



D6.1 Functional Requirements, Privacy Profiles for the Scenarios

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Executive Summary

The key objective of this report is to demonstrate functional requirements and ethical and privacy profiles of three HOLDEN applications in real cyber-physical system (CPS) scenarios: people/object detection in restricted areas, elderly care, and smart TVs. These applications are each derived from one of the three main HOLDEN technical innovations.

Section 1 of the report describes each HOLDEN innovation under development: static holography, dynamic holography and gesture recognition and situates the development of the project prior to choosing the three applications.

Section 2 explains three methodologies. The first is the multi-criteria decision analysis (MCDA) to choose the three applications from the three innovations. The second describes how the functional requirements were determined. The last methodology illustrates the translation of ethical criteria to ethics and privacy profiles.

Sections 3-5 of the report detail each CPS scenario with their functional requirements and ethical and privacy profile.

Section 6 summarizes main findings from this process and next steps. The findings of D6.1 will support Task 2.2 in developing the appropriation study, Task 6.2 in market analysis and Task 6.3 in the application scenarios. This report helps ensure that the design of the applications is guided by ethical and privacy considerations. D6.1 also serves as a preparatory report for the appropriation study provided in D6.8

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1. Introduction

This is a preparatory report for D6.8 “Results from the Appropriation Study.” For this reason, this report does not fully address appropriation, but instead raises questions and considerations that are relevant to the appropriation study. Moreover, in D2.3 “Privacy Analysis and User Requirements on Societal Implications of RF Sensing” we will cover how the technology will affect, mediate and shape human interactions and experience. Therefore, we refrain from deeper philosophical analysis in this report. Instead, we share the methodology for selecting application scenarios and ethical criteria and afterwards we introduce the functional and ethical profiles for each application.

1.1. Innovations

There are three main HOLDEN innovations each with their own work package. These innovations are WP3 Static Holography, WP4 Dynamic Holography, and WP5 Gesture recognition. They are described in brief below to provide more context for the applications that will be introduced later in the report. A more detailed overview of the innovations can be found in D8.9 “Ethics Status Monitor.”

1.1.1. *Static Holography*

Static holography uses ambient RF waves as a light source to capture images using receivers. This type of imagery is similar to that of airport scanners, except that airport scanners have built in wave emitters making the light source both brighter and known. To make such a system work, algorithms such back projection algorithms, or with enhanced performance linearized inverse source solving. Conductive objects (such as humans) are easier to see than dampening objects. This imaging works in the dark and through walls but has a blurry output. High resolution images take longer to create. Noticing that a difference exists between two scenes can be easier than distinguishing what is occurring in a snapshot. This technology does not use machine learning to generate imagery.

1.1.2. *Dynamic Holography*

Dynamic holography in this project consists of three features: localization and people counting; monitoring body movements, postures and activities; and 2D and 3D imaging of the (primarily indoor) environment. Localization and people counting works through walls and in dark and hazy environments. It also requires converting a pre-existing WIFI network (2.4GHz or above) and its signals into a sensing modality. The second feature requires machine learning and 5GHz radio signals or above to distinguish certain activities such as (but not limited to) running, walking, sitting down and standing up. The final feature of imaging can be done at 2.4 GHz and above and requires installing new units to emit and receive the RF waves.

1.1.3. *Gesture Recognition*

Gesture recognition works at varying angles, speeds and distances, regardless of the darkness or haziness of the environment. This technology is being developed to work in a variety of environments such as restaurants, factories, and through the wall. Spatial and temporal features of point clouds and machine learning are used to distinguish between gestures. These point clouds might contain privacy sensitive information.

1.2. From Innovations to Applications

Up till now HOLDEN has primarily focused on improving the capabilities of each innovation as well as developing privacy preserving technical capabilities. One could say that RF Holography is so far an enabling and promising technology, which in this project has been consistently guided by ethical considerations. This report marks the beginning of using the technology to develop applications that may be used in the real world. The following section outlines the methodology followed to choose the final three applications. After that functional requirements of each application are shared along with the ethical profile. These profiles will still be subject to change both for the betterment of the technology and to ensure the most ethical integration into society. Such considerations will be more thoroughly analyzed during the appropriation study.

2. Methodology

Identifying optimal applications for each Holden innovation and defining precise design requirements involved a structured, multi-criteria decision analysis (MCDA) guided by detailed assessment criteria. This approach enables us to effectively evaluate each application's feasibility, innovation potential, and practical impact in the market [1].

Decision theory in MCDA provides a framework for making decisions involving multiple, often conflicting criteria. It encompasses models, techniques, and principles that guide to identify and evaluate trade-offs, incorporate uncertainties, and make rational choices that align with their preferences or goals [2].

MCDA methods support this by structuring and quantifying the decision-making process, enabling a more systematic comparison of alternatives based on multiple criteria [3].

For the application selection, we followed WSM (Weighted Sum Model), which is a popular method within MCDA for evaluating and ranking options based on multiple criteria [4]. In WSM, each criterion is assigned a weight representing its importance relative to others. Each option is then scored on each criterion, and these scores are multiplied by the respective weights. The weighted scores for each criterion are summed to produce an overall score for each option. The option with the highest score is considered the best choice.

Drawing insights from key project documentation, including the Innovation Exploitation Document and ESM Report, we initially screened and figured out a wide range of potential applications. This review helped us narrow down promising applications relevant to diverse use case scenarios.

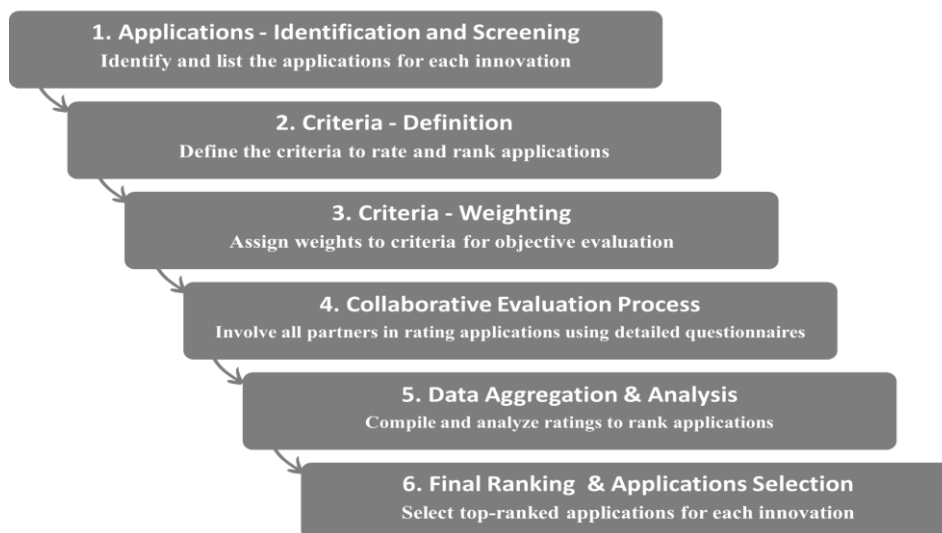


Figure 1 - Application Selection Process

2.1. Application Ranking and Selection

The evaluation process was designed to ensure inclusivity by involving all project partners in a structured and transparent rating system. Partners conducted independent evaluations, rating each application against a series of clearly defined sub-criteria, using a detailed questionnaire prepared for each application. This questionnaire enabled partners to assess the applications consistently according to the established criteria. To calculate the final scores, the Weighted Sum Model was applied, multiplying the weights assigned to each criterion by the individual scores provided by each partner. The applications were then ranked based on their total weighted scores across all criteria. The highest-scoring applications for each innovation were identified. This methodology ensured a fair, transparent, and comprehensive selection process, drawing on the collective expertise of all partners.

2.1.1. Capabilities

The capabilities of a technical innovation typically refer to the specific functionalities, features, and potential applications that the technology enables. Within the Holden Project, capabilities describe what is possible with the RF sensing innovations across three tiers of functionality. The first tier, static capabilities, focuses on detecting and localizing objects or people in a specific space, such as a room or controlled environment. This includes imaging static objects and individuals, both actively and passively, for applications like body imaging and metallic object detection, enabling precise mapping and localization. The second tier, dynamic capabilities, advances to monitoring and analyzing movement and activity, such as identifying and localizing intruders or individuals walking through, into, or out of rooms. This tier capabilities includes recognizing activities like walking gait, speed, and specific actions such as fall detection as well as body shape. Finally, the third tier, gesture recognition capabilities, elevates the technology to an interactive level by detecting gestures within indoor environments. This functionality enables control over smart appliances and systems, allowing users to interact seamlessly with their surroundings through intuitive gesture-based commands. Together, these innovations not only showcase the versatility and transformative power of RF sensing but also pushing the boundaries of applications ranging from enhanced security to smart living solutions.

2.1.2. Applications

The applications of RF sensing innovations were strategically selected through close interaction with Holden project partners and a review of key documents, including the ESM and Innovation Exploitation documents. These sources provided a foundation for identifying diverse use cases across and transformative in their potential to enhance functionality across various industries. For instance, the ability to detect the presence of people or objects in restricted areas addresses critical surveillance and security needs, offering advanced safety solutions in both private and public settings. Similarly, shifting towards more dynamic scenarios, such as assisted living technologies for elderly care, enables remote monitoring of patients, including key health metrics and activities, while providing essential support for healthcare professionals and enhancing patients' quality of life. Innovations in consumer technologies, such as gesture-controlled Smart TVs and interactive gaming systems, represent a leap in user experience, allowing intuitive and immersive interaction with devices. These examples demonstrate the real-world potential of RF sensing technology, highlighting its ability to improve safety, enhance user convenience, and transform interactions with technology. By refining their functionalities and exploring new applications, these innovations can further optimize efficiency, accessibility, and adaptability across various use cases.

2.1.3. Criteria and Weight

Defining clear criteria and assigning appropriate weights are essential steps in the MCDA process before scoring the technological applications identified for each innovation. While these applications are still in the early stages of development, they have the potential to significantly impact real-world systems once refined and integrated. By establishing a balanced set of criteria - spanning technical, market, ethical, and social dimensions - we create a comprehensive evaluation framework. This approach allows us to rank the applications based on their diverse impacts, technical feasibility, and market potential. Properly defined criteria and weight assignment ensure a fair, objective, and strategic selection process.

Innovation

The Innovation criterion aims to assess the degree of advancement of the innovation within its application scenario, focusing on how it differentiates from existing solutions, its readiness for market adoption, and its potential for success. This criterion is divided through three sub-criteria: the technology's Novelty, its Stage of Development, and its Market Impact.

- **Novelty Level:** it assesses how groundbreaking the technology is compared to existing solutions, with higher scores indicating a significant leap forward in innovation.
- **Innovation Readiness:** This evaluates the maturity of the technology on its path to commercialization, considering stages such as early concept, prototype development, or market readiness.
- **Market Potential:** it focuses on external factors, including demand, market segment attractiveness, and overall market conditions that could influence the innovation's success.

Scoring was based on a scale from 0 to 100, where 100 represented a technology with revolutionary novelty, high readiness for market adoption, and exceptional market potential, while lower scores indicated limitations in one or more of these areas.

In the evaluation framework, the Innovation criterion accounted for 15% of the total criteria weight, with the following sub-criteria weights: Novelty Level (40%), Innovation Readiness (30%), and Market Potential (30%).

Complexity

The Complexity criterion evaluates how complex the final system and its components are in making the application operational. It considers factors such as the need for additional components, ease of integration, scalability when required, and deployability. This criterion is divided into four equally weighted sub-criteria: Autonomy, Scalability, Integrability, and Deployability.

- **Autonomy:** Assesses how easily the system can function as a stand-alone module without requiring external dependencies.
- **Scalability:** Evaluates how easily the system can be expanded in size or capacity to meet future needs.
- **Integrability:** Measures how easily the system can be integrated with other systems or components, ensuring smooth interoperability.

- **Deployability:** Focuses on how easily the system can be installed, configured, and made operational.

Scoring for the Complexity criterion ranges from 0 to 100, with a higher score indicating a system that is fully autonomous, highly scalable, seamlessly integrable, and easy to deploy, while lower scores signify significant inefficiencies or limitations in one or more of these aspects.

In the evaluation framework, the Complexity criterion accounts for 15% of the total criteria weight, with each sub-criterion receiving equal weight: Autonomy (25%), Scalability (25%), Integrability (25%), and Deployability (25%).

Economics

The Economics criterion evaluates the cost-effectiveness, funding needs, and market appeal of each technology. This criterion is divided into three equally weighted sub-criteria: Total Cost of Ownership (TCO), Initial Public Funds, and Compelling Investment Appeal.

- **Total Cost of Ownership (TCO):** Assesses the lifecycle cost of the technology, evaluating how cost-effective the technology is over its entire lifespan.
- **Initial Public Funds:** Evaluates the degree of public funding required to create favorable market conditions and support successful market entry.
- **Compelling Investment Appeal:** Measures the technology's ability to attract investors, based on its market readiness and potential return on investment (ROI).

Scoring for the Economics criterion ranges from 0 to 100, with a higher score indicating a technology that is cost-effective, requires no initial public funds, and is highly attractive to investors. Lower scores indicate significant inefficiencies or limitations in one or more of these aspects.

In the evaluation framework, the Economics criterion accounts for 15% of the total criteria weight, with the following sub-criterion weights: TCO (40%), Initial Public Funds (30%), Compelling (30%).

Privacy and Ethics (TWE)

The privacy and ethics criteria in the questionnaire accounted for 40% of the final score. The ethics section worth 20% was divided into personal ethics such as individual rights and the ability to self-govern (autonomy) 30%, collective ethics such as the impact on the collective wellbeing, equality and safety (equity) 30%, and precision, reliability, and understandability of the system (accountability) 40%. The idea being that if the system is unaccountable then both personal and collective rights may be more challenging to maintain. For each of these criteria it was foreseeable that a technology could be capable enhancing and or mitigating the domain. Thus, the scoring worked such that 50 was neutral (the enhancing and mitigating factors canceled out), 100 signified that the technology fully enhanced the domain, and 0 was a significant reduction. All technologies could be ranked anywhere from 1-100.

Privacy received its own subsection of the questionnaire worth 20% of the final score. This criterion was equally divided between amount and level of sensitivity of data used in the application (sensitive data) 25%, amount of sensitive data shared with other third-party systems (sensitive data shared) 25%, whether the app requires long-term and historical data storage (data retention) 25%, and the degree to which those monitored have control over their data and its management (control) 25%.

For these categories 100 represented the most privacy preserving system with the most user control and least historical data storage and 0 was the least privacy sensitive.

Legal

The Legal criterion evaluates how well a technology adheres to regulatory standards, assessing its readiness for legal approval within its application context. This criterion is based on the level of adherence to laws and regulations, ensuring that the technology is positioned for successful market entry.

Scoring for the Legal criterion ranges from 0 to 100, where a score of 100 represents full compliance with all applicable laws and regulations, while a score of 0 indicates non-compliance and significant regulatory challenges.

In the evaluation framework, the Legal criterion accounts for 10% of the total criteria weight.

Lab Reproducibility

Lab Reproducibility Criterion evaluates the application's ability to be consistently reproduced in a partner laboratory within the consortium. This criterion is critical for assessing the technology's robustness and its suitability for further development and deployment.

The scoring for Lab Reproducibility ranges from 0 to 100, where a score of 100 indicates full reproducibility in the lab, and a score of 0 reflects significant challenges in achieving consistent and reliable results across tests.

In the evaluation framework, the Lab Reproducibility criterion accounts for 10% of the total criteria weight.

2.1.4. Scoring and Rating

The scoring process followed a systematic and collaborative methodology designed to ensure fairness and accuracy. A structured set of questionnaires was distributed to the partners, and each partner was requested to independently assess the applications based on predetermined criteria. All partners actively engaged in the individual scoring process, ensuring diverse and thorough input. Once completed, the consolidated scores from each partner were aggregated to generate a final ranking.

This approach is particularly effective in an MCDA scoring and ranking process for several reasons:

- **Objectivity and Consistency:** By requiring each partner to independently score the applications, the process minimizes the risk of bias and ensures that the evaluation is based on clear, predetermined criteria. This helps maintain consistency across all assessments and avoids skewed results from any single perspective.
- **Diverse Expertise:** The participation of multiple partners ensures that the evaluation process captures a broad range of expertise and viewpoints. Each partner may bring a unique perspective, whether from a technical, market, or ethical standpoint, leading to a more comprehensive and balanced assessment of each application.

- **Collaboration and Collective Judgment:** After the independent scoring, the scores from all partners are aggregated. This step ensures that the final evaluation reflects the collective expertise of the consortium, rather than any one individual's opinion.
- **Transparency:** The structured approach, with clearly defined criteria and independent assessments, enhances the transparency of the process.
- **Thoroughness:** The individual scoring process ensures that each partner carefully considers all aspects of the technological applications, leading to a more thorough and detailed evaluation. Aggregating these individual assessments ensures that no critical dimension is overlooked.

By combining independent assessments with a collaborative aggregation process, the final ranking provides a well-rounded and unbiased evaluation of the technological applications. This methodology not only enhances fairness and accuracy but also fosters confidence in the results, ensuring that the best applications are selected based on a comprehensive, multi-faceted evaluation.

2.2. Creating Functional Requirements

Defining functional requirements for the application involves specifying what the system must do to fulfill its intended purpose. Functional requirements are derived by defining the following:

2.2.1. *Scenarios for the Specific Application*

This refers to identifying and analyzing the various situations or conditions under which the application will be used. These scenarios, often called use cases, describe the interactions between users and the system to accomplish specific goals. Such scenarios help in defining the functional requirements, detailing how the system should behave under specific conditions.

2.2.2. *Target Users for the Application*

This involves identifying the intended audience or user groups who will use the application. Understanding the target users helps in tailoring the application's functionality, usability, and design to their needs.

2.2.3. *Technologies/Components of the System Used for the Application:*

this refers to the tools, platforms, and components that will be used to build, deploy, and run the application. The choice of technology influences:

- The capabilities of the system (e.g., scalability, integration with other systems).
- Constraints such as performance, security, and compatibility.
- Development and maintenance efforts.

2.2.4. *Process and Information Flow for the Application*

This entails mapping out the sequence of activities and data movement within the application. It answers questions like:

- How does data flow between different system components?
- What are the steps users follow to achieve a goal?
- How is information processed, stored, and retrieved?

From the above the main system capabilities are derived and for each the functional requirements are defined for the system to fulfil the target capability with reference to the specific identified scenarios, system components and process information flow.

2.3. From Ethics Criteria to Ethics Profiles

In order to employ a system to assess the ethical requirements for each final innovation it was essential to formulate ethics criteria that could be used for each application. Throughout the project, TWE has been employing a variety of philosophical approaches to determine how to ethically employ RF holography. These can be seen in **Figure 2** below.

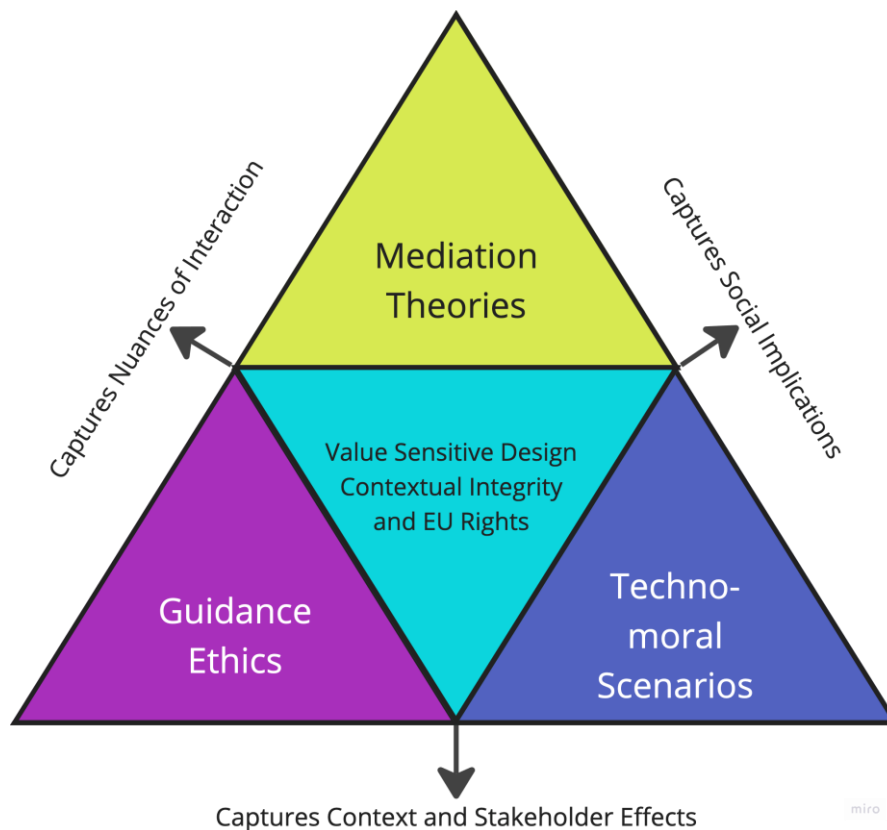


Figure 2 – HOLDEN Ethical Consideration Frameworks Pyramid

This approach combines bottom up stakeholder considerations such as those developed through Guidance Ethics [5], while also considering that socially disruptive new and emerging technology reshape norms and values which might not be captured in a traditional Guidance Ethics workshop. The framework of considering the long-term consequences on morality of new technology is considered by techno-moral scenarios [6]. We also consider that technology mediates our world and behavior in deeper ways reframing our values, transforming our interactions and reshaping the human condition. This perspective is covered through mediation theories. Finally, there are set standards and practices in place that must be centered such as the EU Charter of Fundamental Rights and guidelines for privacy such as contextual integrity [7]. To bring each framework together into design requirements we use Value Sensitive Design [8].

It would be time consuming and repetitive to address each innovation from all angles of the pyramid to build an ethical profile. Instead, we selected values that have resurfaced throughout the duration

of HOLDEN from our philosophical research. These values, which can already be seen under development in D8.9 “Ethics Status Monitor” and mirror the ethics and privacy scoring system from the MCDA, form the bases of an ethical criteria for each application. This criterion asks questions of each application and forms a profile of how well the application addresses potential ethical opportunities and harms. The ethics criteria encompass privacy, accountability, autonomy, equity, and sustainability. A brief description of their relevance and the questions they ask are included below.

2.3.1. Privacy

Privacy is a value enshrined in EU Law. It was also an important factor for stakeholders in our guidance ethics workshop. Privacy and its meaning directly relate to technological artifacts as privacy as a concept has become more important with the invention of cameras and social media. Finally, privacy is one reason this technology is being developed as an alternative to cameras. The privacy criteria questions are in line with contextual integrity.

Sensitive Data

How sensitive is the data in the system? Can it be used to spy on individuals?

Sensitive Data Shared

How much data is accessible to 3rd party applications? Are the elements open source?

Data Retention

Does the application require long-term and historical data storage?

Control

To what degree do those monitored have control over their data and its management?

2.3.2. Accountability

Accountability is essential to maintain ethical standards throughout a products lifecycle. It creates pathways for responsible action and decision making. If a system is not accountable it is difficult to consider other ethical concerns, because the system itself is not well understood. Accountability is more than an application working well under expected conditions. It also considers how transparent the system is and what realms define intended and acceptable use.

Accuracy Is the accuracy of the system known (e.g., false +/- rate)? Are there conditions where the system does not work and are they known?

Ex Ante Are there regulations in place to mitigate the usage/responsibility of the technology?

Ex Post Does the system take appropriate measures if things go awry?

Translation Is it clear what the system does, its limits, and who controls it? Can the *results* and the system be explained to non-expert users?

Visibility Is it evident that the system is in place?

2.3.3. Autonomy

Autonomy is also a value that appeared in our guidance ethics workshop. There are potentials for technology to both enhance autonomy by expanding human capability and to limit autonomy by controlling behavior. Questions of autonomy and how these technologies will reshape human-world interactions, human conduct and human experience can be understood and predicted through mediation theories. Several freedoms in the EU Charter of Fundamental Rights boil down to rights of autonomy as well.

Choice Are people able to opt out of being tracked by RF holography?

Power Does it limit, restrict, or reconstruct natural movement/decision making? Is the data self-serving (advertising etc.) or benefiting the user?

Control To what extent does the user or those surveilled have control over what happens to the data?

2.3.4. Equity

Equity seeks to ensure that the technology will not exacerbate inequalities. This criterion considers the importance of all stakeholders and the diversity of individuals that may be affected by the application. Title III of the EU Charter of Fundamental Rights is Equality. Equity has the potential to go a step beyond by acknowledging individual differences and ensuring that those differences still allow for favorable outcomes.

Equality Does the technology serve to uplift those who could have the greatest benefit from innovation, or does it further exacerbate inequality? If this tool is helpful and may cause positive outcomes, will it be affordable enough to be benefit those who need it?

Identity Does the technology unfairly target a specific group: young, old, etc.? Does the system work for people of different cultures, ethnicities, ages, genders, sizes, and disabilities?

2.3.5. Sustainability

We recognize that the world is facing an environmental crisis. It is important that all new technology brought to the market does not further that crises and at best may alleviate it. The future of the planet will have impact on fundamental rights such as health, safety, and wellbeing.

Consumption Does the technology consume extraordinary amounts of energy or resources especially when compared to comparable solutions?

Upkeep How long does the system last without upkeep? How well can the system be recycled and maintained?

3. Innovation 1 – People/Object Detection

Monitoring and securing restricted areas is essential across diverse environments, ranging from industrial sites such as warehouses and data centers to civil spaces like museums, shopping centers, offices, laboratories, high-security facilities, airports and public transport sites.

Conventional systems, such as CCTV cameras and motion sensors, are widely used but come with inherent limitations. CCTV systems rely on clear lines of sight, often obstructed by walls, furniture, or metallic objects, which can significantly impair their performance. Similarly, motion detectors struggle to detect static or slow-moving entities and are prone to false triggers caused by environmental factors like temperature fluctuations.

In these settings, RF sensing technology provides a non-invasive and reliable method for detecting the presence of objects and individuals. By leveraging radio waves, RF sensing can identify people or objects even when they are hidden from view or concealed behind barriers. This capability offers a robust, complementary monitoring solution that enhances the effectiveness of traditional surveillance methods.

Moreover, RF sensing functionality can be seamlessly integrated into existing technologies, such as cameras, presence sensors, IoT and WiFi devices, eliminating the need for standalone solutions in many cases.

3.1. Scenario Overview

We are considering scenarios in both a museum and an airport. In the museum, RF sensing technology can monitor high-value assets while ensuring visitor safety by detecting objects, including weapons, and identifying unauthorized attempts to remove items. Similarly, at airports, this technology can be used to detect suspicious activities, hidden or dangerous objects, thereby enhancing security measures without the need for intrusive inspections.

3.1.1. Users

Primary Users: Visitor and security personnel who are present in the restricted area under control. RF sensing detects their presence or absence.

Secondary Users: Facility managers, museum curators, airport operations managers, and administrators who remotely monitor the restricted areas, respond to alerts, and take immediate action. Besides law enforcement, and emergency response teams who analyze data or respond to incidents but do not actively monitor in real-time.

3.1.2. Location

The technology is deployed in restricted and sensitive areas such as museum exhibit spaces, storerooms, airside areas at airports, and baggage handling zones, where asset protection and object detection are critical. Security personnel and authorized remote users access real-time data and alerts through centralized control rooms, mobile apps, or dashboards, ensuring timely responses to potential security breaches.

3.1.3. Technologies

- **RF Sensing:** embedded in IoT/Wi-Fi devices, Cameras, and other strategically placed sensors to monitor the presence of people and objects, even behind barriers (e.g., ceiling-mounted sensors for unobtrusive, wide-range monitoring).
- **Edge Processing:** Basic data is processed locally to reduce latency, enabling faster response times.
- **Cloud Platform:** For storing data and performing historical analysis of detected security events.
- **Edge Processing:** For rapid analysis and real-time alerts when unauthorized activities are detected.
- **Cloud Platform:** For data storage and historical analysis of detected security events.
- **Mobile App/Dashboard:** Allows secondary users to monitor data, receive alerts, and interact with the system remotely.
- **Telecommunication Integration:** Connects with emergency services for immediate alerting in critical situations.

3.1.4. Processes

RF Sensing and Detection:

- RF sensors detect the presence/absence of objects, even if they are behind barriers or not in direct line of sight or in dark environment.
- The technology can identify if an individual is attempting to conceal an object or weapon, using radio waves to detect changes in the environment.

Edge Processing:

- Data from RF sensors is processed locally to identify threats or anomalies, such as the presence of unauthorized objects or attempts to remove high-value assets.
- Immediate alerts are generated and sent to security personnel if a breach or suspicious activity is detected.

Data Transmission and Analysis:

- Processed data is transmitted to the cloud for long-term storage and analysis.
- Security personnel can access the data via a dashboard, enabling them to monitor the security of restricted areas in real time and review historical records to improve future security measures.

Alerts and Emergency Response:

- The system sends alerts to security teams if unauthorized access or suspicious activity is detected.
- If a critical situation arises, law enforcement or emergency services are notified for immediate intervention.

3.1.5. Flow of Information

RF Sensing and Object Detection:

- RF sensors embedded in cameras or ceiling-mounted systems continuously monitor the area for any presence/absence of people or objects, analyzing changes in the environment.
- If the sensors detect an attempt to hide or move an unauthorized object/valuable object, an alert is generated using connected device.

Edge Processing and Alerts:

- The data is processed at the edge to identify threats or unusual patterns, such as concealed weapons or attempted theft.
- Real-time alerts are sent to on-site security personnel via their monitoring devices or dashboards.

Data Transmission to the Cloud:

- All data is transmitted to a secure cloud platform for further analysis, allowing for trend identification and the improvement of future security strategies.

Security Dashboard and Emergency Response:

- Security teams monitor real-time data from the cloud using a dashboard, which provides a comprehensive view of all activities and alerts within the restricted area.
- In case of emergencies, integrated telecommunication systems notify law enforcement or emergency response teams, enabling swift action.

3.1.6. Example Use Case Flow

Weapon Detection at Airport Security:

- RF sensors detect an anomaly in a designated area.
- Edge processing identifies the object as a potential threat and sends an immediate alert to security personnel.
- Security staff review the data via the dashboard, verify the threat, and take appropriate action, which may include notifying law enforcement for further investigation.
- If necessary, the system alerts emergency response teams for rapid intervention.

Asset Protection in Museums:

- RF sensors continuously monitor the area where high value items are placed.
- If a visitor attempts to remove or hide an item, the system processes this data locally and sends an instant alert to the museum's security team.
- Security personnel review the alert, locate the suspicious individual, and take action to prevent theft or damage.
- The system records the event data for future analysis and security protocol enhancement.

3.2. Functional Requirements

The following functional requirements are based on the use case scenario that utilizes RF sensing embedded in IoT, Wi-Fi devices, cameras, and other sensors to detect the presence and or absence of individuals and objects within restricted and sensitive areas such as museum exhibit spaces, storerooms, and airside areas at airports. These requirements integrate real-time monitoring and alerting capabilities to enhance security and asset protection, providing a comprehensive surveillance system using RF sensing technology.

1) RF Sensing configured for Presence/Absence Detection

Requirement: The system must be able to detect the presence/absence of people or objects in the restricted areas using RF sensing technology embedded in Wi-Fi/IoT devices, security cameras and other sensors.

Functionality: Detect the presence or absence of individuals in real-time across different zones within the restricted area. Identify whether an object is stationary or has been moved and log movement history. Continuously monitor the area to provide uninterrupted surveillance.

User Data:

- **Location Data:** Real-time location information of individuals and objects to support rapid response and security decisions.
- **User Identification:** Details of authorized personnel to differentiate between authorized and unauthorized users.

2) Object Tracking and Asset Protection

Requirement: The system must track the location of valuable objects and detect if they are moved or tampered with.

Functionality: Continuously monitor high-value assets using RF sensing technology to ensure they remain in designated locations. Generate alerts if an object is moved without proper authorization or if tampering is detected. Maintain a log of all object movements, providing an audit trail for security reviews.

User Data:

- **Asset Information:** Details of valuable objects, including identifiers, designated locations, and security levels.
- **Movement History:** Records of when and where objects were moved for auditing purposes.
- **Authorized User Information:** Details of personnel authorized to access or move specific assets, including user roles, access permissions, and identification data. Logs of interactions by users with tracked objects, such as who accessed or moved the asset and at what time.

3) Crowd and Zone-Based Monitoring

Requirement: The system must be able to detect crowd levels and monitor specific zones for unauthorized access.

Functionality: Identify and alert security personnel if the number of people in a given area exceeds safety or security limits. Use geofencing to define restricted or sensitive zones within the area and trigger alerts if these zones are breached. Monitor and log zone-specific activities to identify potential security threats.

User Data:

- **Zone Configuration:** Details of restricted zones, including boundaries and access permissions.
- **Occupancy Limits:** Predefined limits for the number of individuals allowed in certain areas.

- **Authorized Personnel Data:** Information on individuals allowed in restricted zones, such as badges or credentials, to differentiate between authorized and unauthorized access.
- **Real-Time Occupancy Data:** Continuously updated count of people in each zone to compare with limits and support operational decisions.
- **Alert History Logs:** A record of past alerts triggered by crowd levels or zone breaches, useful for identifying recurring issues or patterns.

4) Unauthorized Entry Detection

Requirement: The system must identify and alert security personnel when unauthorized individuals enter the restricted area.

Functionality: Analyze movement patterns using RF sensing to detect unauthorized entry and notify security personnel in real-time via a mobile app or dashboard. Integrate with access control systems to distinguish between authorized and unauthorized individuals. Minimize false positives through machine learning to enhance system sensitivity and accuracy.

User Data:

- **Access Permissions:** Database of authorized individuals, including names, roles, and credentials.
- **Emergency Contacts:** List of individuals or teams for quick notifications in case of unauthorized entry.
- **Entry/Exit Logs:** Record of all movements for auditing and investigation purposes.
- **Behavioral Profiles:** Typical movement patterns of authorized personnel to refine detection accuracy.
- **Alert Priority Levels:** Predefined categories for alert severity to enable efficient incident management.

5) Edge Processing for Latency Reduction

Requirement: The system must include edge processing capabilities to ensure real-time alerts and responsiveness.

Functionality: Process RF data locally at the edge (e.g., IoT gateways) for immediate detection of unauthorized entries or suspicious activity. Minimize delays in sending alerts by performing basic data analysis close to the data source. Enable local anomaly detection for faster decision-making and immediate action.

User Data:

- **Device Information:** Details of edge devices, including configurations and processing capabilities, for efficient data handling.
- **Location Data:** Locally processed to provide precise, location-specific responses and reduce dependency on cloud systems.
- **Anomaly Thresholds:** Predefined criteria for identifying suspicious patterns or activities in real-time.

- **Alert Settings:** Local configurations for prioritizing and escalating detected issues efficiently.

6) Data Transmission and Integration

Requirement: The system must ensure reliable and secure data transmission for real-time monitoring and integration with other systems.

Functionality: Transmit data securely from IoT devices to the cloud using secure protocols. Ensure continuous and reliable data flow, even in low-coverage areas, to support uninterrupted monitoring. Integrate seamlessly with emergency services and access control systems to automate responses in critical situations.

User Data:

- **Personal Information:** Secure transmission of user details, such as names, roles, and access credentials, for accurate identification during alerts.
- **Asset Data:** Transmit asset information, including movement logs and security details, to ensure secure monitoring and prevent unauthorized access.
- **Incident Data:** Details of any security incidents or triggers, including time, location, and involved personnel.
- **Authorization Logs:** Data on authorized users' access to restricted areas and system interactions.

7) Alerts and Notifications

Requirement: The system must send timely and detailed alerts to security personnel about the status of the restricted area.

Functionality: Provide real-time notifications about unauthorized entries, object movements, or crowd-level breaches. Include actionable information in alerts, such as the type of threat, location, and recommended response actions. Allow security personnel to acknowledge or escalate alerts as needed to ensure appropriate action.

User Data:

- **Notification Preferences:** Settings for how and when security personnel receive alerts (e.g., via app, email, or SMS).
- **Contact Information:** Emergency contact details for immediate response coordination, ensuring swift action in critical situations.
- **Alert History:** Logs of past alerts, including the response status and any follow-up actions taken.
- **Response Time Metrics:** Data on how quickly alerts were acknowledged and acted upon to improve response strategies.

8) User Interface (UI) for Security Personnel

Requirement: The system must provide an intuitive interface for security personnel to monitor and respond to alerts.

Functionality: Display real-time status updates of the restricted area, including presence and movement data of people and objects. Provide historical data and activity logs for review and analysis. Allow customization of alert thresholds and zone configurations to meet specific security needs.

User Data:

- **User Profiles:** Information about security personnel, including roles, access levels, and permissions to ensure appropriate system access and functionality.
- **Audit Logs:** Records of actions taken by security personnel, such as system changes, responses to alerts, and access to sensitive data, to ensure accountability and security compliance.
- **Activity History:** A log of past actions, including alert responses and system interactions, for post-event analysis and performance reviews.

9) Integration with Emergency Response and Access Control Systems

Requirement: The system must integrate with emergency response protocols and existing access control mechanisms.

Functionality: Automatically notify emergency responders if a security breach or critical incident occurs, ensuring rapid intervention. Control access points, such as doors and barriers, based on real-time detection of unauthorized individuals to enhance security measures. Allow manual override by security personnel to lock down or open access points as needed, providing flexibility in critical situations.

User Data:

- **Emergency Response Protocols:** Configurations for notifying emergency responders, including contact information and response guidelines.
- **Access Control Data:** Information about access permissions, such as roles, credentials, and integration settings, to automate responses and ensure proper access management.
- **Override Permissions:** Details of security personnel with manual override authority to ensure proper control over access points during emergencies.

10) Data Storage and Privacy

Requirement: The system must securely store and manage data while complying with privacy regulations.

Functionality: Encrypt all data during transmission and storage to prevent unauthorized access and ensure data security. Provide access control mechanisms to restrict data access to authorized personnel only, maintaining confidentiality. Enable users to review and manage data privacy settings, ensuring compliance with regulations like GDPR.

User Data:

- **Sensitive Information:** Store details securely, including the names and roles of authorized personnel, asset information, and location data, with appropriate encryption and access control.
- **Privacy Settings:** Allow users to configure data retention policies, manage access permissions, and set parameters for how long data is stored, ensuring compliance with privacy regulations.

11) System Maintenance and Updates

Requirement: The system must support routine maintenance and updates to ensure continuous functionality and security.

Functionality: Perform remote software updates to introduce new features, improve system performance, and fix vulnerabilities. Ensure updates do not disrupt ongoing monitoring, alert generation, or real-time operations. Notify security personnel in advance of any scheduled maintenance, updates, or system downtime to avoid surprises and ensure preparedness.

User Data:

- **System Configuration:** Retain user preferences, zone settings, and security protocols during updates, ensuring seamless transitions and consistent operations.
- **Backup Data:** Automatically back up critical data (e.g., security logs, system configurations) to prevent loss during maintenance activities and ensure recovery in case of failure.

3.3. Ethical Profile

| People/Object Detection in Restricted Areas | |
|---|--|
| Privacy | <p>Sensitive Data</p> <ul style="list-style-type: none">● How sensitive is the data in the system? The system collects highly sensitive information, including real-time presence, location, and movement patterns of individuals and objects, potentially revealing personal behaviors. In environments like airports or museums, this data could be exploited to compromise privacy.● Can it be used to spy on individuals? Without strong security protocols, the system could be misused for surveillance, hacking, or unauthorized profiling of individuals. <p>Sensitive Data Shared</p> <ul style="list-style-type: none">● How much data is accessible to 3rd party apps? While the system integrates with emergency services and potentially other external systems, the extent of third-party data access is unclear. Policies governing third-party use and safeguards against misuse must be transparent.● Are the elements open source? The requirements do not confirm open-source components. If any exist, robust safeguards are essential to prevent exposure of sensitive data. |

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| | <p>Data Retention</p> <ul style="list-style-type: none"> • Does the app require long-term and historical data storage? Yes, it does. The requirement for historical analysis implies prolonged data storage. Policies on data retention, deletion timelines, and compliance with privacy regulations (e.g., GDPR) are necessary to ensure responsible handling. <p>Control</p> <ul style="list-style-type: none"> • What is the degree of control over data and management? Individuals being monitored appear to have minimal control over how their data is collected, stored, or managed. Transparent policies should outline user rights and provide mechanisms for requesting data access or deletion. |
| Accountability | <p>Accuracy</p> <ul style="list-style-type: none"> • Is the accuracy of the system known (false +/- rate)? The requirements lack specific metrics on false positives or negatives and the system's performance in varying conditions, such as RF interference or high-density environments. • Are conditions where the system does not work known? Conditions such as extreme interference or environmental factors affecting RF signals are likely but not explicitly addressed. These must be documented and communicated. <p>Ex Ante</p> <ul style="list-style-type: none"> • Are there regulations in place to mitigate the usage/responsibility of the technology? The requirements do not specify regulations or standards in place to ensure ethical deployment and usage. <p>Ex Post</p> <ul style="list-style-type: none"> • Does the system take appropriate measures if things go awry? The system notifies relevant personnel (e.g., law enforcement) in critical situations, but recovery mechanisms for data misuse or breaches are not described. Clear policies for addressing errors, misuse, or data breaches (e.g., incident response plans) are needed to build trust and accountability. <p>Translation</p> <ul style="list-style-type: none"> • Is it clear what the system does, its limits, and who controls it? The system's purpose and operational details are clear for technical users but may require simplification for non-technical audiences. • Can the <i>results</i> and system be explained to non-expert users? Yes, but this requires thoughtful effort to ensure clarity and accessibility. Technical terms and concepts, such as RF sensing and edge processing, may be unfamiliar to non-expert users. Clear, jargon-free explanations, visual aids (e.g., infographics or videos), and practical examples tailored to their context (e.g., how the system detects a concealed object in a museum) can bridge the gap. Additionally, providing straightforward documentation and interactive demonstrations can help users understand the system's functionality, limitations, and benefits <p>Visibility</p> <ul style="list-style-type: none"> • Is it evident the system is in place? |

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| | <p>The system's transparency is unclear, as the requirements do not specify whether users in monitored areas are informed about its presence. This raises ethical concerns, particularly regarding individuals' awareness and consent. To address this, visible indicators such as signs, announcements, or digital notifications should inform users of the RF sensing technology and its purpose, aligning with legal and ethical standards like GDPR. Clear communication of the system's function, limitations, and data use fosters trust and ensures compliance while enhancing user understanding and acceptance.</p> |
| Autonomy | <p>Choice</p> <ul style="list-style-type: none"> • Are people able to opt out of being tracked by RF holography? The system prioritizes security over individual autonomy, offering no options for monitored individuals to opt out, which could conflict with ethical principles in non-critical contexts. <p>Power</p> <ul style="list-style-type: none"> • Does it limit, restrict, or reconstruct natural movement/decision making? RF sensing could inadvertently restrict natural movement or decision-making by creating zones that feel surveilled or inaccessible. • Is the data self-serving (advertising etc.) or benefiting the user? The data predominantly serves institutional security goals rather than the monitored individuals' interests, though safer environments indirectly benefit users. <p>Control</p> <ul style="list-style-type: none"> • To what extent does the user or those surveilled have control over what happens to the data? Monitored individuals have no explicit control over their data. A framework for providing access, corrections, or removal of personal data should be considered. |
| Equity | <p>Equality</p> <ul style="list-style-type: none"> • Does the technology serve to uplift those who could have the greatest benefit from innovation, or does it further exacerbate inequality? The high-tech nature of the system and its infrastructure requirements (e.g., IoT integration) may limit its affordability for underfunded sectors, potentially widening gaps in security and protection. • If this tool is helpful and may cause positive outcomes, will it be affordable enough to be benefit those who need it? The requirements do not address how the system ensures unbiased functionality across demographics, raising concerns about potential detection biases based on physical or cultural factors. <p>Identity</p> <ul style="list-style-type: none"> • Does the technology unfairly target a specific group? The system's performance across different genders, ethnicities, ages, and physical abilities must be rigorously tested to prevent unfair targeting or exclusion. • Does the system work for people of different cultures, ethnicities, ages, genders, sizes, and disabilities? The requirements do not explicitly confirm whether the system works equitably across different cultures, ethnicities, ages, genders, sizes, or |

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| | <p>disabilities. Potential biases may arise from variations in body size, movement patterns, or cultural attire that could affect detection accuracy. Additionally, the system lacks mention of accessibility for individuals with disabilities, such as those using mobility aids. To ensure inclusivity, the system should undergo diverse testing, incorporate adaptable algorithms, and accommodate individuals with disabilities while being sensitive to cultural and behavioral variations. These steps would enhance equity and functionality across diverse populations.</p> |
| Sustainability | <p>Consumption</p> <ul style="list-style-type: none"> • Does the technology consume extraordinary amounts of energy or resources especially when compared to comparable solutions? The system relies on IoT devices, cloud computing, and edge processing, which could have higher energy demands than simpler solutions like standalone motion detectors. <p>Upkeep</p> <ul style="list-style-type: none"> • How long does the system last without upkeep? Routine maintenance, software updates, and potential component recycling are acknowledged, but the document does not specify the lifespan or recyclability of the hardware. • How well can the system be recycled and maintained? The requirements note routine maintenance and updates but lacks details on the system’s overall lifespan, recyclability of components, and adaptability to future technological changes. |

4. Innovation 2: Elderly Care

Providing effective care for elderly individuals presents unique challenges that require personalized, adaptive, and continuously evolving strategies. Achieving holistic support necessitates integrating modern technologies and professional services to promote physical, emotional, and social well-being. Recent advancements in Information and Communication Technologies (ICT) are setting the stage for innovative and transformative progress in a way that can significantly improve the “Elderly Care” process.

Among these, Radio Frequency (RF) sensing technology embedded in IoT and Wi-Fi-enabled devices has the potential to emerge as a game-changer. This technology provides a non-invasive, continuous monitoring solution, capable of tracking vital signs such as heart rate, breathing frequency, body movement, and location—all without the need for physical contact or wearable devices.

This continuous data stream enables real-time health monitoring, including activity tracking, mobility assistance, heartbeat analysis, and cognitive behavior monitoring. Additionally, local data analysis, such as fall detection or identifying irregular heartbeats, is facilitated by edge processing within connectivity devices. This capability allows for instant alerts to secondary users or emergency services when needed.

Besides, RF sensing technology offers caregivers actionable insights, allowing for a deeper understanding of the elderly's needs and fostering a more proactive, tailored approach to care. Furthermore, these features empower family members and caregivers to respond swiftly and effectively when immediate intervention is needed.

4.1. Scenario Overview

A health monitoring system uses RF sensing to track the health and movement of an elderly person (primary user) within their home. This system operates without wearables, relying on RF technology integrated into existing IoT and Wi-Fi devices throughout the home for continuous, non-intrusive health monitoring, including movement detection, fall alerts, heart rate monitoring, and location tracking.

4.1.1. Users

Primary User: The elderly person being monitored; no wearables required. RF sensing track their movement, location, falls, and health indicators like heart rate.

Secondary Users: Caregivers, family members, or healthcare providers who receive health data and alerts through an app or dashboard to monitor the elderly person's well-being.

- **Caregivers:** Oversee health and safety either remotely or on-site.
- **Healthcare Providers:** Review data to make medical decisions.
- **Emergency Services:** Respond to urgent alerts (e.g., falls).

4.1.2. Location

The primary user resides at home or in assisted living. Secondary users may be remote (e.g., family members) or on-site (e.g., caregivers) and can access data via an app, dashboard, or telemedicine platform.

4.1.3. Technologies

- **RF Sensing:** Embedded in IoT/Wi-Fi devices (e.g., routers, smart speakers) to detect movement, presence, and physiological changes like heart rate without wearables.
- **Edge Processing:** Basic data (e.g., falls, heartbeat irregularities) is processed locally to reduce latency and enable quick responses.
- **Cloud Platform:** Central storage and analysis of health and movement data, accessible to secondary users in real time.
- **Mobile App/Dashboard:** Allows secondary users to monitor data, receive alerts, and interact with the system remotely.
- **Telecommunication Integration:** Connects with emergency services for immediate alerting in critical situations.

4.1.4. Processes

Health Data Collection via RF Sensing:

- **Movement and Position Detection:** RF sensors in IoT/Wi-Fi devices track user location and movements (e.g., in bedroom, living room).
- **Heartbeat Detection:** RF technology detects subtle radio wave changes from physiological activity, allowing continuous heart rate monitoring without wearables.
- **Fall Detection:** RF sensors detect abrupt movements (e.g., falls) and can trigger alerts if the user is in a vulnerable position.

Edge Processing:

- Local data analysis (e.g., fall or irregular heartbeat detection) enables instant alerts to secondary users or emergency services.

Data Transmission:

- RF sensing data (movement, heart rate, etc.) is sent to the cloud via IoT protocols (Wi-Fi, Zigbee, LoRa), allowing secondary users real-time access to the elderly person's status.

Health Status Monitoring:

- Caregivers or family monitor health/location using an app or dashboard, receiving alerts for significant changes, such as unusual movement patterns or falls.

Emergency Response:

- For critical alerts, the system notifies secondary users and emergency services via telecom integration for immediate response.

4.1.5. Flow of Information

Primary User: Movements, location, and physiological data (e.g., heartbeat) are continuously detected by RF sensors embedded in IoT/Wi-Fi devices around the home.

IoT Devices: Transmit data to edge devices (e.g., gateways), where basic processing (e.g., fall detection) occurs.

Edge Processing: Detects critical events (e.g., fall or irregular heartbeat) and sends instant alerts.

Cloud Platform: Stores processed data for long-term analysis and remote access by secondary users.

Secondary Users: Access real-time data on the elderly person's health and safety, receiving alerts and notifications.

Emergency Services: Receive automatic alerts in urgent situations, ensuring rapid intervention.

4.1.6. Example Use Case Flow

Fall Detection:

- RF sensors embedded in Wi-Fi devices (such as routers or smart speakers) detect an abrupt change in the primary user's position (e.g., a fall).
- The edge device processes this data and sends an immediate alert to secondary users via a mobile app or dashboard.
- The caregiver or family member checks the primary user's status using the app and, if necessary, contacts emergency services through the integrated telecommunication system.
- Emergency services arrive at the primary user's location promptly, minimizing response time.

Heart rate and breath rate Monitoring:

- RF sensors embedded in IoT and Wi-Fi devices, such as smart speakers or Wi-Fi routers, detect subtle changes in the primary user's heart/breath rate based on radio wave reflection.
- If the heart/breath rate exceeds a certain threshold, the system sends a notification to the secondary user (e.g., caregiver or healthcare provider).
- The secondary user can then assess whether the primary user needs medical attention and take appropriate action.

Position Tracking:

- RF sensors track the primary user's movement throughout the house, detecting when they move from room to room or remain stationary in one spot for too long (potentially indicating a fall or health issue).

- If the system detects that the primary user has remained in one position for an extended period, it sends an alert to the caregiver or family member.

4.2. Functional Requirements

The following functional requirements are based on the use case scenario that utilizes RF sensing embedded in IoT and Wi-Fi devices to monitor the health, movement, and position of the primary user (elderly person) within their home. These requirements integrate both health data and personal information to provide a complete monitoring system for elderly care using RF sensing technology.

1) RF Sensing configured for Movement and Position Detection

Requirement: The system must be able to detect the movement of the primary user within the home environment using RF sensing technology embedded in WiFi/IoT devices (e.g., smart routers, smart speakers, security cameras).

Functionality: Track the position of the primary user in real-time across different rooms in the house. Detects if the primary user is moving or stationary. Alert secondary users if the primary user is stationary for an extended period, suggesting a possible fall or medical issue. Continuously monitor movement without requiring wearable devices.

User Data:

- **Name and Age:** To identify the primary user and tailor alerts or monitoring thresholds based on age (e.g., age-specific heart rate thresholds).
- **Room or Location Data:** Real-time location within the house to help caregivers know where the user is and respond faster if needed.

2) RF Sensing configured for Fall Detection

Requirement: The system must detect a fall or sudden change in the primary user's position.

Functionality: Use RF sensing to identify significant changes in movement patterns, such as a rapid fall or a sudden drop in height. Immediately notify secondary users (caregivers or family members) via app or dashboard when a fall is detected. Trigger emergency services integration to quickly contact first responders in case the primary user cannot manually request help. Minimize false positives by fine-tuning sensitivity to distinguish between normal movement and an actual fall.

User Data:

- **Medical History:** Information about prior medical conditions or known risks (e.g., history of falls, heart conditions) to help optimize fall detection and alert thresholds.
- **Emergency Contacts:** List of emergency contacts (e.g., family members, caregivers) for immediate notifications.

3) RF Sensing configured for Heartbeat and Physiological Monitoring

Requirement: The system must detect and monitor the primary user's heart rate using RF sensing technology embedded in IoT and Wi-Fi devices.

Functionality: Continuously monitor changes in the primary user's heart rate without requiring wearable devices. Use RF technology to detect subtle variations in the radio wave reflection due to the movement of the user's chest. Send alerts to secondary users if the heart rate exceeds or falls below predefined thresholds, indicating a potential medical issue. Provide the ability for healthcare providers to review heart rate data remotely for proactive health management.

User Data:

- **Health Data:** Continuous monitoring of heart rate, body temperature, and other relevant physiological metrics (e.g., blood oxygen levels, if available).
- **Name and Health Conditions:** To personalize heart rate thresholds based on the individual's health status, age, or specific conditions (e.g., arrhythmias).

4) Edge Processing for Latency Reduction

Requirement: The system must include edge processing capabilities to reduce latency in the detection of critical events, such as falls or abnormal heart rates.

Functionality: Process RF data locally (at the gateway or local IoT devices) for time-sensitive events, ensuring that alerts are sent immediately without relying solely on cloud processing. Ensure minimal delay in transmitting critical data to secondary users and emergency services. Provide local analysis of movement patterns and health data to minimize response time in emergencies.

User Data:

- **Location and Device Information:** The system should process location-based data for personalized responses depending on the user's location in the home (e.g., room-specific alerts).

5) Data Transmission and Integration

Requirement: The system must provide reliable and low-latency data transmission to ensure real-time monitoring and responsiveness.

Functionality: Transmit other health data securely from IoT/Wearable devices to the cloud platform via IoT protocols such as Wi-Fi, Zigbee, or Lora. Ensure that data transmission is continuous and reliable, even in low-coverage areas of the home. Enable seamless integration with emergency services for immediate response when critical events, such as falls, are detected.

User Data:

- **Personal Data:** Transmission of the primary user's name, age, emergency contacts, and medical information to ensure accurate identification and efficient emergency response.

- **Health Data:** Securely transmit health metrics to secondary users or healthcare providers.

6) Alerts and Notifications

Requirement: The system must send timely alerts and notifications to secondary users about the primary user's health status and safety.

Functionality: Provide real-time notifications to caregivers, family members, or healthcare providers if a fall, abnormal heart rate, or stationary position is detected. Ensure that the notifications include actionable information, such as the user's current location in the house (via position tracking) and the type of alert (e.g., fall, abnormal heartbeat). Allow secondary users to acknowledge or dismiss alerts, with the option to escalate the alert to emergency services if necessary.

User Data:

- **User Preferences:** Allow secondary users to set notification preferences, such as receiving alerts via mobile app, email, or text.
- **Emergency Contact Information:** Immediate notification to pre-configured emergency contacts with the primary user's name, location, and medical status.

7) User Interface (UI) for Secondary Users

Requirement: The system must provide an easy-to-use interface for secondary users (caregivers, family members, healthcare providers) to monitor and manage the primary user's health data.

Functionality: Provide a mobile app or web-based dashboard to display real-time health data and alerts from the primary user. Enable secondary users to access historical data, including movement patterns, heart rate trends, and fall detection events. Allow secondary users to configure alert thresholds for heart rate and movement patterns to tailor the system to the primary user's specific needs.

User Data:

- **Secondary User Information:** Store and manage details of secondary users (e.g., caregiver name, phone number) to ensure they receive personalized notifications and alerts.
- **Primary User Data:** Show detailed information of the primary user, such as their health data (heart rate, movements), medical history, and emergency contacts.

8) Emergency Services Integration

Requirement: The system must ensure that all health and movement data is securely stored and managed, with respect for user privacy.

Functionality: Store health data (e.g., movement patterns, heart rate) securely in the cloud for easy access by secondary users. Implement encryption for both data transmission and storage to

protect sensitive health information. Provide users with the ability to review and manage their data privacy settings, ensuring compliance with relevant regulations (e.g., HIPAA for healthcare data).

User Data:

- **Primary User Information:** Automatically provide emergency services with the name, location, and medical history (e.g., heart conditions, allergies) of the primary user.
- **Emergency Contacts:** Notify the user's emergency contacts of the situation and provide updates if needed.

9) Data Storage and Privacy

Requirement: The system must ensure that all health and movement data is securely stored and managed, with respect for user privacy.

Functionality: Store health data (e.g., movement patterns, heart rate) securely in the cloud for easy access by secondary users. Implement encryption for both data transmission and storage to protect sensitive health information. Provide users with the ability to review and manage their data privacy settings, ensuring compliance with relevant regulations (e.g., HIPAA for healthcare data).

User Data:

- **Personal Data:** Safely store and manage the primary user's personal details (name, contact information) alongside health data.
- **Health Data:** Store and allow controlled access to sensitive health data, ensuring that only authorized secondary users can access it.

10) System Maintenance and Updates

Requirement: The system must be able to perform routine maintenance and updates to ensure continuous functionality.

Functionality: Allow for remote software updates to improve the system's performance and introduce new features. Ensure that updates do not disrupt service or cause downtime, especially in critical monitoring scenarios. Provide alerts or notifications to secondary users in the event of any system maintenance or updates.

User Data:

- **Primary User Settings:** Ensure that user preferences, emergency contact details, and health data are retained and updated during system upgrades.
- **Data Backup:** Automatically back up health data to prevent data loss during maintenance activities.

4.3. Ethical Profile

| Elderly Care Ethical Profile | |
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| Privacy | <p>Sensitive Data</p> <ul style="list-style-type: none"> • How sensitive is the data in the system? The data collected includes health indicators (e.g., heart rate, breathing rate), location, movement patterns, and emergency alerts (e.g., falls). This data is highly sensitive, as it pertains to intimate details of an individual’s health and daily life. Misuse of this data could lead to privacy violations, stigmatization, or even physical harm if accessed by malicious actors. • Can it be used to spy on individuals? If misused, certainly. The system continuously monitors the primary user’s activities within their home, creating potential risks if access controls and encryption are not robust. Safeguards, such as limiting access to authorized users and auditing access logs, mitigate this risk. <p>Sensitive Data Shared</p> <ul style="list-style-type: none"> • How much data is accessible to 3rd party apps? Data sharing is minimized and only occurs with the explicit consent of the primary user. Third-party access is limited to healthcare interfaces (e.g., telemedicine platforms), and strict privacy agreements ensure no unauthorized use. No data is shared for advertising or unrelated purposes. However, monitoring vulnerabilities (e.g. merging databases) is key here. • Are the elements open source? The application uses proprietary components for RF sensing but may incorporate open-source IoT protocols for interoperability. Transparency about these components is key to ensure trust. However, incorporating open-source elements might increase the risk of unwanted sharing of data with third parties. <p>Data Retention</p> <ul style="list-style-type: none"> • Does the app require long-term and historical data storage? Historical data is necessary for analyzing trends, such as detecting gradual health deterioration or recurrent falls. However, data retention policies comply with privacy regulations (e.g., GDPR), ensuring that data is stored only as long as required and securely deleted thereafter. Also, here monitoring vulnerabilities is necessary (e.g. maintenance of relevant functions). <p>Control</p> <ul style="list-style-type: none"> • What is the degree of control over data and management? The primary user has, or at least is promised, full control over their data through the system’s interface. They can review, modify, and delete stored data. Consent mechanisms are in place for sharing data with secondary users or third-party applications. Secondary users, such as caregivers, must adhere to these preferences. Point of attention is here that elderly might not have the capabilities to |

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| | operate the system; secondary users or others might potentially misuse this lack of digital literacy. |
| Accountability | <p>Accuracy</p> <ul style="list-style-type: none"> • Is the accuracy of the system known (false +/- rate)? The system undergoes extensive testing to ensure high accuracy, especially for critical functions like fall detection and heart rate monitoring. While false positives (e.g., normal movement misclassified as a fall) and negatives (e.g., missed falls) cannot be entirely eliminated, periodic recalibration and machine learning improvements must reduce these errors over time. How many errors are acceptable will depend on the function and situation and needs further assessment. • Are conditions where the system does not work known? RF sensing may face challenges in environments with significant interference (e.g., multiple RF-emitting devices) or physical obstructions (e.g., dense furniture). These limitations are documented, and users are guided on how to optimize their environment for reliable operation. Uncertainty remains regarding the dynamics within a space and the choices made to keep it manageable. <p>Ex Ante</p> <ul style="list-style-type: none"> • Are there regulations in place to mitigate the usage/responsibility of the technology? The system complies with GDPR and HIPAA for data protection and operational transparency. Preemptive measures include user agreements, informed consent protocols, and guidelines for appropriate use by secondary users. Attention should be paid to the fact that elderly people may not be able to process information correctly and give real consent, depending on their health. <p>Ex Post</p> <ul style="list-style-type: none"> • Does the system take appropriate measures if things go awry? Alerts are sent for anomalies such as a breach or malfunction. Corrective actions include system recalibration, enhanced security updates, and user notifications. An incident response plan supports that issues are resolved promptly. Alignment in who should do what when something goes wrong (system and/or people) is crucial here. <p>Translation</p> <ul style="list-style-type: none"> • Is it clear what the system does, its limits, and who controls it? The system includes user-friendly documentation and interfaces. Educational resources are provided to explain system functions, limitations (e.g., no coverage outside monitored areas), and data ownership clearly to all stakeholders. Since the system will be used by elderly at different stages of life, it is essential to ensure that the information and interface are tailored to meet their specific needs and preferences • Can the <i>results</i> and system be explained to non-expert users? |

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| | <p>This technology requires more information to be explainable to non-expert users.</p> <p>Visibility</p> <ul style="list-style-type: none"> • Is it evident the system is in place? Devices such as smart speakers and routers are visibly installed, with users informed about their presence and purpose. Consent is always obtained prior to installation. Given that the system will be used by elderly individuals at different stages of life and with varying health conditions, it is essential to raise awareness about the system’s features and usage in a tailored manner and at appropriate intervals. |
| Autonomy | <p>Choice</p> <ul style="list-style-type: none"> • Are people able to opt out of being tracked by RF holography? Users have the option to deactivate tracking functions or even the entire system if desired. For instance, privacy settings enable users to disable movement monitoring during private activities. However, opting out may reduce the system’s ability to deliver effective care. To address this, discussions about when and to what extent the system’s features should be active may need to be conducted in advance and systematically coordinated with the elderly and their caregivers. <p>Power</p> <ul style="list-style-type: none"> • Does it limit, restrict, or reconstruct natural movement/decision making? The system is non-invasive and operates passively. It does not restrict or influence the primary user’s behavior but rather empowers them by enabling health monitoring without the burden of wearable devices. However, knowing that you are being tracked can still have an indirect impact, especially if certain aspects of the system cannot be easily turned on or off. • Is the data self-serving (advertising etc.) or benefiting the user? The data is used exclusively to support the user’s health and safety, with secondary uses (e.g., advertising) strictly prohibited by design. However, this raises the question of whether such a system can remain affordable for everyone without generating revenue through alternative means (e.g. advertising). This could lead to ethical dilemmas. <p>Control</p> <ul style="list-style-type: none"> • To what extent does the user or those surveilled have control over what happens to the data? Users retain complete control over their data through granular privacy settings, allowing them to manage permissions, monitor data usage, and restrict access to secondary users or applications. It is essential to ensure that this control remains safeguarded, even in the event of significant adjustments or system changes. |
| Equity | <p>Equality</p> <ul style="list-style-type: none"> • Does the technology serve to uplift those who could have the greatest benefit from innovation, or does it further exacerbate inequality? |

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| | <p>The system is designed for accessibility, focusing on vulnerable populations such as elderly individuals living alone. Efforts to make it affordable and scalable are key to reaching those in greatest need. This will require attention and support at various levels, including governments, municipalities, and insurance companies.</p> <ul style="list-style-type: none"> • If this tool is helpful and may cause positive outcomes, will it be affordable enough to benefit those who need it? This technology will likely only be accessible to those with the resources to afford it or in regions or communities where that is supported. <p>Identity</p> <ul style="list-style-type: none"> • Does the technology unfairly target a specific group? The system is inclusive, offering adaptive settings to accommodate diverse demographics, including various cultural, physical, and health conditions. However, regular updates will be necessary to ensure the system evolves to account for groups it does not yet recognize, as well as those undergoing changes over time. • Does the system work for people of different cultures, ethnicities, ages, genders, sizes, and disabilities? Customizable thresholds and sensitivity settings ensure the system remains effective for a wide range of users, accommodating individual differences. Likewise, the system must be continuously updated and trained to stay current, ensuring it can effectively detect—or intentionally not detect—and adapt to diverse needs and situations. |
| Sustainability | <p>Consumption</p> <ul style="list-style-type: none"> • Does the technology consume extraordinary amounts of energy or resources especially when compared to comparable solutions? RF sensing technology leverages existing IoT devices, minimizing the need for additional infrastructure. Energy-efficient protocols are employed to ensure low power consumption. However, additional devices required to support the overall system could still have an impact on energy usage. <p>Upkeep</p> <ul style="list-style-type: none"> • How long does the system last without upkeep? Regular updates and maintenance are recommended, but the system can operate autonomously for extended periods between updates. Routine maintenance, such as firmware updates, ensures long-term functionality. However, attention must be given to asynchronous aging between software parts, which could lead to compatibility issues or system disruptions. • How well can the system be recycled and maintained? Components are modular and recyclable, reducing environmental impact, with environmental considerations integrated into the product design to minimize waste. However, the key question is: how much reduction is achievable, and what level of impact is acceptable, especially when balanced against other factors such as costs and practicality? |

5. Innovation 3: Smart TV

In the evolving landscape of home entertainment, Smart TVs have become integral to the connected home ecosystem, driven by advancements in Wi-Fi integration and diversified media content. Beyond delivering superior audio-visual experiences, Smart TVs now serve as interactive hubs for IoT technologies, facilitating information access, interaction, and smart home control. By incorporating RF sensing technology, Smart TVs can further enhance user experiences by enabling advanced personalization through the recognition and interpretation of physical movements, all without physical contact. RF sensing opens possibilities for gesture control, user presence detection, and even health and wellness tracking. The integration of RF sensing within Smart TVs represents a transformative leap, offering intuitive and non-intrusive features that redefine interaction and usability.

5.1. Scenario Overview

In a smart home, a family of four enjoys an enriched living experience with a Smart TV enhanced by RF sensing technology. The family includes two parents, a teenage son who loves gaming, and a grandmother who uses sign language due to a hearing impairment. The Smart TV serves as a hub for interaction and entertainment, offering gesture-based control, personalized content, immersive gaming for the son, and fitness routines for the parents. Its inclusive design ensures accessible communication for all family members, while parental controls and adaptive settings make it an essential part of their connected lifestyle.

5.1.1. Users

- **Primary Users:** The entire family, using the Smart TV for entertainment, including interactive media content for the grandmother, who communicates using sign language due to a hearing impairment, and the teenage son, who enjoys gaming.
- **Secondary Users:** Family members who remotely interact with and control the media content, enhancing the family experience.

5.1.2. Location

Smart TVs with RF sensing are typically located in the primary living area of a home, where they serve as the main center for entertainment and interaction. They may also be placed in bedrooms or home offices, depending on the family's preferences. With Wi-Fi connectivity, these Smart TVs are accessible remotely, enabling family members to adjust settings or manage content from different locations within the home or while away.

5.1.3. Technologies

- **RF Sensing:** RF sensors embedded in Smart TVs detect user presence, gesture movements, and support interactive gaming activities. This non-contact technology enables hands-free navigation, gesture-based control for adults (especially useful for the grandmother who communicates using sign language), and immersive gaming experiences for the teenage son. It detects movements for gaming control, creating an interactive, engaging environment.

- **Edge Processing:** Local data processing ensures quick response times for activities like gesture recognition and gaming interactions. By processing data on-site, it reduces latency, enhancing the responsiveness of gesture controls and gaming activities.
- **Cloud Platform:** Stores data related to usage patterns, screen time, gaming preferences, and personalized content insights. Secondary users can access this data remotely via the cloud, allowing them to monitor usage or adjust settings for entertainment and gaming content.
- **Mobile App/Dashboard:** Provides secondary users (like parents) with remote access to TV settings, screen time data, and gaming activity. The app supports notifications for both media content and gaming, allowing parents to manage and monitor the family's entertainment experience, including interactive gaming for children.

5.1.4. Processes

Data Collection through RF Sensing:

- **Gesture Control:** RF sensors interpret gestures like swiping, tapping, or pointing, enabling users to control the TV hands-free. This includes gesture-based control for the grandmother (using sign language) and the teenage son for gaming interactions. The system also allows parents to monitor children's interaction with media content by limiting options based on gestures.
- **User Presence Detection:** Detects when someone is near or away from the TV, adjusting settings like power, brightness, and volume accordingly. It also enhances the user experience by triggering personalized content based on who is present (e.g., gaming suggestions for the son or media content for the parents).
- **Gaming Interaction:** RF sensors detect gestures specific to gaming (e.g., hand movements or controller-like gestures) to control gameplay without physical controllers.

Data Transmission and Analysis:

- **Edge Processing:** Processes movement and user interaction data locally, enabling instant responses for high-priority tasks, such as gesture recognition or gaming control or wellness insights. This minimizes latency for a seamless gaming and media interaction experience.
- **Cloud Storage and Analysis:** Transmits non-critical data to the cloud, allowing secondary users (parents) to view trends, screen time data, and monitor gaming activity or media preferences remotely. This data can also inform personalized content recommendations for family members.

Content Personalization:

- **User Recognition and Content Suggestion:** Recognizes individual users and suggests personalized content based on preferences, past activity, and interactions (e.g., media for the parents, gaming content for the son). The system adjusts settings such as volume or brightness based on user distance or presence, ensuring an optimal viewing or gaming experience for each user.
- **Gaming Preferences and History:** Tracks the son's gaming history and preferences, allowing the system to provide personalized gaming suggestions or notifications based on his activity, such as new game options or multiplayer opportunities.
- **Parental Control Features:** Allows parents to set screen time limits or restrict certain types of media or gaming content based on the son's activity, ensuring a safe and balanced media experience for children.

Mobile App/Dashboard:

- **Remote Parental Controls:** Secondary users (parents) can use the mobile app or dashboard to remotely manage gaming content, set screen time limits, and restrict certain types of media or gaming content. The app provides control over the family's media interaction, ensuring safe usage and age-appropriate content for children.
- **Gaming Preferences and History:** Parents can remotely monitor and review the son's gaming preferences, usage history, and gameplay data, allowing them to make informed decisions about restrictions or recommendations.
- **Screen Time Management:** Allows parents to track and limit screen time for each family member, ensuring a balanced media consumption experience

5.1.5. Flow of Information

Gesture Control and User Interaction:

- **Hands-Free Navigation:** Users can use simple gestures to turn on the TV, adjust volume, or browse content
- **Sign Language Recognition:** The grandmother controls the TV using global sign language. The technology recognizes standard signs and learns her personalized gestures, making the TV accessible and empowering.
- **Adaptive Learning:** The TV continuously learns and adapts to location-specific and personalized signs, improving interaction for the grandmother.

Presence Detection and Personalization:

- **Personalized Content Suggestions:** The TV recognizes family members and suggests content based on their preferences. For instance, it offers sports and games for the teenage son and relaxing shows for the grandmother. This allows the family to enjoy tailored content based on their individual tastes.
- **Automatic On/Off:** The TV automatically turns on when a family member is present and switches off when the room is empty, optimizing energy use. This feature ensures that the TV is only active when needed, promoting energy efficiency.
- **Adaptive Brightness and Sound:** The TV adjusts settings like brightness and volume based on the user's distance from the screen, ensuring a comfortable and personalized viewing experience. This feature ensures that each family member enjoys optimal screen clarity and sound levels.

Gaming Interaction and Entertainment:

- **Gaming Interaction:** RF sensors detect gestures specific to gaming, such as hand movements or controller-like gestures, enabling gameplay without the need for physical controllers. This allows the teenage son to enjoy immersive gaming experiences using just gestures.
- **Gaming Preferences and History:** The system tracks the son's gaming history and preferences, providing personalized gaming suggestions or notifications based on his activity, such as new game options or multiplayer opportunities.

Parental Controls and Management:

- **Child Monitoring and Parental Controls:** Parents can set screen time limits and ensure that the son maintains a healthy viewing distance. They can also restrict certain types of media or gaming content based on the son's activity, ensuring a balanced and safe media consumption experience.

- **Remote Parental Controls:** Through a mobile app or dashboard, parents can remotely manage gaming content, set screen time limits, and restrict media options for their children. This ensures that the TV usage remains appropriate for all family members, especially for the younger users.

Smart Meetings and Productivity:

- **Virtual Whiteboard Control:** The mother uses gesture controls for remote work, navigating presentations and annotating slides effortlessly. This feature makes the Smart TV an effective productivity tool, extending its use beyond entertainment to support professional tasks.

Fitness and Interactive Workouts:

- **Virtual Fitness Sessions:** The parents follow workout routines guided by the fitness app on the TV, which tracks their movements and provides real-time feedback, acting as a virtual fitness trainer. This interactive workout experience encourages the parents to stay active and healthy by offering personalized fitness routines.

5.2. Functional Requirements

The following functional requirements are based on the use case scenario of a Smart TV embedded with RF sensing technology, designed to enhance user interaction through gesture recognition, personalized content, and immersive gaming experiences. These requirements aim to create an intuitive, responsive, and secure entertainment and productivity experience for a family, with features tailored for both adults and children, and special attention to the grandmother who communicates using sign language, ensuring accessibility and ease of use for all family members.

1) Presence Detection and Personalization (Automatic On/Off)

Requirement: The TV must detect user presence to turn the TV on or off automatically, optimizing energy consumption.

Functionality: Power on when a user enters the room and switch off when the room is empty. Adjust settings based on user proximity, such as volume and brightness.

User Data:

- **Presence Logs:** Track user presence to learn usage patterns.

2) Gesture Control and User Interaction (Hands-Free Navigation)

Requirement: The TV must enable gesture-based control for turning the TV on/off, adjusting the volume, changing channels, and browsing content.

Functionality: Recognize simple and complex gestures, such as swiping or pointing, for precise control. Differentiate between intentional gestures and background movements to prevent accidental interactions.

User Data:

- **Gesture History:** Store personalized gestures for a more tailored and responsive experience.

3) Sign Language Recognition

Requirement: The TV must support sign language recognition to allow users to control the TV using (global) standard and personalized signs.

Functionality: Adapt to individual sign language styles and continuously learn to improve accuracy. Recognize both standard and personalized signs for intuitive control.

User Data:

- **User Profiles:** Store unique sign language data for each user.

4) Multiplayer Gesture Gaming

Requirement: The TV must detect and differentiate between multiple players, allowing gesture-based multiplayer gaming.

Functionality: Identify and track individual players in real-time. Enable competitive or cooperative gaming experiences based on gesture input.

User Data:

- **Player Profiles:** Store preferences and game history for a personalized gaming experience.

5) Personalized Content Suggestions

Requirement: The TV must recognize individual users and provide personalized content recommendations.

Functionality: Use machine learning to analyze viewing habits and suggest tailored content. Offer gaming recommendations based on the son's preferences and viewing habits for the parents.

User Data:

- **Viewing History:** Maintain a record of each user's favorite genres and past content.

6) Adaptive Brightness and Sound

Requirement: The TV must adjust the TV's brightness and sound based on the user's distance from the screen.

Functionality: Optimize settings for a comfortable viewing experience, with the option for users to override default adjustments. Adjust brightness and sound according to the user's proximity.

User Data:

- **User Preferences:** Allow customization of brightness and sound settings.

7) Wellness and Fitness (Posture Detection)

Requirement: The TV must monitor the user's posture and provide reminders for maintaining a healthy position.

Functionality: Offer customizable reminders based on user preferences or disable this feature entirely.

User Data:

- **Posture Settings:** Store individual posture preferences and reminder configurations.

8) Virtual Fitness Sessions

Requirement: The TV must provide fitness guidance and track user movements to offer real-time feedback.

Functionality: Monitor posture and form, acting as a virtual fitness trainer. Track the user's movements during fitness routines and offer real-time corrections.

User Data:

- **Workout History:** Keep track of exercise routines and performance metrics.

9) Smart Meetings and Productivity (Virtual Whiteboard Control)

Requirement: The TV must monitor the user's posture and provide reminders for maintaining a healthy position.

Functionality: Recognize gestures for navigating slides, writing on a virtual whiteboard, and managing video calls.

User Data:

- **Meeting Settings:** Save user preferences for professional or educational use.

10) Data Storage and Privacy (Data Security)

Requirement: The TV must encrypt user data both during transmission and at rest to protect privacy.

Functionality: Implement secure protocols for data transmission and provide users with data management options.

User Data:

- **Privacy Settings:** Allow users to review and modify data-sharing preferences.

11) Remote Parental Control and Management (Mobile App and Remote Dashboard)

Requirement: The system must allow parents to access and control the TV through a dedicated mobile app or a remote dashboard, providing them full control over the family's media experience.

Functionality: Parents can access a mobile app or web-based dashboard to manage settings, content restrictions, and screen time limits in real time. The app/dashboard must support remote monitoring of the child's viewing habits, including active content, screen time usage, and gaming activity. The app allows parents to adjust settings such as screen time limits, content restrictions, and gaming preferences for their children remotely. Enable real-time notifications to parents about screen time, content access, and any violation of the predefined restrictions.

User Data:

- **Remote Control Settings:** Store parental control preferences and any changes made remotely through the mobile app or dashboard.

- **Activities and Notifications:** Track parental actions, such as content restrictions or screen time adjustments, and notify parents when content is being accessed outside the allowed parameters.

5.3. Ethical Profile

| Smart TV Ethical Profile | |
|--------------------------|---|
| Privacy | <p>Sensitive Data</p> <ul style="list-style-type: none"> • How sensitive is the data in the system? The Smart TV stores biometric information to identify and distinguish between individual users. It also captures their usage patterns, content, and may track health information such as posture. The data is sensitive. • Can it be used to spy on individuals? The parental control settings can be used for the owners of the application to track usage and content of others. (Ex: parents spying on their teenage son.) If the system is hacked this information can also be found by others. <p>Sensitive Data Shared</p> <ul style="list-style-type: none"> • How much data is accessible to 3rd party apps? 3rd party applications may access information needed to run secondary programs such as video games and other interactive content. There is the possibility that any data stored to the cloud may be shared to third parties. Explicit consent should be required to share any cloud data to 3rd parties. • Are the elements open source? No. Theoretically for third party apps to run on the TV there must be open APIs that can connect with the system though. <p>Data Retention</p> <ul style="list-style-type: none"> • Does the app require long-term and historical data storage? Not all elements of the application require long-term storage. Biometric data would need to be stored long-term to recognize users. User preferences and settings also need to be stored long-term. Long-term storage of other data such as usage patterns should be opt in. <p>Control</p> <ul style="list-style-type: none"> • What is the degree of control over data and management? The owners of the system have the highest degree of control over the features and settings that they opt into and out of. Other users such as visitors or children have less control. Once opting in to 3rd party services users have little control over what will happen to the 3rd party data. |
| Accountability | <p>Accuracy</p> <ul style="list-style-type: none"> • Is the accuracy of the system known (false +/- rate)? Currently no, it is too early in the prototyping process. • Are conditions where the system does not work known? Currently no, it is too early in the prototyping process. <p>Ex Ante</p> <ul style="list-style-type: none"> • Are there regulations in place to mitigate the usage/responsibility of the technology? |

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| | <p>There is work to be done in this domain. Users should be able to opt in and out of various services without being pressured to switch.</p> <p>Ex Post</p> <ul style="list-style-type: none"> • Does the system take appropriate measures if things go awry? Currently no. It might be helpful to consider having a backup system such as a physical remote, on/off button, and ability to factory reset and remove all data, ideally from 3rd parties as well. <p>Translation</p> <ul style="list-style-type: none"> • Is it clear what the system does, its limits, and who controls it? For those using the system there should be a tutorial program that explains how the system works and what happens to the data. For visitors it will be unclear. Additionally, there should be a page where users can go to quickly understand their settings and what data is being processed. • Can the <i>results</i> and system be explained to non-expert users? For direct interactions it will be evident that the TV is sensing movement and responding accordingly. The volume adjustment due to distance from the TV posture detection, recommendations and identity recognition will be more obscure. <p>Visibility</p> <ul style="list-style-type: none"> • Is it evident the system is in place? It will likely look like a normal TV. There could be a system where the screen shares that it is a smart TV when someone is in the room, and it is on standby mode. |
| Autonomy | <p>Choice</p> <ul style="list-style-type: none"> • Are people able to opt out of being tracked by RF holography? It seems difficult for family members or individuals in the vicinity of the Smart TV to opt out of being tracked. Given that the TV is designed to recognize individuals it could perhaps be set to ignore non-identified individuals. This might be unfair to those who are visiting and want access to the system. <p>Power</p> <ul style="list-style-type: none"> • Does it limit, restrict, or reconstruct natural movement/decision making? This technology is primed to reshape human behavior. If the technology is dictating what constitutes good posture, appropriate decibel level, correct workout form etc. it will reshape how the user would normally behave. This may be good if the system is correct in its analysis and the user is willing and interested to make these changes. However, the system might not always know what is best for the user there should be options to limit such paternalistic systems so that they operate by the user's choice. Moreover, the TV automatically turning on when someone enters the room might entice them against their better judgement to watch TV. • Is the data self-serving (advertising etc.) or benefiting the user? Some of the data may be shared to third parties to offer user recommendations that sell services or harvest data for other means. Other data might benefit the user such as keeping track of screentime or monitoring factors that the user wants to improve. <p>Control</p> |

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| | <ul style="list-style-type: none"> • To what extent does the user or those surveilled have control over what happens to the data? The owner of the system has the most control over the system settings. Visitors, children or other users will be subject to the sharing settings of the one who controls the password and is likely paying for the service. |
| Equity | <p>Equality</p> <ul style="list-style-type: none"> • Does the technology serve to uplift those who could have the greatest benefit from innovation, or does it further exacerbate inequality? If the technology works well for those who use sign language it could be helpful, of course a remote or console may work just as well. Such a system might be even more challenging for paralyzed individuals or those with reduced motor control to navigate the system. • If this tool is helpful and may cause positive outcomes, will it be affordable enough to be benefit those who need it? It does not appear that this technology will relatively lower the quality of life or opportunities for those who do not have access. <p>Identity</p> <ul style="list-style-type: none"> • Does the technology unfairly target a specific group? This technology has features to limit the capabilities of young users for their own safety based on their parents' wishes. • Does the system work for people of different cultures, ethnicities, ages, genders, sizes, and disabilities? It needs to be tested that the accuracy is the same across differently sized individuals with various mobility levels. |
| Sustainability | <p>Consumption</p> <ul style="list-style-type: none"> • Does the technology consume extraordinary amounts of energy or resources especially when compared to comparable solutions? Energy consumption levels still need to be tested in comparison to traditional TVs also when on standby mode. It might not make sense for the television to automatically turn on when someone enters the room. Putting the screen on off or standby when people are away might save energy. <p>Upkeep</p> <ul style="list-style-type: none"> • How long does the system last without upkeep? This still needs to be determined. • How well can the system be recycled and maintained? This still needs to be determined. |

6. Conclusion

This report covers the process of going from innovations to applications as well as the initial development of those applications in terms of their functional requirements and ethical profiles. With this baseline we can now begin to further explore, prototype and adapt the technologies in context. It is essential that the applications be built for and adapted to the real world. Both the functional requirements and ethical profiles are starting points that will continue to influence each other. As these technologies evolve, their deployment will demand a more nuanced understanding of their potential societal impacts and long-term effects on users and institutions alike.

The ethics profiles show that there are still questions that have yet to be answered to ensure ethical use. The translation of the purpose of the technology and how it works to those interacting with the applications needs to be developed alongside the functional requirements. Certain ethical concerns need further development of the technology to address. It is impossible to test whether a system is biased until it exists in some form – but with knowledge of such concerns it can be designed to mitigate these risks early. This dynamic process underscores the necessity of iterative development, where insights gained from early implementation phases guide refinements.

Deeper analysis of how the technology affects stakeholders and their values will be addressed in the appropriation studies. Mediation theories offer valuable perspectives on how these technologies may shape human behavior and societal values and norms. These technologies might influence interactions, behavior and value systems in ways currently imperceptible. For instance, gesture controls and holography could enhance accessibility but also demand user adaptation. These theories emphasize the duality of technological influence: empowering users through novel capabilities while simultaneously reshaping their behaviors and expectations. The explanatory power of mediation theories is evident in their ability to provide insight in intended and unintended consequences. For example, the adoption of RF sensing in public spaces could inadvertently create environments of hyper-surveillance, where individuals alter their behavior due to perceived monitoring. Understanding such dynamics enables stakeholders to design systems that respect autonomy and foster trust. Regular stakeholder consultations and iterative feedback loops, using theory and documented experience, can ensure the interventions remain grounded in real-world needs and expectations.

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