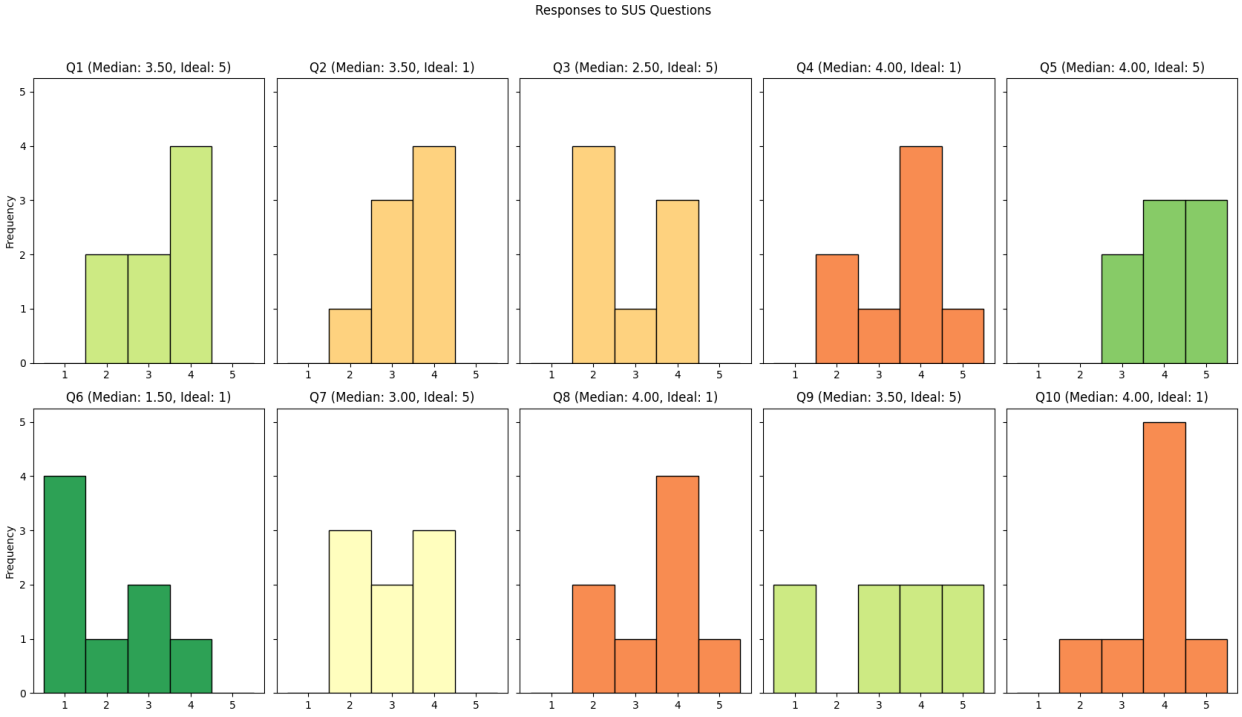

Figure 16 – Likert's Scale Chart Representation of all SUS questions [Q1 to Q10]. In each histogram, we find at the top the median values of the responses and the ideal value. For visual aid we have a gradient of colors [green to red] where green means the question does not need to be revised and red means the grade was not the ideal and we need to understand why we got this valuation. By understanding all the reds, we could compose new scenarios and update the assistant and therefore obtain a better evaluation in SUS SCORE

In conclusion, despite the System Usability Score being on the lower side, there are several positive takeaways from the survey that highlights the potential of the virtual assistant. The fact that none of the participants had prior experience with virtual assistants and yet were able to complete the tasks demonstrates the accessibility and intuitiveness of the system. Additionally, all participants recognized the value of a virtual assistant with these capabilities, underscoring its potential usefulness. Given that the average age of the participants was 72.88 years and that many had only beginner-level technological knowledge, the completion of tasks indicates a promising level of user-friendliness. These insights suggest that with some refinements, the assistant could become a highly effective tool for its intended audience.

6 Conclusions and Future Work

As we reach the final chapter of this project, we will draw conclusions based on our research and development efforts. This chapter will also provide a brief discussion of potential future work in this area, by identifying areas for improvement and proposing further advancements based on answers obtained. We hope that by identifying areas for improvement and proposing further advancements, we continue to help serve the seniors, promoting their health, independence, and overall quality of life.

6.1 Conclusions

In this report, we introduce an innovative virtual assistant designed to help seniors maintain their independence and autonomy. This assistant provides guided, step-by-step assistance for meal preparation, tracks pantry inventory, sends email reminders for products nearing expiration, and allows users to create shopping lists to ensure they do not forget essential items while shopping.

Our development process followed a user-centered design approach, enabling us to create a system that closely aligns with users' real needs, based on their feedback from the early stages. Following the implementation phase and tests with target users, we gathered several insightful conclusions.

Firstly, the overall score we obtained on the System Usability Scale (SUS) was 51. While this score is on the lower end of the spectrum, it is noteworthy considering the context. The average participant was around 73 years old with minimal to no technology experience. Despite finding the tasks challenging, participants recognized the system as a highly needed tool and appreciated its purpose.

This project has aggregated significant value to Casa Viva+ and will undoubtedly contribute to the next phase of this initiative, promising to be of great importance for the future of our aging population.

Proving that the role of technology is essential for this group to maintain their independence and autonomy. We hope the development of such resources does continue and becomes a reality in the near

future, not only creating the much-needed attention this part of the population needs but also to keep them active.

Before concluding this subsection is important to note, we also developed doxygen documentation, which we briefly mentioned above. Given we believe this project has only started, and thinking of the future development of it, we decided this would be the best approach.

6.2 Future Work

Based on the User Centered Design, we successfully completed one cycle. Moving forward, the adequate steps would be defining new scenarios, gathering new requirements, and incorporating feedback from the survey participants, thereby allowing for continuous improvements and refinements. Below, is a list of some of the improvements we could carry out, based on the users' suggestions and our own ideas.

- **Creation of a timer** – Would help in the preparation of some recipes where a certain time is needed between steps, making the assistant a lot closer to the senior.
- **New way to start interaction** – Given that the interaction always starts with an activation word, some seniors find it tiring and suggested a new way to interact, either a push to talk button, or a "start" button.
- **New way for the assistant to capture the user's intent** – Due to the different pace some people speak at, starting and interacting with the assistant was not always the easiest task, therefore, finding a new way to capture the user's intent by amplifying the time of capture or calculating metrics behind the speech of each individual.
- **Adjust recipe quantity** – Despite referring this possibility in the early stages, we abandoned the idea for not being a priority. As of now we believe would be a great feature to add to the assistant, given some of the seniors do not leave alone and they would love the freedom to cook for friends and family despite the amount of people.
- **New ways to interact with the system** – Given that the architecture was built to be intermodal, it is easy to assume that in the future gestures/touch might be incorporated in the use of the assistant.
- **The assistant gives nutritional information** – Assistant could give the nutritional values of an item and let the user know if it is adequate for them to consume based on their health information.
- **Adjust meal plans based on user profile** – Based on the information of the user, the system should be able to suggest or limit the recipes displayed, to further improve the user's health. Further ahead, we could incorporate a role for an external caretaker/caregiver to provide the assistant with some guidance on the older adult's health/diet.

6.3 On going work

Before concluding this report, there are a few important updates we would like to share. Recently, we modified the assistant to accommodate our participation in the students@deti showcase. Given that our assistant operates primarily through voice input and the event space will be crowded, we decided to incorporate a keyboard interaction feature. This adjustment suppresses the need for voice commands, allowing participants to test out our system effectively in a noisy environment.

Another significant development is the creation of doxygen documentation, which we briefly mentioned earlier. We believe this project is still in its early stages, and comprehensive documentation will be crucial for its future development. Therefore, we decided that adopting doxygen would be the best approach to ensure clear and thorough documentation.

Additionally, our supervisors provided us with the opportunity and encouragement to write and submit a paper to a conference related to the theme of our project. The conference, DSAI 2024 — 11th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, will take place in Dubai from November 13th to 15th, 2024. This opportunity not only validates the importance of our work but also allows us to share our findings and innovations with a broader audience.

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8 Appendix

Appendix A - First Scenarios

The Assistant helps manage the stock of food products

Mr. Mário: Viva! Vou às compras,podes dizer-me o que me falta na depensa?

Kitchen Assistant: Na despensa faltam ovos, cebolas, arroz e no frigorifico falta queijo e iogurtes - o assistente envia por msg a lista de compras –

Mr. Mário: - chega das compras – Adiciona com o scanner os produtos que comprou.

The Assistant notifies three days in advance of products with approaching expiration date

Mr. Mário: Viva! Quero saber que produtos tenho perto de acabar a validade.

Kitchen Assistant: Tem os seguintes produtos (...) acabam a validade nos próximos 3 dias.

The Assistant helps manage the stock of food products

Mr. Mário: Viva! O meu médico disse que tenho colesterol alto, podes-me ajudar a trocar alguns produtos que tenho consumido?

Kitchen Assistant: Analisando o que tem na despensa deveria comprar fruta e abacate. Não deveria comprar bacon, bolachas ou carne vermelha. Fico feliz por ter ajudado, estou disponível sempre que precisar.

The Assistant suggests recipes with the requested ingredient

Mr. Mário: Viva! Tenho de fazer o almoço e preciso de ideias, sendo que me apetece frango.

Kitchen Assistant: Eu sugiro que faça a receita Frango à Brás.

Mr. Mário: Já fiz essa receita ontem.

Kitchen Assistant: Sugiro que faça Frango com Amêndoa.

Mr. Mário: Boa ideia, vamos começar a cozinhar.

Kitchen Assistant: Vamos então começar por ... (...) Receita completa, estou disponível sempre que precisar.

The Assistant adjusts the quantity of ingredients based on the number of people

Mr. Mário: Viva! Quero fazer feijoada para 10 pessoas.

Kitchen Assistant: Pode especificar o tipo de feijoada? Feijoada à Portuguesa ou Feijoada à brasileira?

Mr. Mário: Feijoada à Portuguesa.

Kitchen Assistant: Tem na despensa os ingredientes necessários para fazer a receita para 10 pessoas. Quando quiser podemos começar com a confeção da receita.

Mr. Mário: Muito Bem, vamos então começar.

Kitchen Assistant: - depois de todos os passos da receita - Receita completa, estou disponível sempre que precisar.

Appendix B - Structured Survey

Kitchen Assistant for Active Ageing at Home

Público-Alvo:

População mais envelhecida.

Objetivo

Obter informações sobre como um assistente virtual poderá ser útil na cozinha. Sendo que o propósito do assistente é auxiliar nas tarefas da cozinha com alertas sonoros e conversação (Receitas, inventário de alimentos).

Nota:

O inquérito é feito de forma anónima.

Idade

_____

Género.

☐ Masculino ☐ Feminino

Vive Sozinho ou Acompanhado?

☐ Sozinho ☐ Acompanhado

Responda Sim/Não consoante a sua opinião

1.Se tiver produtos alimentares a terminar o prazo, gostaria que o assistente virtual o notificasse com 3 dias de antecedência?

☐ Sim | ☐ Não

2.Seria útil ter um dispositivo que pudesse fornecer receitas e orientações passo a passo durante a confeção da receita?

☐ Sim | ☐ Não

3.Gostaria de ter a ajuda de um assistente para ajustar as receitas consoante o número de pessoas para as quais vai cozinhar?

☐ Sim | ☐ Não

4.Se tivesse uma funcionalidade para saber quais os ingredientes que tem na despensa, usaria?

☐ Sim | ☐ Não

5.Gostaria que o assistente enviasse uma mensagem com a lista de produtos em falta?

☐ Sim | ☐ Não

6.Quão útil pensa que um assistente virtual seria para preparar e confecionar uma receita?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inútil Extremamente útil

Kitchen Assistant for Active Ageing at Home

Continuação...

7.Quão útil seria saber os produtos que costuma comprar e que estão em falta na sua despensa?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inútil Extremamente útil

8.Quão útil seria uma ferramenta que lhe desse alertas quando os itens que tem na despensa estão próximos do prazo de validade?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inútil Extremamente útil

9.Quão útil seria a ajuda do assistente (em termos de deficiência móvel, questões de tempo, etc...)?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inútil Extremamente útil

10.Quão útil seria se o assistente ajudasse na gestão das suas preferências alimentares e restrições dietéticas?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Inútil Extremamente útil

Tendo em conta a sua experiência do dia-a-dia na cozinha, responda as seguintes perguntas

11.Quais quais funcionalidades pode um assistente ajudar nas tarefas?

_____

_____

12.Qual a tarefa que sente que precisa de ajuda de alguém?

_____

_____

13.Qual a ação que gostaria de ver implementada?

_____

_____

14.Gostaria de ter ajuda nos passos culinários? Ou eventualmente ter a indicação para interação com eletrodomésticos?

_____

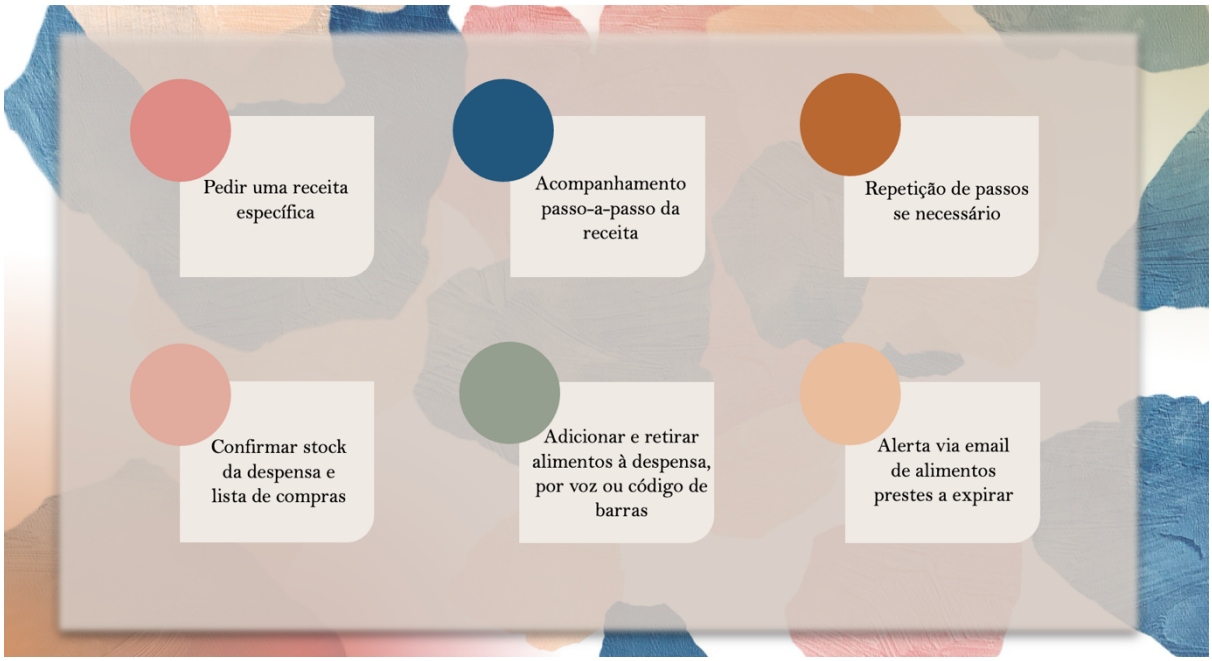
_____

15.Tem alguma preocupação em relação à privacidade e segurança ao usar um assistente?

_____

_____

Appendix C - Assistant's main abilities slide for the Usability and Acceptance Survey



Appendix D - Informed Consent

Enquadramento:
O estudo "Casa Viva+: Kitchen Assistant for Active Ageing at Home" está enquadrado no projeto "Casa Viva+".

Equipa de Investigação:
Inês Águia, Pedro Carneiro, David Palricas (alunos), Nuno Almeida, Ana Rocha, António Teixeira (orientadores)

Objetivo do Estudo:
O principal objetivo do estudo é investigar qual a viabilidade, e o respetivo impacto de utilizar um assistente virtual. Servindo este, para o acompanhamento na confeção das receitas, gestão do stock da despensa e respetivas datas de validade e lista de compras.

População-Alvo:
O estudo destina-se a pessoas sem problemas graves de saúde com idade superior a 45 anos.

Procedimento Específico:
Este estudo implica a realização de tarefas específicas pelo participante, seguidas da avaliação da dificuldade enfrentada em cada tarefa. Após a conclusão das tarefas, será solicitado ao participante para preencher um questionário sobre sua experiência de utilização do assistente. Além disso, serão recolhidas informações das interações com o assistente, tais como a maneira como o participante interage com ele, e vice-versa.
Será também pedida, a idade e o género do participante por uma questão de estatística. No entanto, nenhum dado que o possa identificar diretamente será recolhido.

Duração:
O presente estudo terá uma duração aproximada de 20 minutos.

Natureza Voluntária da sua Participação:
A sua participação é voluntária, pelo que poderá optar, a qualquer momento, por desistir do estudo, sem que daí advenham quaisquer prejuízos ou consequências.

Riscos e Benefícios Associados:

Este estudo não implicará qualquer risco físico e/ou emocional e não envolverá contrapartidas financeiras. Com a participação neste estudo estará a contribuir para o desenvolvimento de uma solução para que uma população mais envelhecida possa manter a autonomia na preparação das suas refeições por meio de indicações visuais e por voz.

Confidencialidade e Anonimato:
A informação fornecida ou quaisquer dados recolhidos ao longo deste estudo serão usados apenas para fins de investigação científica. Todos os dados recolhidos são anónimos, isto é, não permitem a identificação direta ou indireta do participante, estando assim salvaguardada a total confidencialidade das informações recolhidas.

Responsáveis pelo Tratamento, Acesso e Partilha dos Dados Anonimizados:

Todos os elementos da equipa de investigação indicada acima têm acesso à base de dados anónima e são responsáveis pelo seu tratamento. A base de dados também poderá ser partilhada com revistas internacionais e outras publicações e apresentada em congressos científicos e outros eventos.

Contactos/Esclarecimentos:
Agradecemos a sua participação neste estudo. Caso deseje obter informações adicionais sobre este estudo, poderá contactar os responsáveis pelo estudo Nuno Almeida (nunoalmeida@ua.pt) e Ana Rocha (aprocha@ua.pt). O estudo dá cumprimento ao estipulado no Regulamento Geral de Proteção de Dados (RGPD), garantindo a segurança e confidencialidade de todos os dados facultados pelos participantes, em todas as fases do processo. O estudo segue também as recomendações da Declaração de Helsínquia para a investigação científica.

***Declaro que:**

Tenho 45 anos ou mais, que tomei conhecimento do objetivo do estudo e do que tenho de fazer para participar no mesmo. Declaro também que tive oportunidade de ler na íntegra este consentimento informado, que o considero explícito e que concordo com o seu conteúdo.
Fui informado/a que tenho o direito de recusar participar ou desistir em qualquer momento do estudo, e que essa recusa ou desistência não terá consequências para mim.
Foi-me garantida a confidencialidade da minha participação neste estudo.

Assim declaro participar na presente investigação, conduzida em estrita obediência ao Regulamento Geral da Proteção de Dados e da sua Lei de Execução Nacional.

Escolher uma das seguintes respostas
Apenas aceitando os termos e condições validaremos as suas respostas às questões que se seguem.

- ○ Aceito
- ○ Não Aceito

Appendix E - Usability and Acceptance Survey

Informações Pessoais

*Idade:

Neste campo só é possível introduzir números.

*Género:

Feminino | Masculino

*Qual a maior ou maiores dificuldades que encontrou na execução das tarefas no sistema?

*Quais são os pontos mais fortes ou as mais valias que o sistema possui, com base na sua experiência?

*Concorda que este sistema pode ser uma mais valia no auxílio da preparação de refeições e na gestão do stock da despensa e da lista de compras?

Informações Adicionais

*Vive Sozinho/a?

Sim | Não

*Tem dificuldades auditivas?

Sim | Não

*Tem dificuldades visuais?

Sim | Não

*Qual é o seu grau de conhecimento tecnológico? Assinale a opção que melhor o/a representa.

Escolher uma das seguintes respostas

- Iniciante
- Intermédio
- Avançado
- Especialista

*Já teve contacto com algum assistente virtual? Assinale a opção que mais se adequa.

Escolher uma das seguintes respostas

- Nunca
- Poucas vezes
- Frequentemente
- Diariamente

Seja o mais honesto/a possível nas respostas, todas as informações fornecidas são vitais para o melhoramento do sistema.
Por favor, leia com atenção as seguintes questões, e em caso de dúvida, solicite ajuda.

*Escolha com base na escala de 1 a 5 (sendo **1 - Discordo totalmente, 2 - Discordo, 3 - Neutro, 4 - Concordo, 5 - Concordo Totalmente**), o número que melhor representa a sua opinião.

	1	2	3	4	5
Acho que gostaria de utilizar este produto com frequência	○	○	○	○	○
Considerei o produto mais complexo do que necessário	○	○	○	○	○
Achei o produto fácil de utilizar	○	○	○	○	○
Acho que necessitaria de ajuda de um técnico para conseguir para utilizar este produto	○	○	○	○	○
Considerei que as várias funcionalidades deste produto estavam bem integradas	○	○	○	○	○
Achei que este produto tinha muitas inconsistências	○	○	○	○	○
Suponho que a maioria das pessoas aprenderia a utilizar rapidamente este produto	○	○	○	○	○
Considerei o produto muito complicado de utilizar	○	○	○	○	○
Senti-me muito confiante a utilizar este produto	○	○	○	○	○
Tive que aprender muito antes de conseguir lidar com este produto	○	○	○	○	○

*Classifique a dificuldade de cada uma das tarefas executadas com base na escala de 1 a 5 (sendo **1 - Fácil, 2 - Baixo, 3 - Moderado, 4 - Difícil, 5 - Muito Difícil**)

	1	2	3	4	5
Tarefa 1: Peça ao assistente uma receita de mousse, percorra a mesma, e após os dois primeiros passos peça ao assistente que repita o último. Continue a receita até completá-la.	○	○	○	○	○
Tarefa 2: Adicione os dois artigos que se encontram à sua frente à despensa. Peça agora ao assistente para retirar um deles e confirme o stock.	○	○	○	○	○
Tarefa 3: Pergunte ao assistente se têm em stock arroz, se não tiver peça-lhe que o adicione à lista de compras.	○	○	○	○	○