RadarID: Radar-Based User Identification in Smart Environments

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Abstract

This report introduces the early stage of our RadarID project, which will explore using radar and sensor technology for human identification in smart environments. We focus on an extensive literature review and conceptual development at this preliminary stage without any experimental results or implementation.

Our approach centers around the user-centered methodology, making our technology deeply intertwined with understanding and addressing the specific needs of target users. The RadarID system aims to profile a wide range of humans by identifying and comparing various human movements and interactions. However, the practical validation of these capabilities will be subject to empirical testing and research in the upcoming phases of the project.

Our current work on the RadarID project focuses on indoor scenario analysis and developing user personas to define system requirements. We are also conceptualizing the system's architecture to help us better understand how it can be integrated seamlessly with existing infrastructure and adapt to various environmental conditions. Our goals are to achieve accurate results, make them reliable, and improve current practices in human identification technology.

Keywords: radar systems, human identification, smart homes, machine learning

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Acronyms

mmWave Millimeter-Wave

UWB Ultra-Wideband

MWDR MicroWave Doppler Radar

FFT Fast Fourier Transform

CNN Convolutional Neural Network

RF Random Forest

FMCW Frequency Modulated Continuous Wave

Bi-LSTM Bidirectional LSTM

NBC Naive Bayes Combiner

KNN K-Nearest Neighbor

SVM Support-Vector Machines

W3C MMI W3C Multimodal Interaction

AM4I Adaptive Multiplatform Multidevice Multilingual Multimodal Interaction

FR Functional Requirements

NFR Non-functional Requirements

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Chapter 1

Introduction

1.1 Context

In the contemporary era, our living spaces are transitioning into intelligent environments capable of collecting detailed data about their inhabitants. Some devices incorporate a variety of sensors that retrieve information about the space itself and the individuals within it. Many sensors, such as microphones, motion detectors, and biometric scanners, contribute to a comprehensive data set.

Microphones can pick up audio data, potentially capturing conversations and ambient sounds. Motion detectors register movement within the space, providing insights into the occupants' activities. Biometric scanners, including facial recognition technology, can identify individuals and track their movements. These sensors collectively contribute to a wealth of information that reflects the people's behaviors, preferences, and routines in these intelligent environments.

The implications of such data collection raise privacy, surveillance, and consent concerns. Striking a balance between the benefits of enhanced functionality and the protection of personal privacy is a critical aspect of designing and implementing these intelligent systems. As we navigate this technological landscape, we must consider ethical standards and legal frameworks to ensure the responsible and transparent use of the gathered data.[1]

1.2 Motivation

In the broader context of intelligent environments, our motivation is centered on achieving effective individual identification, a fundamental aspect for realizing the full potential of smart spaces. This potential involves recognizing people, adapting interactions to individual preferences, and improving security by detecting guests or unfamiliar individuals. As smart homes offer a wealth of information, the actual value lies in linking these data to specific individuals, particularly in shared spaces. The work aspires to contribute to the responsible and transparent integration of technology into homes, fostering adaptability, security, and personalized interactions.

1.3 Challenges

Human identification has long been a domain that presents substantial data acquisition and security challenges. Privacy concerns are one of the public's main drawbacks, especially when the data acquisition involves recording visual data. Therefore, an improvement to this drawback might rely on radars since they do not capture images of the humans subject to identification. However, this alternative approach introduces its own set of challenges.

Radars are primarily employed to detect and track objects based on their different attributes, such as position and velocity. An attempt to repurpose radars to perform human identification is a complex task that requires specialized technologies such as biometrics.

Designing an effective radar system for human identification poses a multifaceted challenge. Determining the optimal number of radars required, single or multi-radar setup, is essential. With each radar comes the concern of strategically placing them within a given space, range, and sensitivity.

Furthermore, the absence of protection for sensitive information gathered by the radar would only escalate the public's concern about privacy. The system must be designed to safeguard the data collected to avert this.

The performance of radar-based identification can be affected by various environmental factors such as furniture layout, multiple people in the same space, and non-human movements (like pets). Overcoming these interferences is essential for the system's good performance.

Another challenge is ensuring compatibility and seamless integration with various existing smart home technologies and systems. Therefore, it is essential that the system is adaptable and flexible to work in diverse settings.

1.4 Objective

The primary objective of this project is to develop a system that utilizes radar technology to identify individuals accurately. This involves detecting a person's presence and obtaining unique characteristics that distinguish one individual from another. We aim to achieve accurate results in identification, thereby reliable, where we can monitor people and adapt the interaction with the house for each user. We also want to distinguish between people who live there from guests or intruders.

1.5 Expected Results

The expected outcomes of our project include the successful development of a prototype radar-based solution for human identification utilizing methods to extract relevant data. Then use that data to obtain and train using machine-learning a model that identifies users within a smart environment.

We anticipate the prototype to be able to distinguish residents, guests, and potential intruders, facilitated by algorithms for prompt and accurate radar data processing.

Privacy compliance is a fundamental aspect of our design,therefore the prototype should be crafted to adhere to privacy standards and safeguard user information.

Moreover, the architeture of system should be able to add or be improved by new modules, without making significant changes on the main architecture, allowing for broader adoption and practical implementation in diverse settings.

The prototype is intended to lay the foundation for future enhancements and explore more sophisticated applications of radar technology within smart environments.

1.6 Document Structure

This report initiates with chapter 2, an overview of the current state-of-the-art. This chapter synthesizes critical studies, summarizing their findings on human tracking, vital sign detection, and identification systems. And also a literature review. Subsequently, our exploration extends to the literature that provided critical insights that supported the selection of tools and technologies for developing our solution.

chapter 3 includes detailed personas and scenarios that act as the guiding compass for system development, enabling us to extract both functional and non-functional requirements.

The chapter 4 initiates a detailed exploration of the proposed system architecture. Starting with a holistic system overview, we break down the user identification modality and delve into the intricacies of model evaluation and training.

Chapter 2

State-of-the-Art

This chapter begins with an overview of the current state-of-the-art. Within this chapter, we synthesize critical studies, summarize their findings on human tracking, vital sign detection, and identification systems, and conduct a literature review. We also delve into the literature that provided critical insights supporting the selection of tools and technologies for developing our solution. This chapter serves as a reference point for existing knowledge related to our topic, reiterating the relevance of our work.

2.1 Related Work

Before we started working on our project, we looked into many articles. This search helped us learn more about how radar is used for identification, showing us different ways it is applied. Below, we share six important examples from our research that helped shape our project, showing radar technology's variety and technical details.

Our method involved a research process using specific keywords related to radar technology and human identification. We applied filters to narrow our search, focusing on articles from the last decade to ensure their relevance and currency. Additionally, we selected articles that explicitly utilized radar technology, a criterion emphasized to ensure alignment with the goals of our project. This strategic approach contributed to the selection of articles that significantly influenced the development of our project.

2.1.1 Studies Summary

Table 2.1 summarizes the articles read, analyzed, and considered relevant to our project. Through observation of the different kinds of articles, we are capable of concluding the diversity of elements of every paper, such as the usage of different types of radars like the Millimeter-Wave (mmWave), the Ultra-Wideband (UWB), the MicroWave Doppler Radar (MWDR) and the

Frequency Modulated Continuous Wave (FMCW) and its distance from the subject being analyzed. In that case, it was used distances between 1 meter and 5 meters.

Even though the studies cannot be directly compared, since they are diverse from the data acquisition to the validation of methods, the accuracy is predominantly high, ranging between 90% and 99%.

Reference (Year)	**Radar Type**	**Algorithm**	**Distance from Radar**	**Accuracy**
Wankhade at al. [2] (2022)	UWB	Fast Fourier Transform (FFT), Convolutional Neural Network (CNN), Random Forest (RF)	1.5 m, 3 m and 5 m	94.38% (two targets) and 73.33% (three targets)
Zhao at al. [3] (2021)	mmWave	FFT, Hungarian Algorithm, DBSCAN	-	99%
Li at al. [4] (2021)	FMCW	Trilateration Algorithm, Bidirectional LSTM (Bi-LSTM), Naive Bayes Combiner (NBC), RF	-	93%
Kang at al. [5] (2021)	Microwave Doppler radar	Levenberg–Marquadrt back propagation, CNN	1.5 m	90%
Hämäläinen at al. [6] (2021)	UWB	Trilateration Algorithm, Bi-LSTM, NBC	3.1 m to 4.3 m	99%
Islam at al. [7] (2020)	mmWave	Levenberg - Marquardt Back Propagation Algorithm, K-Nearest Neighbor (KNN), Support-Vector Machines (SVM)	-	95%

Table 2.1: Summary of the selected related works on Human identification, including information regarding Radar Type, Algorithm, Distance from Radar and Accuracy.

2.1.2 Detailed analysis of the articles

In this subsection, we provide detailed summaries of each article listed in Table 2.1, dedicating a unique subsubsection to each article.

2.1.2.1 Human tracking and identification through a millimeter wave radar

In this paper [3], a novel human tracking and identification system named mID is introduced, utilizing mmWave radar technology. This system addresses privacy concerns associated with visual tracking methods by using a non-intrusive radar approach. The mmWave radar, a single chip device operating in the 77-81 GHz band, is capable of penetrating thin materials, allowing it to be concealed in furniture or walls, thus enhancing user acceptance. mID generates sparse point clouds to create trajectories and employs a deep recurrent neural network for person identification, achieving an identification accuracy of 89% and intruder detection accuracy of 73% for 12 individuals. By extending observation time from 2 seconds to 7 seconds, identification accuracy increases to 99%. This research demonstrates the effectiveness of mmWave radar in accurately tracking and identifying individuals, providing a promising solution for non-intrusive identification in smart spaces.

2.1.2.2 Multiple Target Vital Sign Detection Using Ultra-Wideband Radar

This paper [2], introduces an advanced radar-based method for detecting multiple living beings through walls or under debris, overcoming the limitations of traditional single-target detection. Utilizing UWB radars, the method employs FFT for identifying the number of targets and their breathing frequencies. A novel aspect is the use of a CNN for faster pre-processing and classification of the number of targets. The research demonstrates that combining CNN as a feature extractor with a RF classifier yields high accuracy rates: 94.38% for two targets and 73.33% for three targets, without needing pre-processing of radar data. This approach significantly reduces detection time compared to conventional algorithms and offers a reliable and efficient solution for vital sign detection in rescue operations, with potential for future expansion to more targets and diverse wall structures.

2.1.2.3 Sequential Human Gait Classification With Distributed Radar Sensor Fusion

The paper [4], presents a study about the classification of human gait patterns and fall detection through the usage of a network of radar sensors, such as: FMCW radar and three UWB pulse radars.

In the research it's used different patterns of gait, individual and sequential, involving multiple walking styles. Different information fusion approaches are used in the study, operating at signal and decision levels. In signal-level fusion, a trilateration algorithm is implemented using range data from three UWB sensors, yielding good classification results with a Bi-LSTM neural network classifier, without relying on micro-Doppler information. In decision-level fusion, the classification results of individual radars using the Bi-LSTM network are combined using a robust NBC, showing improvements compared to using a single radar. The dataset has 14 participants and 12 different walking styles, achieving overall classification accuracy of 93% and 90% for the two fusion approaches.

2.1.2.4 Identification of Human Motion Using Radar Sensor in an Indoor Environment

This paper [5], introduces an approach to continuous motion analysis through the utilization of mmWave radar sensor data. By capturing distinct patterns in human motion without requiring direct physical contact or line-of-sight, the proposed technique addresses privacy concerns associated with camera-based sensors.

Several experiments were conducted using a small radar sensor operating in the mmWave band with high range resolution. The integration of the developed technique with camera sensors is intended for indoor movement detection and monitoring. This integration provides a great solution for identifying and tracking human motion in different environments. This work signifies an advancement in radar-based motion analysis, showing the potential for improved indoor monitoring.

2.1.2.5 Ultra-Wideband Radar-Based Indoor Activity Monitoring for Elderly Care

This paper [6], introduces a remote monitoring architecture designed for the seamless monitoring of elderly citizens in their homes, employing UWB radar as the primary sensing device. Using an experimental approach, the study shows the extraction of diferent kinds of movements (walking, falling), steady positions (standing, sitting,) and other things like breathing, and coughing from the collected UWB radar data. The paper uses a k-nearest neighbor machine learning algorithm to automatically discriminate and classify static postures, achieving a classification accuracy consistently exceeding 99%. The study was made only with one device per room, striking a balance between implementation cost and achieved detection accuracy.

2.1.2.6 Radar-Based Non-Contact Continuous Identity Authentication

The paper [7], explores the usage of microwave Doppler radar in continuous identity authentication, offering a non-contact, privacy-preserving alternative to traditional biometric methods. This technology captures unique physiological signatures without direct physical contact or line-of-sight, this way addressing privacy concerns from video-based sensors. It's reviewed various studies employing Doppler radar for detecting individual-specific patterns in respiration and heart dynamic, to demonstrate the importance in employing radar for continuous monitoring and authentication. The Doppler radar systems operate at frequencies that detect skin-surface motion (primarily), being able to discern subtle physiological movements caused by heartbeat, respiration, or arterial pulsation. The singularity of cardiopulmonary motion, influenced by individual physical characteristics and neural or chemical control, makes it a reliable marker for identity verification.

Challenges and future potential of this technology are examined, particularly its application in diverse and practical settings, and the need for a larger dataset validation with different physiological states and activities. The integration of machine learning and big data analytics amplify the effectiveness of radar-based authentication, potentially evolving how continuous identity verification is conducted in various domains.

2.2 Tools and Technologies

In our project, we plan to use a FMCW radar, model AWR1642 from Texas Instruments, and we will also utilize the W3C Multimodal Interaction (W3C MMI) and AM4I frameworks for the seamless integration and interpretation of radar data in our smart environment system.

2.2.1 Radars

Radars are systems that use radio waves to detect, locate, and track objects. The term "radar" stands for "radio detection and ranging". These systems play a crucial role in various applications, including military, aviation, weather monitoring, and traffic control. There are different types of radars, and one notable example is the FMCW radar, such as the AWR1642 model.

The AWR1642 FMCW radar operates by emitting a continuous wave signal whose frequency varies in a known pattern over time. This signal, upon encountering an object - such as a person - is partially reflected back towards the radar. The radar then measures the difference in frequency between the transmitted signal and the received signal. This difference, known as the frequency shift, is used to calculate the distance to the object based on the time it takes for the signal to return. Moreover, by analyzing the frequency shift over time, the radar can also determine the speed and direction of the object's movement.

One of the key advantages of the AWR1642 radar is its high-resolution capabilities, enabling it to detect even subtle movements, such as human breathing. The AWR1642 radar's advanced sensing capabilities will be instrumental in accurately identifying and tracking people within a given space.

This radar technology offers precision and reliability, key factors in environments where real-time monitoring is crucial.

2.2.2 Multimodal Interaction Architectures and Frame- works

Multimodal Interaction Architectures and Frameworks are essential for navigating the intricacies of contemporary smart environments. These frameworks provide a distributed and modular solution, fostering seamless interaction among systems, devices, and sensors. Their core strength lies in adeptly supporting and integrating diverse communication methods, adapting to evolving contexts and user preferences.

These architectures facilitate the development of multimodal interactions, enabling users to engage with their environment through various channels like speech, gestures, or touch. They streamline the integration of different devices, dynamically managing them as they evolve. Designed to evolve with emerging technologies, these frameworks serve as versatile solutions for smart homes, buildings, and cities.

A noteworthy example is the AM4I framework, which stands out for its practical approach in implementing multimodal interactive capabilities. This framework efficiently manages input and output modalities through an Interaction Manager, equipped with Fusion and Fission services, delivering a cohesive user experience

The AM4I framework ensures flexibility and seamless integration, essential for modern smart spaces. It allows various elements, such as sensors and interaction devices, to operate independently or in unison, creating a cohesive smart ecosystem. Notably, the AM4I architecture is designed to evolve with emerging technologies and interaction designs, making it future-proof.

Built on this architecture (Figure 2.1), the AM4I framework provides a practical approach for implementing multimodal interactive capabilities in smart environments. It manages various input and output modalities through an Interaction Manager, equipped with Fusion and Fission services, offering an integrated user experience. Notably, the framework's multi-device capability supports a wide range of devices, from smartphones to environmental sensors, across different operating systems like iOS, Windows, Android, or Linux.

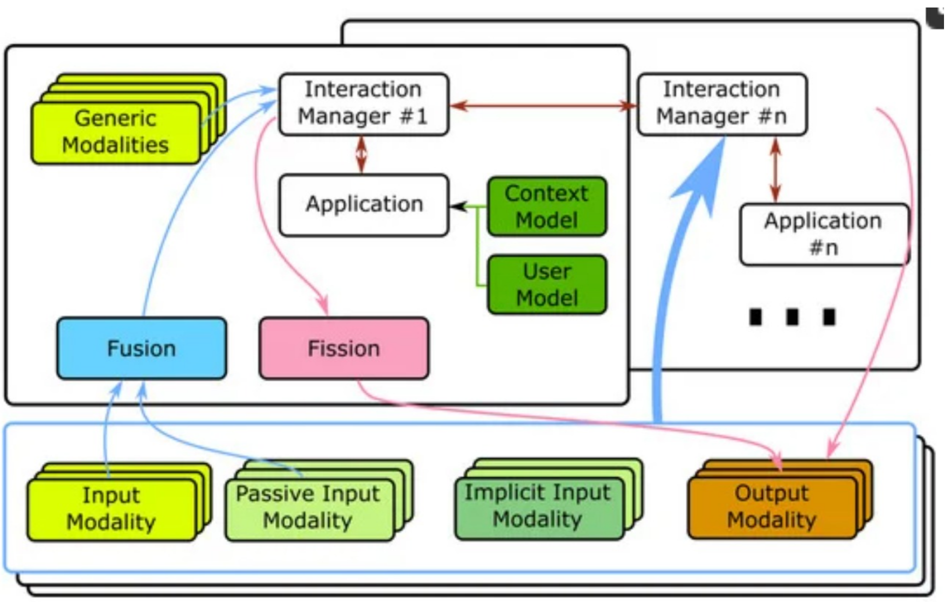

Figure 2.1: AM4I proposed architecture with the core modules. [8]

Chapter 3

Requirements Gathering

This chapter explores the methodologies used in the requirements gathering. We adopted a user centered design approach, analyzing a group of individuals primarily consisting of family and friends. Following this, we crafted personas based on the insights gathered from those interviews. These personas were instrumental in developing scenarios aimed at addressing each persona's specific challenges, utilizing innovative ideas we conceived. Subsequently, we meticulously analyzed these scenarios to identify and extract key elements that needed to be integrated into our project.

3.1 Personas and Scenarios

To help understanding the needs, interests, and behaviors of potential clients, we depicted a variety of personas with diverse physical and psychological attributes, representing members of a typical family. The personas include a grandmother, a father, a mother, and a son.

The main goal is to understand how the members of this family would use and interact with the system. By having different profiles of personas and different scenarios we can extract what are going to be the requirements of this system.

3.1.1 Personas

Our goal is to develop a system capable of catering to a broad range of individuals, encompassing diverse demographics and unique needs. By creating four personas representing a family, we can effectively address the varied requirements of potential users.

To define these four personas we were inspired by discussions with individuals who possessed enough qualities to be considered target users. Our engagement ranged from colleagues to members of the families of those directly involved in the project. This approach ensured that, while adhering to our predefined criteria for potential customers, there remained a margin for differentiation based on various attributes, including age and other physical traits. The diverse user representation and personalized user experiences was vital in obtaining precise and well-articulated requirements.

Luísa

- Mrs. Luísa, an elderly woman, was born in a village in Guimarães, where she has lived her entire life without the advancements of technology. She stands out as an independent and persistent person who prefers to manage without assistance. However, due to her health issues, her son encouraged and convinced her to leave her home and move in with the family, where her physical condition can be better attended to. The doctor recommends that she engage in physical exercise throughout the day. However, both the doctor and the family doubt her compliance with the prescribed activities. Consequently, she was provided with a smartwatch to monitor and record her physical activities throughout the day. Due to her limited computer knowledge, Mrs. Luísa struggles to understand how to use the device and chooses not to use it.
- **Motivation:** As she is unable to record her daily progress through the recommended device, she seeks another method to track her activities. This way, she can demonstrate to her family and the doctor that she has fulfilled the prescribed requirements.

Ricardo

- Mr. Ricardo, son of Mrs. Luísa, is an adult man who spends most of his day working as a teacher. He is known for being dedicated and cautious, preferring prevention over exposing himself to risks. Recently, his son gained the privilege of carrying the house keys, despite his father having some concerns about it. Among these concerns, he emphasizes the ease with which his son could lose his belongings, posing a danger to the entire family. This insecurity troubles him, and Mr. Ricardo is currently considering the possibility of revoking the rights previously granted to his son.
- **Motivation:** As he doesn't want to sadden his son, Mr. Ricardo is looking for a security system that allows him to distinguish his family from intruders. He seeks solution that empowers him to react promptly to dangerous events, thereby reducing his concern about his family's safety.

Maria

- Mrs. Maria, wife of Mr. Ricardo, is an adult woman who works as a preschool educator. She is known for being dedicated and patient, placing extreme importance on the happiness of children. Despite her passion for her profession, she considers it can be tiring at times, as the energy of children is occasionally expressed through excessive noise and restlessness. She views her home as a refuge of comfort and tranquility. However, she is constantly bothered when entering her home after a day of work, with the loud music played by her son.
- **Motivation:** As her son doesn't lower the volume of the music when Mrs. Maria arrives home, she wishes it were possible for the volume to automatically decrease without causing discomfort upon entering her sanctuary.

Pedro

- Pedro, the young son of Mr. Ricardo and Mrs. Maria, is a high school student. He is characterized as forgetful and irresponsible, despite his attempts to correct these traits. Recently, due to the absence of his parents who are busy with their professions, he was tasked with the responsibility of cooking dinner whenever he arrived home before them. However, due to habit and inconsistency in his parents' schedules, he often forgets to fulfill his duties.
- **Motivation:** As he doesn't want to disappoint his parents and maintain his bad habits, Pedro wishes to receive a notification whenever he doesn't stay in the kitchen for a short period, even when his parents aren't at home.

3.1.2 Scenarios

To illustrate the potential applications of our interaction system, we created specific scenarios for each family member. These situations showcase the various ways in which members of this family can interact with our system, taking into account their unique characteristics and motivations, as detailed in subsection 3.1.1.

We used the scenarios to extract the system requirements, which are indicated within parentheses in the scenarios themselves. The complete list can be found in section 3.2.

3.1.2.1 Healthy Commitment

Mrs. Luísa, with a steadfast commitment to adhering to medical advice, has decided to investigate alternative methods for monitoring her physical activities at home. Upon discovering a sophisticated motion radar system designed for indoor environments, she recognizes the potential to track her movements without the need for a smartwatch. This radar efficiently identifies her activity patterns and systematically documents her daily efforts without the need for personal identification. As a result, it provides her with a reliable means to demonstrate to her family and physician that she is faithfully adhering to the prescribed exercise regimen, all without leaving her home. As an integral part of this experience, she can, for example, use a tablet after a week of using the system, automatically accessing the control panel to show her family how her physical activity has increased throughout the week (3.2FR1, 3.2FR9).

3.1.2.2 Ensuring Security

Motivated by a deep concern for his family's safety, Mr. Ricardo chooses to install an intelligent home security system tailored for indoor use. Using a presence radar, he establishes a protected zone for his family. If the radar detects the presence of family members, it keeps the system in a deactivated state. However, if it identifies suspicious or unfamiliar movements, it autonomously triggers security protocols, notifying Mr. Ricardo and affording him the opportunity to promptly respond to any potential threat (3.2FR6, 3.2FR7). This approach allows him to safeguard his family without infringing upon his son's privilege of carrying the house keys, thereby fostering contentment among all family members in light of this positive change (3.2FR1, 3.2FR3, 3.2FR4).

3.1.2.3 Peaceful Home

Mrs. Maria, consistently prioritizing a tranquil home environment, decides to implement an intelligent volume control system inside her house. By installing a presence radar at the entrance, she configures the system to automatically lower the music volume upon her arrival (3.2FR8, 3.2FR4). This refined solution affords her the ability to enjoy personal comfort without the disturbance of excessive noise from her son. As a result, Mrs. Maria can maintain a peaceful atmosphere within her home, regardless of occasions when her son neglects to regulate the audio levels. This scenario emphasizes how personas, like Mrs. Maria, use and interact with the system to enhance their living environment (3.2FR1, 3.2FR2, 3.2FR3).

3.1.2.4 Culinary Commitment

In an unwavering commitment to meet his parents' expectations, Pedro decides to integrate an alert system into the kitchen. By installing a presence radar, he adeptly sets up notifications triggered in the event that he fails to remain in the kitchen for a specified duration. If this timeframe expire without detecting his presence, the system promptly sends an alert to his mobile device, reminding him of his culinary duties (3.2FR2, 3.2FR3, 3.2FR5). This thoughtful arrangement ensures that, even on days marked by erratic schedules, Pedro receives timely reminders to ensure a prepared dinner upon his parents' return home. This scenario illustrates how personas, like Pedro, use and interact with the system to enhance their daily routines within the household.

3.2 Requirements

Through the scenarios described in the section above, it was possible to establish an initial set of requirements that can guide us in the good development of the system, by analyzing key user needs and performance criteria. Functional requirements refer to the actions that the system must be able to perform. Non-functional requirements refer to the characteristics and/or qualities that the system must present. Below, you can find two tables presenting the Functional Requirements (FR) (Table 3.1) and Non-functional Requirements (NFR) (Table 3.2).

Functional Requirements	**Description**
FR1	Identify user movements.
FR2	Execute the action assigned by the user movement.
FR3	Identify the presence of one or more individuals at its place of use.
FR4	Identify and differentiate users based on their movement patterns.
FR5	Store movements and their respective actions to be executed.
FR6	Alert for the detection of unregistered individuals.
FR7	Data should be stored in local database.
FR8	Adjust the environment according to the detected user.
FR9	Record activities performed by a user.

Table 3.1: Functional requirements of the system.

Non-Functional requirements	**Description**
NFR1	Learn user movement habits and execute/identify those tasks more easily and autonomously.
NFR2	Must capture gestures within a certain distance (distance to be defined).
NFR3	Must request feedback from the user during the initial readings of a new gesture.
NFR4	Have a quick reading time for movements and task execution (time to be defined).
NFR5	Encrypt data before sending it to the database.
NFR6	The system must have a significantly long lifespan (time to be defined).

Table 3.2: Non-functional requirements of the system.

Chapter 4

System Architecture

In this chapter you can find the proposed architecture for this project and explanations for all the main blocks that we will be working with or developing.

4.1 System Overview

Based on the objectives for this project and the system requirements, we have defined the architecture illustrated in Figure 4.1. The architecture comprises two main blocks: the User ID Modality and the Model Evaluation and Training. The remaining components indicated by dashed lines are not the primary focus of our project. They are included to illustrate how our solution could integrate with other smart environment solutions, leveraging the user identification modality within a smart house environment.

Our system begins with one or more radars that generate data utilized by the User ID modality for identifying users based on their movement or interactions with the system. This modality relies on a pre-trained model, which undergoes a phase involving the evaluation of multiple models and the training of the selected final model. The output from the User ID modality is then transmitted through the Interaction Manager, instructing applications on actions to take based on user preferences.

The User ID modality is responsible for identifying the user using data from the radars. The Model Evaluation and Training block employ machine learning to train and assess models, with the best-performing model being selected for user identification.

As depicted in Figure 4.1, the information from the User ID modality is employed by the Device Manager to instruct the Home service in controlling the devices within the Smart House. For instance, when a user enters a room, specific devices can be turned on or off according to the preferences predefined by that user.

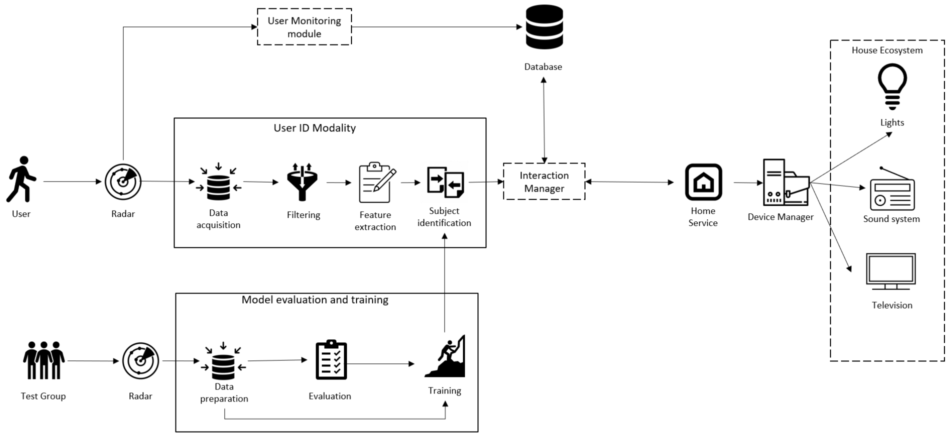

Figure 4.1: The architecture of the propose system and it´s main blocks (boxes with full lines) and other blocks that it can be implemented with (boxes with the dashed lines).

4.2 User modality

In the initial phase of the User ID modality, the primary objective is to collect user data through the radar. After acquiring user data, the subsequent crucial step involves filtering out any noise or irrelevant information. In the subject identification process, the system utilizes a pre-trained model and features extracted from the filtered data to output the IDs of the individuals from whom the data originates. This output is then transmitted to the home service through the Interaction Manager.

4.3 Model evaluation and training

In the subsequent offline pipeline, multiple potential models for user identification are evaluated based on a previously collected dataset. The dataset preparation involves a test group executing predetermined movements and other actions, which are captured by the radars. Following the evaluation, the method yielding the best results is selected, and the final model is trained using the complete dataset. This trained model is then employed in the User ID modality for online identification purposes.

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