# Smart Living Robotic Workforce Research

*by* Marian Banica

**Submission date:** 03-Oct-2025 11:25AM (UTC+0300)
**Submission ID:** 2769618148
**File name:** 2025_PhD_UPB_Smart_Living_Robotic_Workforce_Research_v.1.2.2.pdf (19.69M)
**Word count:** 9398
**Character count:** 57682

**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY POLITEHNICA BUCHAREST**

**Doctoral School of Automatic Control and Computer Science**

# SCIENTIFIC REPORT

**no.** 1 **from** 2025

## PhD student: Marian BĂNICĂ


| | |
|---|---|
| **Prof. Dr. Ing. Ciprian-Gabriel Lupu**<br>POLITEHNICA Bucharest | PhD Supervisor |
| **Prof. Dr. Ing. Florin Pop**<br>POLITEHNICA Bucharest | Mentoring commission member |
| **Prof. Dr. Ing. ..............................**<br>University of Craiova | Mentoring commission member |
| **Dr. Ing. ..............................**<br>POLITEHNICA Bucharest | Mentoring commission member |


**BUCHAREST 2025**

## Smart Living Solutions using Robotic Workforce

### Abstract

This report provides a review of the current state of smart living solutions and the integration of robotic workforces within these environments. It covers the **foundational definitions, technological advancements, and diverse applications** that can be seen both in scientific literature but also at engineering trade fairs such as 2025 Hannover Messe (March 31-April 4, 2025, Hannover, Germany)

An important part of this report is dedicated to the challenges associated with integrating robotics into smart living, including issues of privacy, security, user acceptance, ethical considerations, and regulatory compliance in different countries.

Most of the actual work is based on the living solutions provided by **Wuppertal Living**

**Lab NRW (North Rhine Westphalia) Wuppertal, Germany[1], with focus on two models of smart houses:**

1. **Local+ Aachen [2]**

The **LOCAL+** project, developed by FH Aachen (University of Applied Sciences Aachen)[3], addresses the challenges of sustainable and socially inclusive urban housing.

The design concept focuses on creating adaptable living environments while reducing the ecological footprint of residential construction. The project combines a modular solid wood structure with integrated photovoltaic and green façade systems, enabling the building to cover approximately two-thirds of its energy demand through on-site generation. Flexibility is achieved through the use of movable “CUBEs,” multifunctional furniture modules that allow residents to reconfigure their living spaces according to changing needs.

Beyond energy efficiency and resource-conscious construction, LOCAL+ creates new forms of collective living, targeting the growing demographic of single-person households and promoting shared use of space and resources. [4]

---

[1] https://livinglabnrw.uni-wuppertal.de/de/
[2] https://www.fh-aachen.de/fachbereiche/architektur/vortraege-projekte/local
[3] https://www.fh-aachen.de/
[4] https://building-competition.org/EU2021/FHA FH Aachen Project Manual7_2022_07_20.pdf

2. **MIMO - Hochschule Dusselforf** [5]


The **MIMO (Minimal Impact – Maximum Output)** project, developed by Hochschule

[5] https://mimo-hsd.de/

Düsseldorf, explored strategies for sustainable urban densification and building refurbishment. Using a modular solid wood construction system, MIMO demonstrated how prefabricated units can reduce embodied energy, streamline assembly, and enable flexible residential layouts.

The report also outlines strategic methodologies for implementing a living lab focused on smart living solutions utilizing a robotic workforce.

## 1. Introduction to Smart Living and Robotic Workforce

Smart technologies are part of everyday life, creating what we call "smart living." At the same time, robots are getting better and easier to use, making it possible to build a "robotic workforce" that can handle many different jobs. This section explains what both terms mean and looks at how they connect, as well as the new possibilities that come from combining them.

### 1.1 The Evolution of Smart Living

1

Smart living is a **lifestyle** that applies technology to improve quality of life, increase efficiency, and reduce waste in everyday activities.[1] It covers areas such as homes, workplaces, and urban transport, aiming to raise living standards while supporting economic efficiency and lowering environmental impact.[4] In academic terms, smart living is viewed as a **multi-dimensional concept** built on four main areas: **technology, security, health, and education.**[1]

Key features of smart living environments include energy efficiency, the use of big data, Internet of Things (IoT) adoption, smart transport systems, effective waste management, and modern electricity grids.[5] Another important factor is **Human Action Recognition (HAR)**, which supports the success of smart living services.[2]

1

Smart living is closely linked to the wider idea of smart cities, which are generally described through six components: **smart economy, smart people, smart governance, smart mobility, smart environment, and smart living.**[2]

### 1.2 Use of the Robotic Workforce

Robots are generally defined as machines programmed through computer algorithms to carry out both simple and complex tasks.[7] A central feature that separates robots from standard automated machines is their ability to adapt tasks in response to changes in their environment.[7]

The robotic workforce can be grouped into several categories: industrial robots, professional and personal service robots, and collaborative robots (cobots).[7]

The rise of collaborative robots and mobile robots is reshaping safety practices and human-robot interaction (HRI). Unlike traditional industrial robots, where safety was ensured through strict physical separation in guarded areas,[7] cobots and mobile robots are built to work directly alongside humans.[8] This shift makes old separation measures outdated.[11] As a result, new methods for risk assessment and control must be developed and tested.[11] Research into HRI has therefore become essential, moving beyond basic task execution to address mutual understanding, predictability, trust, and safety in shared workspaces.[12] This change emphasizes the need to study how people perceive and interact with robots in close proximity, a key challenge for their successful use in domestic and workplace environments.

### 1.3 Synergies and Opportunities

The integration of a robotic workforce presents major opportunities for strengthening smart living solutions. Robots can improve efficiency, increase safety, and enhance overall quality of life within smart environments.[1] They can take on repetitive and physically demanding tasks, easing the workload of human caregivers and allowing for more personalized care.[14] Practical applications include home automation, healthcare support, and security services.[3]

Beyond task automation, the growing use of robots also drives job transformation and the creation of new employment opportunities.[13] Their integration often requires human oversight and maintenance roles, combining technical expertise with traditional job functions.[13] In addition, new jobs continue to emerge in the design, programming, manufacturing, data collection, and analysis of robotic systems.[13]

The adoption of a robotic workforce thus offers a dual opportunity: improving smart living solutions while also fostering new human-robot relationships and generating new skill-based career paths. While public discussions on robotics often stress the risk of job loss, available evidence shows that robots not only "transform" existing jobs but also "create new opportunities."[13] This highlights that the relationship between smart living and robotics is not simply about automation replacing human labor, but about a co-evolution where humans and robots collaborate to develop new forms of work. These roles require specialized knowledge in fields such as robot design, programming, maintenance, and data analysis.[13]

For living lab environments, this means research should go beyond assessing technical performance. It must also examine human factors such as training, adaptation, and collaboration models that build trust and efficiency in human-robot partnerships. Taking this broader approach will help create a more connected, effective, and sustainable smart living ecosystem.

## 2. Current State-of-the-Art in Smart Living Solutions

This section provides a detailed examination of the current smart living solutions, exploring their fundamental components, applications across various domains, and the emerging trends shaping their future. A particular emphasis is placed on the critical role of data management and interoperability standards in realizing the full potential of these intelligent environments.

### 2.1 Core Components and Key Indicators

Smart living environments are fundamentally built upon the integration of advanced Information and Communication Technology (ICT), smart sensing technology, robust big data analytics, and intelligent decision-making frameworks.[2] These technological foundations serve to optimize energy consumption, enhance healthcare services, and generally improve living standards for inhabitants.[3]

**Table 2.1: Key Dimensions and Indicators of Smart Living Solutions**

| Dimension/Category | Key Indicators/Components |
|---|---|
| **Foundational Technologies** | Internet of Things (IoT), Big Data, Information and Communication Technology (ICT), Smart Sensing Technology, Ubiquitous Computing, Intelligent Decision-Making, Human Action Recognition (HAR) |
| **Core Operational Aspects** | Context Awareness, Data Availability, Personalization, Privacy, Real-time Processing, Interoperability, Multimodality, Resource-Constrained Processing |
| **Societal & Environmental Impact** | Quality of Life, Efficiency, Waste Minimization, Energy Savings, Reduced Carbon Footprint, Health, Education, Security, Citizen Participation |
| **Urban & Infrastructure Elements** | Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment, Smart Living (as a component), Transportation Systems, Waste Management, Smart Electricity, Smart Lighting, Smart Water, Smart Traffic, Smart Parking, Smart Buildings, Smart Industry |

## 2.2 Applications Across Domains

The concept of smart living has found diverse applications across numerous domains, extending its influence beyond mere residential automation.

In **smart homes**, the application of intelligent systems has revolutionized various sectors, including healthcare ecosystems, efficient household energy consumption management, and enhanced security and emergency response protocols.[18] Smart homes are designed to detect potential threats and initiate appropriate actions based on the nature and severity of these threats, thereby ensuring a safe, secure, and comfortable lifestyle for their inhabitants.[18]

Within **healthcare**, smart IoT-based applications have brought about transformative changes. They enable advanced assisted living solutions [3], comprehensive health monitoring systems [18], and even specialized applications such as navigation systems for visually impaired individuals.[18] These technologies are increasingly utilized to support the early diagnosis of critical conditions, including cardiovascular, neurological, and pulmonary diseases.[19]

**Energy management** is another significant domain for smart living applications, with a primary objective to optimize energy consumption.[3] This involves the efficient management of household energy usage [18] and the development of sophisticated systems that learn occupant behavior to interact dynamically with the energy grid for peak load shifting and shedding, thereby enhancing energy efficiency and reducing strain on infrastructure.[20]

In terms of **security and surveillance**, smart homes provide robust security and emergency response capabilities.[18] Human Action Recognition (HAR) plays a pivotal role in these systems, contributing to home automation, healthcare, safety, and security by enabling real-time responses and personalized support.[3] Furthermore, advanced security robotics, equipped with AI-driven analytics, are deployed for autonomous patrolling, real-time data analysis, and proactive threat detection, significantly enhancing overall security postures.[21]

The broader scope of smart living is intricately linked with **transportation and urban living**. It encompasses various aspects of smart cities, including smart lighting, smart water management, smart traffic control, smart parking solutions, smart buildings, and smart industry initiatives.[2] AI-based smart traffic management systems, for instance, are designed to optimize traffic flow and alleviate congestion in urban environments.[22]

Human Action Recognition (HAR) is a foundational technology that bridges various smart living applications, enabling more intelligent and responsive systems, particularly for assisted living and human-robot interaction. HAR is not merely a supplementary component but is identified as a "critical success factor" for smart living services across a diverse array of domains, including energy management, healthcare, and transportation.[2] Its core function involves the accurate identification and interpretation of human actions.[3] This capability, in turn, empowers smart living systems to provide "real-time responses, delivering personalized support and assistance".[3] This implies that continued investment in HAR research, especially focusing on multimodal sensing capabilities, is crucial for developing truly "smart" and adaptive environments. In such environments, robotic workforces can effectively assist, anticipate user needs, and interact naturally with residents. This advancement shifts the paradigm beyond simple automation to intelligent, context-aware assistance, directly enhancing the efficacy and user experience of robotic workforces within smart living contexts.

### 2.3 Emerging Technologies and Future Trends (2023-2025)

The landscape of smart living solutions is continuously shaped by rapid advancements in emerging technologies, particularly Artificial Intelligence (AI).

**AI-powered personalization** is set to revolutionize User Experience (UX) and User Interface (UI) design by enabling increasingly tailored user experiences.[23] AI systems analyze extensive user data to dynamically adjust UI elements, content, and navigation in real-time, leading to hyper-personalized digital interactions.[24] This extends beyond simple content recommendations, evolving to adapt menu structures and even color schemes based on individual user preferences.[24]

The evolution of **conversational interfaces** is another prominent trend. AI chatbots and voice assistants are moving beyond basic query responses to understand complex contexts, anticipate user needs, and provide intuitive, human-like interactions.[23] Future systems are expected to recognize emotional tone, predict user frustrations, and proactively offer assistance before users explicitly request it.[24]

**Generative AI** is also making significant inroads into UX/UI design. AI-powered design tools automate layout suggestions, optimize color palettes, and streamline UX workflows, thereby enhancing efficiency rather than replacing human creativity.[24] Automated wireframing and AI-generated A/B testing variations are anticipated to become standard practices.[24]

A notable trend is the rise of **Zero UI design**, which aims to reduce the reliance on traditional visual interfaces. Interactions are increasingly shifting towards voice commands, gestures, and sensor-based inputs.[23] Wearable devices and Augmented Reality (AR) glasses are prioritizing screen-free experiences, making technology more seamlessly integrated into the environment.[23]

**Immersive experiences with AR and VR** (Augmented and Virtual Reality) are redefining user engagement across various sectors, including e-commerce, education, and healthcare.[23] Businesses that effectively integrate AR/VR into their platforms are poised to differentiate themselves in user experience. This includes virtual shopping experiences, interactive learning environments, and real-time AR overlays that enhance how users interact with digital content.[24]

Finally, **AI is transforming traditional appliances and home security systems**. AI-powered washing machines, for instance, can automatically select optimal settings [20], while smart refrigerators assist in minimizing food waste, and cooking ranges can prevent food from burning.[20] Home security is significantly bolstered by AI, with advanced smart locks capable of tracking precise location and movement for enhanced access control.[20]

### 2.4 Data Management in Smart Living Environments

The proliferation of Internet of Things (IoT) devices in smart homes, while offering unprecedented connectivity, also introduces significant data management challenges.

**Challenges** in this domain include the sheer volume and increasing complexity of data generated by myriad devices.[26] A pervasive issue is the existence of data silos, which hinder the seamless integration and leveraging of data from heterogeneous internal and external sources.[26] Ensuring the confidentiality, integrity, and availability of IoT data is a paramount concern, as smart living environments are susceptible to unauthorized access, privacy breaches, and data manipulation.[27]

To address these complexities, various **solutions** are being developed and implemented. Cloud-first data platforms, such as InterSystems IRIS, are specifically designed to simplify the construction and deployment of high-performance, AI-enabled applications that effectively connect disparate data and application silos.[26] These platforms are engineered to support both SQL and NoSQL databases, capable of handling transactions and concurrent analytics at scale within a single database management system (DBMS) engine.[26] They further enable the creation of intelligent enterprise applications powered by semantic search and generative AI across any data type.[26]

### 2.5 Interoperability Standards for Smart Home IoT Devices

The successful operation of a smart home ecosystem is critically dependent on the seamless interaction between its various devices and platforms.[29] Interoperability testing is therefore essential, as it validates the ability of different devices and applications to communicate and operate effectively within this integrated environment.[29]

Key components of interoperability testing include **protocol testing**, which ensures that various communication protocols like Wi-Fi, Bluetooth, Zigbee, and Z-Wave function together efficiently; **platform compatibility testing**, verifying seamless functionality across different operating systems such as iOS and Android; **device verification**, which ensures devices from different manufacturers can work together without compatibility issues; and comprehensive **system integration testing**, which validates the overall performance of all hardware, software, communication protocols, and applications within the smart home ecosystem.[29]

Several organizations are actively developing **current standards and initiatives** to address these needs:

- **ETSI (European Telecommunications Standards Institute):** The ETSI EN 303 645 standard, "Cybersecurity for Consumer Internet of Things: Baseline Requirements," updated in 2024, is widely recognized and referenced. It establishes a security baseline for connected consumer products and includes crucial data protection provisions.[30]
- **NIST (National Institute of Standards and Technology) - US Cyber Trust Mark:** NIST has published foundational cybersecurity guidelines for IoT device manufacturers, including the IR 8259 series and the core baseline for consumer IoT products (IR 8425).[30] The U.S. Cyber Trust Mark, a voluntary labeling program launched in January 2025, is based on NIST requirements and aims to help consumers identify secure devices.[30]
- **ISO/IEC (International Organization for Standardization / International Electrotechnical Commission):** ISO/IEC 27402:2023 focuses on "Cybersecurity — IoT security and privacy — Device baseline requirements".[30] Additionally, ISO/IEC 27403:2024 provides specific guidelines for IoT-domotics, or home automation systems.[30]

Despite these concerted efforts, a significant **challenge** remains: the IoT cybersecurity standardization landscape is fragmented globally.[30] Different regions often adopt multiple approaches, leading to a persistent lack of unification across the industry.[30]

## 2.6 Interoperability Standards for Smart Home IoT Devices

A major challenge in the development of smart living solutions is the lack of interoperability between devices from different manufacturers. This "walled garden" approach limits consumer choice and hinders the creation of a truly integrated and seamless smart home experience. To address this issue, several open standards and alliances have emerged, with the goal of creating a common language for smart home devices.[3] One of the most promising of these is the **Matter** standard, which is backed by major industry players such as Apple, Google, and Amazon. Matter aims to provide a unified application layer that allows devices to communicate with each other regardless of the underlying network protocol (e.g., Wi-Fi, Thread, or Ethernet). Another important standard is **Zigbee**, which is a low-power wireless mesh network protocol that is widely used in smart home devices. The Zigbee Alliance, now known as the Connectivity Standards Alliance, is also behind the development of the Matter standard.

### KNX: A Global Standard for Home and Building Control

A significant and well-established standard in home and building automation is **KNX**. It is an open standard (EN 50090, ISO/IEC 14543) that has been in use for over three decades, ensuring a high degree of reliability and interoperability among devices from different manufacturers. KNX is not limited to a single manufacturer or platform, with over 500 companies producing compatible products, offering a wide range of choices for consumers and system integrators.

#### KNX Architecture and Communication Media

The KNX system is decentralized, meaning that each device has its own intelligence and can communicate directly with other devices on the network. This eliminates the need for a central controller, which increases the reliability of the system – if one device fails, the rest of the network continues to operate. KNX supports several communication media, providing flexibility for both new and existing buildings:

- **Twisted Pair (TP):** This is the most common medium, using a dedicated two-wire bus cable for communication and power supply to the devices.
- **Powerline (PL):** This medium uses the existing mains wiring to transmit data, making it suitable for retrofitting.
- **Radio Frequency (RF):** KNX RF is a wireless solution that is ideal for situations

where it is difficult to run new cables.

- **IP/Ethernet:** KNXnet/IP allows for the integration of KNX systems with IP networks, enabling communication over local area networks (LANs) and the internet.

**Advantages of KNX**

- **Interoperability:** As an open standard, KNX guarantees that devices from different manufacturers will work together seamlessly.
- **Flexibility and Scalability:** A KNX system can be easily expanded and adapted to new needs. New devices can be added to the network at any time.
- **Reliability and Robustness:** The decentralized architecture and the use of a dedicated bus cable make KNX systems very reliable.
- **Energy Efficiency:** By intelligently controlling lighting, heating, ventilation, and other systems, KNX can significantly reduce energy consumption in a building.
- **Security:** KNX includes security features to protect against unauthorized access and manipulation.

**Disadvantages of KNX**

- **Initial Cost:** The initial investment for a KNX system can be higher compared to some proprietary or DIY solutions.
- **Complexity and Installation:** The planning, installation, and commissioning of a KNX system require specialized knowledge and are typically carried out by certified professionals using the ETS (Engineering Tool Software).

**KNX and Interoperability with Other Systems**

KNX systems can be integrated with other smart home ecosystems. Gateways and interfaces are available to connect KNX with systems like **Google Home**, **Amazon Alexa**, and **Apple HomeKit**, allowing for voice control and integration with a wider range of consumer smart devices. This makes it possible to combine the robustness and reliability of a wired KNX installation with the convenience and user-friendliness of popular smart home platforms.

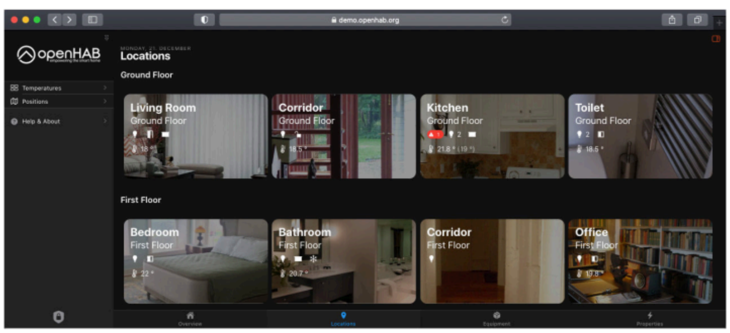
## 2.7 openHAB and Home Assistant: Open-Source Smart Home Platforms

In addition to established standards like KNX, the open-source community has produced powerful and flexible smart home platforms that offer a high degree of customization and control. Two of the most prominent are **openHAB** and **Home Assistant**. These platforms act as central hubs, integrating a vast array of devices and services from different manufacturers and protocols.

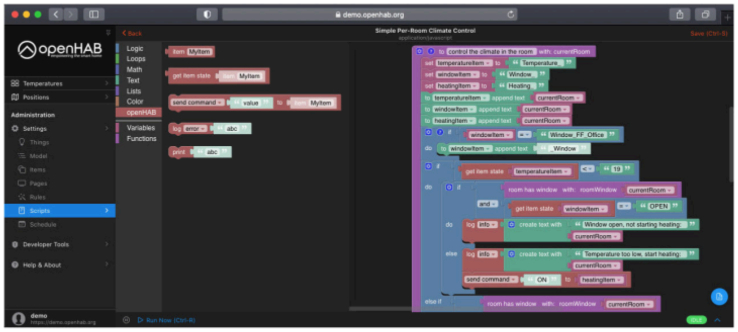
### 2.7.1 openHAB

openHAB[6] (Open Home Automation Bus) is a mature, Java-based platform that has been in development since 2010. It is designed to be vendor- and technology-agnostic, with a strong emphasis on interoperability and a pluggable architecture.

- **Architecture and Features:** openHAB is built on an OSGi (Open Services Gateway initiative) runtime environment, which allows for a modular and extensible system. Its architecture is divided into a core system, bindings that provide support for specific technologies or devices, and user interfaces. A key concept in openHAB is the "Thing," which represents a physical device, and "Items," which represent the capabilities of a Thing (e.g., a light switch's on/off state). This abstraction layer allows for a consistent way to interact with different devices.
- **Automation:** openHAB offers a powerful rules engine that allows for the creation of complex automation routines. Rules can be triggered by time, events, or changes in the state of Items.
- **Interoperability:** openHAB supports over 400 bindings, enabling integration with a vast range of devices and services, including popular platforms like Google Assistant, Amazon Alexa, and Apple HomeKit.




[6] https://www.openhab.org

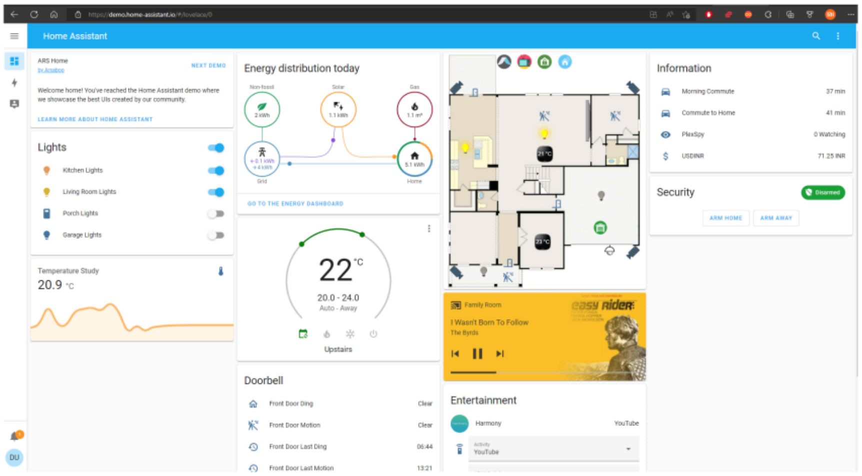


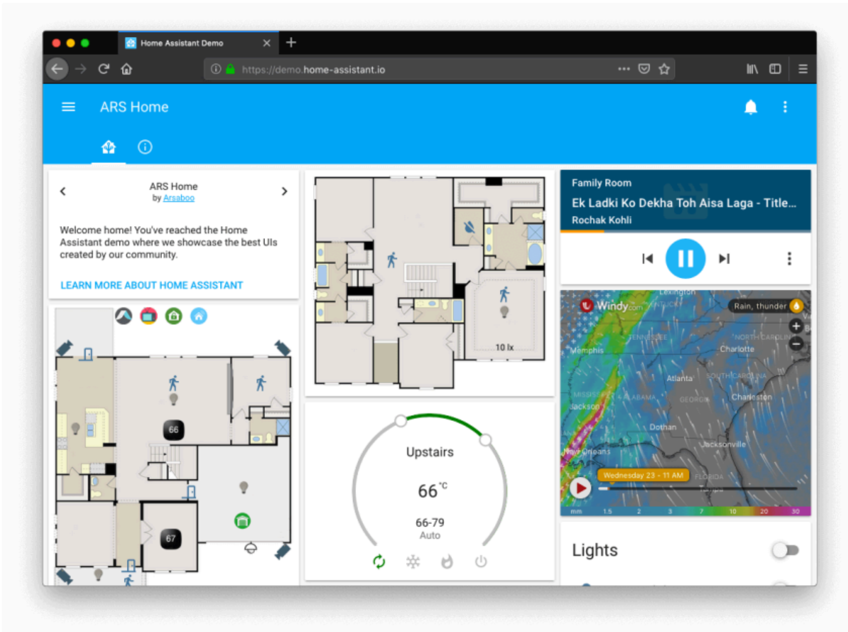

### 2.7.2 Home Assistant

Home Assistant[7] is a Python-based open-source home automation platform that has gained significant popularity due to its user-friendly interface, powerful features, and active community.

- **Architecture and Features:** Home Assistant's architecture is also modular, with a core that manages the event bus, state machine, and service registry. "Integrations" provide support for different devices and services. A key feature is its ability to automatically discover new devices on the network, simplifying the setup process. Home Assistant also has a strong focus on local control and privacy, with the ability to run entirely without a cloud connection.
- **Automation:** Home Assistant provides a user-friendly automation editor in its web interface, allowing users to create automations using a visual workflow. For more advanced users, automations can also be created and edited using YAML.
- **Interoperability:** Home Assistant boasts over 1,000 integrations, making it one of the most versatile smart home platforms available. It also has a strong focus on interoperability with other smart home ecosystems and supports a wide range of protocols, including Zigbee, Z-Wave, and Thread, through the use of USB dongles.

[7] https://www.home-assistant.io


Home Assistant
ARS Home
NEXT DEMO
Welcome home! You've reached the Home Assistant demo where we showcase the best UIs created by our community.
LEARN MORE ABOUT HOME ASSISTANT
Lights
Kitchen Lights
Living Room Lights
Porch Lights
Garage Lights
Temperature Study
20.9 °C
Energy distribution today
Non-fossil
Solar
Gas
Grid
Home
GO TO THE ENERGY DASHBOARD
22 °C
20.0 - 24.0
Auto - Away
Upstairs
Doorbell
Front Door Ding
Clear
Front Door Motion
Clear
Front Door Last Ding
06:44
Front Door Last Motion
13:21
Family Room
I Wasn't Born To Follow
The Byrds
Entertainment
Harmony
YouTube
Activity
YouTube
Information
Morning Commute
37 min
Commute to Home
41 min
PlexSpy
0 Watching
USDINR
71.25 INR
Security
Disarmed
ARM HOME
ARM AWAY




**Comparison and Use Cases**

Both openHAB and Home Assistant are powerful and flexible platforms, but they have different strengths and appeal to different users.

- **openHAB** is often seen as a more robust and developer-centric platform, with a steeper learning curve but also a high degree of flexibility and customization. Its strong abstraction layer makes it well-suited for complex and highly customized installations.
- **Home Assistant** is generally considered more user-friendly, with a more polished user interface and an easier setup process. Its large and active community provides a wealth of documentation, tutorials, and community-developed integrations.

Both platforms are excellent choices for creating a customized and interoperable smart home. The choice between them often comes down to the user's technical expertise, their specific needs, and their personal preferences.

### 3. Current State-of-Art in Robotic Workforce for Smart Living

The integration of robotic systems into daily life, particularly within smart living environments, represents a significant frontier in technological advancement. This section details the various categories and capabilities of service robots, their specific applications in domestic and assisted living settings, and the technical and economic limitations that currently impede their adoption.

## 3.1 Classification and Applications of Robotic Workforce in Smart Living

| Robot Category/Type | Key Capabilities | Application Domains in Smart Living |
|---|---|---|
| **Industrial Robots** | Welding, Painting, Assembling, Moving, Testing, Palletizing | Manufacturing, Construction (e.g., modular building), Heavy-duty tasks in smart factories |
| **Professional Service Robots** | Picking, Sorting, Transporting, Inspecting, Data Monitoring/Analysis, Handling hazardous tasks | Warehousing & Logistics, Agriculture, Oil & Gas, Infrastructure Inspection, Security & Surveillance |
| **Personal Service Robots** | Home automation (cleaning, cooking, mobility assistance), Daily chores, Entertainment, Social interaction | Domestic Environments (smart homes), Assisted Living Facilities |
| **Collaborative Robots (Cobots)** | Working alongside humans, Assisting with assembly/packaging, Responding to workflow changes, Human-Robot | Manufacturing (smart factories), Logistics, Healthcare (assisting staff), Domestic (shared tasks) |

| | Interaction (HRI) | |
|---|---|---|
| **Autonomous Mobile Robots (AMRs)** | Transporting goods, Sorting packages, Managing inventory, Autonomous navigation | Warehousing & Logistics, Domestic (e.g., robot vacuums, delivery robots), Healthcare (transporting supplies) |
| **Drones (UAVs)** | Inspecting structures, Monitoring environments, Surveillance, Delivery | Security & Surveillance, Infrastructure Management, Smart City monitoring, Agriculture (crop monitoring) |
| **Assistive Robots** | Medication reminders, Health monitoring, Physical rehabilitation support, Assistive feeding, Mobility support, Emotional support | Healthcare, Assisted Living Facilities, Independent Living (aging in place) |

## 3.2 Applications in Domestic and Assisted Living

The application of robotic workforces is expanding significantly into domestic and assisted living environments, addressing a growing range of needs.

In **domestic applications**, robots are increasingly performing household tasks, evolving from simple functions like sweeping and chatting to more complex activities such as warming meals and tidying desks.[34] Common examples already prevalent include robot vacuum and mop hybrids [35] and other smart robot vacuums designed to manage household messes.[35]

Within **healthcare and assisted living**, service robots are making substantial contributions to health monitoring, daily assistance, emotional support, and the overall efficiency of facility management in senior communities.[14] These robots are capable of taking over repetitive and physically demanding caregiving tasks, thereby alleviating the burden on human caregivers and enabling more personalized care delivery.[14] Specific applications include providing medication reminders, continuous health monitoring, offering physical rehabilitation support [14], and even specialized functions like assistive feeding arms for individuals with motor impairments.[32] Beyond physical assistance, social robots are increasingly utilized to address mental health challenges prevalent among older adults, such as depression, anxiety, and loneliness.[36]

For **independent living support**, robots empower elderly individuals to live autonomously for longer periods. This is achieved through home-based care systems equipped with motion sensors, speech recognition, and health-monitoring devices.[37] These systems can assist with various daily activities, enhance individual independence and autonomy, and crucially, reduce the risk of falls and other adverse events.[38] Companies like Labrador Systems are at the forefront of pioneering assistive robots specifically designed to help people live more independently by physically assisting with everyday tasks, such as delivering meals, carrying laundry, or keeping critical items within easy reach.[39]

## 3.3 RoboCasa: A Simulation Framework for Generalist Robots

RoboCasa[8] is a large-scale simulation framework designed to train generalist robots for everyday tasks, with a focus on home and kitchen environments. The project addresses the scarcity of massive robot datasets by using realistic physical simulation to scale environments, tasks, and data for robot learning methods.

[8] https://www.robocasa.ai

### Key Components and Contributions

- **Diverse Assets**: The framework includes over 120 kitchen scenes with various floor plans and styles, and a repository of over 2,500 3D objects across more than 150 categories. Generative AI tools, such as text-to-3D models and text-to-image models, were used to create these assets and environment textures, enhancing realism and diversity.
- **Tasks and Skills**: RoboCasa features 100 tasks for systematic evaluation, including 25 **atomic tasks** (foundational skills like picking, placing, and opening doors) and 75 **composite tasks** (sequences of skills for activities like cooking and cleaning). The composite tasks were created with the guidance of large language models (LLMs) to reflect naturalistic human behaviors and reduce human labor in task definition.
- **Massive Datasets**: The project provides a large multi-task dataset with over 100,000 trajectories. This dataset combines high-quality human demonstrations with a much larger number of synthetically generated trajectories created using the MimicGen system. Experiments show that using this generated data significantly improves a robot's generalization abilities compared to relying solely on human demonstrations, and that co-training with this data can increase success rates in real-world robot deployments.

### Significance

RoboCasa is presented as a simulation framework because it integrates a large array of tasks, room-scale scenes, and objects with AI-generated content and tasks, a combination not previously achieved by other platforms. The framework and its accompanying dataset offer a crucial resource for the robot learning community, facilitating scalable and reproducible research towards creating general-purpose home robots.

## 4. Challenges and Solutions for Integrating Robotic Workforce into Smart Living Environments

The integration of robotic workforces into smart living environments, while promising, introduces a complex array of challenges that extend beyond mere technical feasibility. This section addresses the critical issues of privacy, security, user acceptance, ethical considerations, and the evolving regulatory landscape, proposing solutions to facilitate a harmonious and effective co-existence between humans and robots.

### 4.1 Privacy and Security

The pervasive nature of smart home devices, including integrated robots, necessitates extensive data collection, which raises significant privacy and security concerns.

**Privacy concerns** stem from the collection of vast amounts of personal data about inhabitants' habits, preferences, and daily routines.[15] This leads to legitimate anxieties regarding data acquisition and processing, the potential for data leaks and misuse, and the creation of detailed user profiles.[15] The constant presence of cameras, microphones, and other sensors in private spaces further intensifies questions of trust and the potential for unwanted surveillance.[16]

Regarding **security risks**, IoT devices are inherently vulnerable to cyber threats, including unauthorized access, identity theft, and even physical threats if their security measures are inadequate.[15] Common vulnerabilities include default passwords, weaknesses in interconnected e-systems, and the exploitation of local network protocols as side-channels to access sensitive information without user awareness.[16] The spectrum of attacks can range from jamming and spoofing to more sophisticated manipulation and software vulnerabilities.[50]

To mitigate these risks, robust **mitigation strategies** are crucial. These include implementing strong passwords, ensuring regular software updates, deploying firewalls, and establishing secure networks.[15] The encryption of data transferred between devices and associated applications is essential for protecting sensitive information.[15] Furthermore, consumers are advised to choose trustworthy manufacturers with a proven track record of good privacy practices and a strong commitment to security.[15] Proactive measures in development involve rigorous data verification, validation, sanitization, and promptly patching known vulnerabilities.[50]

### 4.2 Ethical Considerations

The deployment of AI-based robots in sensitive smart living contexts, particularly in caregiving roles for older adults, raises profound ethical questions that extend beyond mere technical performance.

These **moral dilemmas** are complex and multifaceted [36]:

- **Autonomy vs. Automation:** A central question is whether robots, by taking over tasks, inadvertently reduce the independence of elderly individuals, or conversely, whether they empower them to live more autonomously.[37]
- **Consent and Privacy:** Continuous monitoring by robots, while beneficial for safety and health, raises ethical concerns about compromising personal freedom, especially for individuals with cognitive impairments who may have diminished capacity to provide ongoing consent.[36]
- **Emotional Support:** A critical debate revolves around whether an algorithm can genuinely replace the compassionate care or companionship provided by a human caregiver. This also includes considerations of the implications of emotional attachment that users might develop towards machines.[36]
- **Algorithmic Bias:** The potential for AI systems to misinterpret symptoms or make flawed decisions due to biases in their training data carries severe consequences, potentially leading to fatal outcomes.[37]

#### 4.3 Regulatory Frameworks and Compliance

The rapid evolution of robotic capabilities and their integration into smart living environments necessitate robust regulatory frameworks to ensure safety, ethics, and public trust.

The **necessity of regulation** is paramount to ensure that robots are designed and operated in a manner that prioritizes human safety and adheres to established ethical standards.[52]

The **evolving regulatory landscape in the European Union** provides a comprehensive example of how jurisdictions are adapting to these technological advancements:

- **AI Act:** This regulatory framework introduces divergent compliance obligations based on risk levels. High-risk applications, such as drones, will require rigorous conformity assessments, human oversight protocols, and granular data governance. Limited-risk applications, like inventory management systems, may only need to provide transparency to users about their decision-making processes. The highest-risk applications, such as workplace emotion recognition systems, are already prohibited in the EU.[58]

- **Other Legislative Changes:** The General Product Safety Regulation, effective in the EU since December 2024, expands safety obligations for consumer-facing products, including AI systems and robots, imposing ongoing safety, cybersecurity, and traceability responsibilities across supply chains. The UK Product Security and Telecommunications Infrastructure Act and the EU Cyber Resilience Act also impose independent cybersecurity obligations on connected devices. Furthermore, the Ecodesign for Sustainable Products Regulation establishes a framework for design obligations on machinery, mandating considerations for repairability and environmental impact.[58]

These regulatory developments highlight the **challenges** of ensuring compliance across diverse applications, achieving harmonization across different jurisdictions, and keeping pace with rapid technological advancements.[42]

Effective **solutions** involve a continuous assessment of regulatory requirements, the development of comprehensive compliance frameworks, and the integration of compliance measures directly into the design and development processes of robotic systems.[52] This mandates rigorous testing and validation procedures to verify that robotic systems operate safely, ethically, and within legal boundaries, followed by ongoing monitoring and auditing throughout their lifecycle.[52]

# 5. Research Plan: Smart Living Tiny House Lab

### Executive Summary

The primary goal of this **three-year research project** is to design, build, and test a fully functional "tiny house mobile" that serves as a living lab for smart living solutions using a robotic workforce. The project will move from foundational infrastructure to advanced robotic integration and, finally, to user-centric testing and research dissemination, with the final deliverable being a mobile, fully operational, and research-validated smart home.

## Year 1: Foundation & Infrastructure

Objective: Establish the core physical and digital infrastructure of the tiny house lab. This includes finalizing the design, building the physical structure, and integrating a basic, functional smart home system.

- Milestone 1: Architectural & Technology Design

    - **Date: End of March 2026**
    - Description: Finalize the tiny house blueprint, integrating specific layouts for robotic charging stations, sensor placement, and data infrastructure. This involves selecting a core home automation platform (e.g., Home Assistant) and defining the software architecture for all IoT devices and robotic control systems. Concurrently, all major components will be procured to ensure timely delivery.
    - Deliverables:
        - Detailed architectural and electrical blueprints.
        - A finalized technology stack document.
        - Completed procurement list for all hardware and software.
- Milestone 2: Tiny House Construction & System Installation
    - **Date: End of September 2026**
    - Description: Complete the physical construction of the tiny house, including all interior and exterior finishing. Install and configure all smart home IoT devices, sensors (environmental, motion), and the central hub. Integrate the initial robotic platform (e.g., a domestic cleaning robot), focusing on foundational tasks like autonomous navigation and pathfinding within the small space.
    - Deliverables:
        - A fully built and physically functional tiny house.
        - A functional home automation system with a central dashboard.
        - A documented proof-of-concept demonstrating robot navigation and a simple pre-programmed task.

### Year 2: Integration & Advanced Capabilities

Objective: Expand the living lab's capabilities by introducing more complex robotic systems and developing core human-robot interaction (HRI) protocols for user-centric research.

- Milestone 3: Advanced Robotic & AI Integration
    - **Date: End of March 2027**
    - Description: Integrate a second, more complex robotic platform, such as an assistive or collaborative robot (cobot) for specific tasks like object retrieval or meal preparation assistance. Develop and implement a data analysis and AI layer for Human Action Recognition (HAR) to enable robots to understand user context and anticipate needs.
    - Deliverables:

        - A demonstration of multi-robot collaboration.
        - Functional code for HAR and a context-aware robot control system.
        - A report detailing the development of new HRI protocols.
- Milestone 4: User-Centric Testing & Initial Findings
    - **Date: End of September 2027**
    - Description: Conduct the first round of user studies within the living lab. Recruit a small cohort of participants to live or interact with the tiny house for a defined period. Collect extensive quantitative (system performance, power consumption) and qualitative (user feedback, trust, acceptance) data to inform future optimizations and address the research questions on the challenges from the report.
    - Deliverables:
        - Raw data sets from the initial user studies.
        - A preliminary research paper draft on user acceptance and ethical challenges.
        - A report outlining key findings and refinement plans for Year 3.

### Year 3: Optimization & Dissemination

Objective: Refine the living lab based on research findings, document all work, and disseminate the results to the academic and public communities.

- Milestone 5: System Optimization & Finalization
    - **Date: End of March 2028**
    - Description: Implement a new, optimized iteration of the entire system based on feedback and data from Year 2. Focus on improving robot reliability, system security, and energy efficiency. Conduct a final round of validation tests to ensure all systems are robust and perform as intended for the final demonstration.
    - Deliverables:
        - A fully optimized and integrated tiny house living lab.
        - A comprehensive data analysis report on all research findings.
- Milestone 6: Thesis Completion & Dissemination
    - **Date: End of September 2028**
    - Description: Complete and submit the final PhD thesis, incorporating all research findings, methodologies, and conclusions from the three-year project. Prepare and submit multiple research papers for publication in high-impact journals and conferences. Finalize all public-facing

materials, including a video tour of the tiny house lab and a project website to share findings and impact.

- Deliverables:
  - A completed and approved PhD thesis.
  - Accepted peer-reviewed publications.
  - A public-facing demonstration and digital portfolio of the project.

## 6. Research Activity Report

**PhD Student:** Marian BĂNICĂ

**Reporting Period:** Second Semester Academic Year 20242-2025

### 1. Trade Fair Attendance: 2025 Hannover Messe


**Date:** March 31 - April 4, 2025 **Location:** Hannover, Germany

I attended the **2025 Hannover Messe**, the world's leading trade fair for industrial technology. This year's event focused on the themes of **climate protection, digitalization, and sustainability**, under the lead theme "Energizing a Sustainable Industry."

The conference provided an opportunity to undestand the latest advancements in

**automation, robotics, artificial intelligence, and energy solutions**. I attended several keynote presentations and expert-led forums that covered industrial trends, decarbonization, and smart technologies. Of particular relevance to my research were the exhibits and demonstrations in the **Automation & AI** and **Smart Manufacturing** sections. I had the opportunity to interact with leading companies and researchers, gaining insights into the current state-of-the-art and future directions of industrial and domestic automation. The partner country for this year's event was **Canada**, which showcased its innovations in AI, quantum computing, and clean energy.

---

### 2. Research Visit: Wuppertal Living Lab NRW

**Date:** April 2025 (2 weeks) **Location:** Wuppertal, Germany

Following the Hannover Messe, I conducted a two-week research visit to the **Wuppertal Living Lab NRW**. During this visit, I had the privilege of meeting with **Professor Karsten Voss**, the coordinator of the living lab, who provided a comprehensive overview of the facility and its ongoing research projects.

My primary focus was to gain a detailed understanding of the two smart house models at the lab:

- **Local+:** This model emphasizes self-sufficiency and sustainability, with a focus on energy efficiency and the use of local resources.
- **MIMO:** This model is designed for flexibility and adaptability, with a modular design that can be easily reconfigured to meet the changing needs of its occupants.

89

I was able to observe the operation of the various smart technologies integrated into these models, including automated lighting, climate control, and security systems. This hands-on experience has provided me with a solid foundation for the design and implementation of my own tiny house living lab.

---

### 3. Summer School: 2025 Early Skills Program

**Date:** June 22 - September 8, 2025

I co-organized  the **2025 Early Skills Program**, a summer school attended by approximately 20 students. The program covered a range of topics relevant to my research, including **domotics, smart home automation, robotics, and electronics**.

A significant part of the program was dedicated to the development of practical skills in modeling and simulation. We used two primary software tools:

43

- **Sweet Home 3D:** This free and open-source architectural design software allowed us to create 2D plans of houses with a 3D preview. We used it to design and visualize the layout of smart homes, experimenting with different furniture arrangements and device placements. The software's ability to import blueprints and export to various formats was particularly useful for our projects.
- **Autodesk Fusion:** This is a comprehensive 3D design, modeling, and manufacturing platform. We used Fusion to create more detailed and simple 3D models of smart home components and robotic systems.

  This summer school has been instrumental in developing my practical skills and has provided me with a valuable network of peers with similar research interests. The knowledge and experience gained from these activities will be directly applied to my ongoing PhD research.

## 7. Conclusion

Smart living solutions are evolving quickly, powered by new technologies that improve quality of life, efficiency, and sustainability. Smart living is not just about gadgets—it includes health, security, technology, and the environment. Because of this, research and development require a broad, interdisciplinary approach. At the same time, the rise of robotic systems offers new opportunities. Robots are moving beyond factories and can now play supportive, collaborative roles in everyday life.

Living Labs—such as the Wuppertal Living Lab—provide a practical way to explore these complex challenges. They use real-world testing and collaboration with different stakeholders to bridge the gap between controlled experiments and real applications. By focusing on user feedback, co-creation, and continuous evaluation, Living Labs help ensure that robotic solutions are useful, ethical, and socially accepted.

To create a Living Lab that explores smart living with robotic support, several elements must come together: strong technological infrastructure, advanced AI for smooth human-robot interaction, and a design process centered on user needs. Ethical, privacy, and regulatory issues also need to be addressed from the very beginning. With the right balance of innovation, ethics, and collaboration, such a Living Lab can lead the way in building sustainable, human-centered smart environments for the future.

### 7.1 Challenges and Research Questions

The integration of a robotic workforce into smart living environments raises a number of challenges and research questions that need to be addressed. These include:

- **Privacy and Security:** How can we ensure that the data collected by smart home devices and robots is kept private and secure?[4]
- **User Acceptance and Trust:** How can we design robots that are not only functional but also accepted and trusted by their human users?

- **Ethical Considerations:** What are the ethical implications of using robots in the home, particularly for tasks that involve personal care and companionship?[5]
- **Regulatory Compliance:** What are the legal and regulatory frameworks that need to be in place to govern the use of robots in the home?

## 7.2 Three years milestones

| Milestone Name | Description | Deliverables | Timeline |
| --- | --- | --- | --- |
| **Milestone 1: Architectural & Technology Design** | Lay the foundational concepts and digital plans for the tiny house living lab, including physical design, component selection, and procurement. | • Detailed architectural blueprints • Comprehensive technology stack document • Finalized procurement list | End of March 2026 |
| **Milestone 2: Tiny House Construction & System Installation** | Construct the physical tiny house, install all foundational smart home systems, and integrate the first robotic platform for initial testing. | • Physically functional tiny house • Operational smart home system • First robotic proof-of-concept | End of September 2026 |

| | | | |
|---|---|---|---|
| **Milestone 3: Advanced Robotic & AI Integration** | Introduce more complex robotic systems and develop the artificial intelligence layer that will allow the system to be context-aware and enable more sophisticated human-robot interactions (HRI). | • Multi-robot collaboration demonstration • Functional AI/HAR code • HRI protocols report | End of March 2027 |
| **Milestone 4: User-Centric Testing & Initial Findings** | Conduct the first round of immersive user studies within the tiny house, collecting both quantitative and qualitative data to inform future research and address key challenges. | • Raw user study data sets • Preliminary research paper draft • System refinement report | End of September 2027 |
| **Milestone 5: System Optimization & Finalization** | Refine and optimize the entire living lab based on the valuable feedback from the user studies, focusing on improving performance, reliability, and | • A fully optimized living lab • Comprehensive data analysis report | End of March 2028 |

| | | | |
|---|---|---|---|
| | security. | | |
| **Milestone 6: Thesis Completion & Dissemination** | Bring all the research together into the final PhD thesis. Share the findings with the academic community through publications and with the public through a compelling portfolio. | • Completed PhD thesis • Accepted peer-reviewed publications • Public demonstration portfolio | End of September 2028 |

This table provides a concise, at-a-glance view of your entire research journey. You can use it to track your progress and present the plan to your advisors.

Would you like to delve into a specific part of this plan in more detail, such as the specific technologies for a milestone or the methodology for a deliverable?

**Works cited**


1. pmc.ncbi.nlm.nih.govhttps://pmc.ncbi.nlm.nih.gov/articles/PMC10346639/#:~:text=Smart%20living%20is%20an%20innovative,%2C%20and%20education%20%5B1%5D.
2. Human Action Recognition in Smart Living Services and Applications: Context Awareness, Data Availability, Personalization, and Privacy - MDPIhttps://www.mdpi.com/1424-8220/23/13/6040
3. Review on Human Action Recognition in Smart Living: Sensing Technology, Multimodality, Real-Time Processing, Interoperability, and Resource-Constrained Processing - MDPIhttps://www.mdpi.com/1424-8220/23/11/5281
4. Smart Living - European Commissionhttps://ec.europa.eu/docsroom/documents/13407/attachments/2/translations/en/renditions/native
5. www.researchgate.nethttps://www.researchgate.net/figure/Key-Indicators-for-S

mart-Living_tbl1_334414360#:~:text=The%20detected%20indicators%20were%20as,%2C%20governmental%20efficiency%2C%20smart%20electricity%2C

6. (PDF) Review on Human Action Recognition in Smart Living: Multimodality, Real-time Processing, Interoperability, Resource-Constrained Processing, and Sensing Technology - ResearchGatehttps://www.researchgate.net/publication/370547104_Review_on_Human_Action_Recognition_in_Smart_Living_Multimodality_Real-time_Processing_Interoperability_Resource-Constrained_Processing_and_Sensing_Technology
7. Working Safely with Robot Workers: Recommendations for the New Workplace - PMChttps://pmc.ncbi.nlm.nih.gov/articles/PMC4779796/
8. Robots in the Workplace | Michigan Tech Global Campus Newshttps://blogs.mtu.edu/globalcampus/2023/02/robots-in-the-workplace/
9. The Real-World Application of Robotics | UTI - Universal Technical Institutehttps://www.uti.edu/blog/robotics-and-automation/application-of-robotics
10. The Rise and Risks of Autonomous Robots in the Workplace | The Hartfordhttps://www.thehartford.com/insights/technology/autonomous-robots-in-the-workplace
11. The Role of Robotics in the Future of Work - CDC Blogshttps://blogs.cdc.gov/niosh-science-blog/2022/06/03/robotics-fow/
12. Designing Intent: A Multimodal Framework for Human-Robot Cooperation in Industrial Workspaces - arXivhttps://arxiv.org/html/2506.15293v1
13. Robots: Helpers or Substitutes for Workers? - Federal Reserve Bank of St. Louishttps://www.stlouisfed.org/open-vault/2024/sep/are-robots-helpers-or-substitutes-for-workers
14. Key Performance Indicators for Service Robotics in Senior Community-Based Settingshttps://pmc.ncbi.nlm.nih.gov/articles/PMC11989145/
15. Smart Home Privacy Concerns | News - Robin Data GmbHhttps://www.robin-data.io/en/data-protection-and-data-security-academy/news/smart-home-applications-data-protection
16. New research reveals alarming privacy and security threats in Smart Homeshttps://engineering.nyu.edu/news/new-research-reveals-alarming-privacy-and-security-threats-smart-homes
17. User Acceptance of a Home Robotic Assistant for Individuals With Physical Disabilities: Explorative Qualitative Study - PubMed Centralhttps://pmc.ncbi.nlm.nih.gov/articles/PMC11758889/
18. Full article: Systematic analysis of smart homes: Current trends and future recommendationshttps://www.tandfonline.com/doi/full/10.1080/23311916.2024.2344452
19. Plymouth Community Homes Digital Living Lab - University of ...https://www.plymouth.ac.uk/research/centre-for-health-technology/plymouth-community-homes-digital-living-lab
20. The Future of Smart Homes: Trends to Watch in 2025! - GSAVShttps://gsavs.com/blog/the-future-of-smart-homes-trends-to-watch-in-2025

21. How Robotics is Changing the Future of Security Technology https://kabam.ai/blogs/how-robotics-is-changing-the-future-of-security-technology/
22. [2502.02821] AIoT-based smart traffic management system - arXiv https://arxiv.org/abs/2502.02821
23. UX/UI Trends for 2025: Innovations That Will Transform Digital ... https://www.nivelics.com/en/blog/ux-ui-trends-2025
24. UX Design Trends 2025 & UI Innovations: The Future of UX ... https://www.fullstack.com/labs/resources/blog/top-5-ux-ui-design-trends-in-2025-the-future-of-user-experiences
25. Latest AI Breakthroughs and News: May-June 2025 - Crescendo.ai https://www.crescendo.ai/news/latest-ai-news-and-updates
26. Data Management System (DBMS): InterSystems IRIS Data Platform ... https://www.intersystems.com/products/intersystems-iris/
27. Unveiling the core of IoT: comprehensive review on data security challenges and mitigation strategies - Frontiers https://www.frontiersin.org/journals/computer-science/articles/10.3389/fcomp.2024.1420680/full
28. Analysis of IoT Security Challenges and Its Solutions Using Artificial Intelligence - PMC https://pmc.ncbi.nlm.nih.gov/articles/PMC10136937/
29. IoT Testing for Smart Home Devices: Ensuring Interoperability and Security - Compunnel https://www.compunnel.com/blogs/iot-testing-for-smart-home-devices-ensuring-interoperability-and-security/
30. Untitled - Connectivity Standards Alliance https://csa-iot.org/wp-content/uploads/2025/06/Consumer-IoT-Device-Cybersecurity-Standards-Policies-and-Certification-Schemes-2025-_FINAL.pdf
31. [2506.08890] Human-Robot Teaming Field Deployments: A Comparison Between Verbal and Non-verbal Communication - arXiv https://arxiv.org/abs/2506.08890
32. Real-World Trials: UW's Assistive Feeding Robot Tested Beyond the - Bioengineer.org https://bioengineer.org/real-world-trials-uws-assistive-feeding-robot-tested-beyond-the-laboratory/
33. Assistive Robotics Lab - YouTube https://www.youtube.com/watch?v=ULzGK46Z4Ms
34. Task cognition and planning for service robots - OAE Publishing Inc. https://www.oaepublish.com/articles/ir.2025.08
35. TP-Link: Your Smart Home, Simplified https://www.tp-link.com/us/
36. Ethical considerations in the use of social robots for supporting mental health and wellbeing in older adults in long-term care - Frontiers https://www.frontiersin.org/journals/robotics-and-ai/articles/10.3389/frobt.2025.1560214/full
37. Challenges in 2025 for AI Robots in Elderly Care | Zemplee https://www.zemplee.com/2025/05/05/ai-robots-elderly-care-2025-challenges-ethical-questions/

38. Revolutionizing Long-Term Care with Robotics - Number Analytics https://www.numberanalytics.com/blog/revolutionizing-long-term-care-with-robotics
39. Labrador Systems - A New Generation of Assistive Robots https://labradorsystems.com/
40. Can AI help address future home care worker shortages? | Aging and Health Technology Watch https://www.ageinplacetech.com/blog/technology-and-ai-will-help-address-future-issues-home-care
41. Environment Modeling for Service Robots From a Task Execution Perspective - arXiv https://arxiv.org/html/2501.05931v1
42. Challenges and Opportunities in the Service Robotics Industry and Future Trends https://www.reportsnreports.com/semiconductor-and-electronics/challenges-and-opportunities-in-the-service-robotics-industry-and-future-trends/
43. $R^2D^2$: Adapting Dexterous Robots with NVIDIA Research Workflows and Models https://developer.nvidia.com/blog/r2d2-adapting-dexterous-robots-with-nvidia-research-workflows-and-models/
44. Robot machine price: How much do they cost? - Standard Bots https://standardbots.com/blog/robot-machine-price-how-much-do-they-cost
45. Professional Humanoid Robots - RobotShop https://www.robotshop.com/collections/professional-humanoid-robots
46. 5 Challenges to Address in Scaling Robotics Solutions in the Workforce - ARTiBA https://www.artiba.org/blog/5-challenges-to-address-in-scaling-robotics-solutions-in-the-workforce
47. Robotics Maintenance and Troubleshooting: A Comprehensive Guide | Tooling U-SME https://learn.toolingu.com/blog-start/2024/september/robotics-maintenance-troubleshooting-guide/
48. Green Robotics: Energy Consumption & Sustainability Stats - PatentPC https://patentpc.com/blog/green-robotics-energy-consumption-sustainability-stats
49. Sustainable Manufacturing Series: How to Effectively Manage Robot Energy Consumption https://www.automate.org/industry-insights/how-to-effectively-manage-robot-energy-consumption
50. Security Considerations in AI-Robotics: A Survey of Current Methods, Challenges, and Opportunities - arXiv https://arxiv.org/html/2310.08565v3
51. Artificial Intelligence and the Future of Teaching and Learning (PDF) - Department of Education https://www.ed.gov/sites/ed/files/documents/ai-report/ai-report.pdf
52. Robot Law Compliance - Meegle https://www.meegle.com/en_us/topics/robotics/robot-law-compliance
53. Challenges in Seniors Adopting Assistive Robots: A Systematic Review - ResearchGate https://www.researchgate.net/publication/309747949_Challenges_in_Seniors_Adopting_Assistive_Robots_A_Systematic_Review

54. Enablers and barriers to the implementation of socially assistive humanoid robots in health and social care: a systematic review - PubMed Central https://pmc.ncbi.nlm.nih.gov/articles/PMC6955545/
55. pmc.ncbi.nlm.nih.gov https://pmc.ncbi.nlm.nih.gov/articles/PMC11758889/#:~:text=Participants%20were%20generally%20positive%20about,could%20perform%20most%20tasks%20autonomously.
56. Domestic Robots: Human Integration Guide - Number Analytics https://www.numberanalytics.com/blog/domestic-robots-human-integration-guide
57. Effects of Robot Capability on User Acceptance https://www.ri.cmu.edu/pub_files/2013/3/LateBreakReport.pdf
58. Robotics at a global regulatory crossroads: compliance challenges for autonomous systemshttps://www.osborneclarke.com/insights/robotics-global-regulatory-crossroads-compliance-challenges-autonomous-systems
59. Living lab - Wikipedia https://en.wikipedia.org/wiki/Living_lab
60. D3.3 – Implementation Living Lab methodology - CORDIS https://cordis.europa.eu/docs/projects/cnect/5/632905/080/deliverables/001-D33ImplementationLivingLabMethodology.pdf
61. Living Lab Methodology - North Wales Collaborativehttps://www.northwalescollaborative.wales/wp-content/uploads/2020/10/Living-lab-methodology-handbook_r.pdf
62. Living Labs - ENoLLhttps://enoll.org/living-labs/
63. living labs, innovation, models - ENI CBC Medhttps://www.enicbcmed.eu/sites/default/files/2024-05/D_WP5_OP5.7_A5.7.1_Living%20Lab%20handbook.pdf
64. Our Facility - Robot Househttps://robothouse.herts.ac.uk/facility/
65. Smart City Living Lab | Herman Hollerith Zentrumhttps://www.hhz.de/en/location/smart-city-living-lab
66. How to Implement a Living Lab: A Guide for Cities - Factual Consulting How to Implement a Living Lab: A Guide for Cities - Factual Consulting
67. The Living Lab approach and citizen engagement https://living-in.eu/sites/default/files/files/the-living-lab-approach-and-citizen-engagement-1.pdf
68. A framework for the evaluation of living labs as boundary spanners in innovation | SWEET Lantern https://sweet-lantern.ch/wp-content/uploads/2024/02/Van-Geenhuizen-M.-2018.-A-framework-for-the-evaluation-of-living-labs-as-boundary-spanners-in-innovation.pdf
69. A harmonized assessment method and KPIs for evaluating Living Labs - ResearchGate https://www.researchgate.net/publication/382181444_A_harmonized_assessment_method_and_KPIs_for_evaluating_Living_Labs

70. Living Lab NRW https://livinglabnrw.uni-wuppertal.de/de/
71. Veröffentlichungen https://livinglabnrw.uni-wuppertal.de/de/veroeffentlichungen/
72. Technology for Living - Technology for Independent Living https://www.technologyforliving.org/technology-for-independent-living-program-til/
73. Research - ARMLab Stanford https://arm.stanford.edu/research/
74. ARMLab Stanford: Home https://arm.stanford.edu/
75. FZI Living Lab Service Robotics - FZI Forschungszentrum Informatik https://www.fzi.de/en/experience/house-of-living-labs/fzi-living-lab-service-robotics/
76. Innovative, usable solutions | Intelligent Technologies for Wellness https://uwaterloo.ca/intelligent-technologies-wellness-independent-living/
77. Living Labs | Medical devices and health technologies - PATH https://www.path.org/who-we-are/programs/mdht/living-labs-initiative/
78. A roadmap for safe, regulation-compliant Living Labs for AI and digital health development https://pmc.ncbi.nlm.nih.gov/articles/PMC12077496/
79. Living lab business models and services – Scanbalt https://scanbalt.org/wp-content/uploads/2020/04/Laurea-Julkaisut-137.pdf
80. Funding | The Lemelson Foundation https://www.lemelson.org/funding/
81. Cascade Funding Opportunities – May 2025 https://cascadefunding.eu/cascade-funding-opportunities-may-2025/
82. Open Calls - Cascade Funding Hub https://cascadefunding.eu/open-calls/
83. Assistive Technology - Northwest Access Fund https://www.nwaccessfund.org/general-assistive-technology-resources/
84. Assistive Technology | ACL Administration for Community Living https://acl.gov/programs/assistive-technology/assistive-technology
85. The living lab approach in the smart living innovation process - Verhaal Zo-Dichtbij The living lab approach in the smart living innovation process

# Smart Living Robotic Workforce Research

ORIGINALITY REPORT

| 22% | 17% | 9% | 11% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | pmc.ncbi.nlm.nih.gov<br>Internet Source | 2% |
| 2 | www.lexology.com<br>Internet Source | 1% |
| 3 | www.mdpi.com<br>Internet Source | 1% |
| 4 | www.fullstack.com<br>Internet Source | 1% |
| 5 | www.frontiersin.org<br>Internet Source | 1% |
| 6 | Submitted to Asia Pacific University College of Technology and Innovation (UCTI)<br>Student Paper | 1% |
| 7 | www.compunnel.com<br>Internet Source | <1% |
| 8 | www.intersystems.com<br>Internet Source | <1% |
| 9 | www.preprints.org<br>Internet Source | <1% |
| 10 | Submitted to University of North Carolina - Wilmington<br>Student Paper | <1% |
| 11 | Submitted to University Politehnica of Bucharest<br>Student Paper | <1% |

| | | |
|---|---|---|
| 12 | academic.oup.com<br>Internet Source | <1 % |
| 13 | kabam.ai<br>Internet Source | <1 % |
| 14 | Submitted to Los Osos High School<br>Student Paper | <1 % |
| 15 | Submitted to The Independent Institute of Education (IIE)<br>Student Paper | <1 % |
| 16 | journalspress.com<br>Internet Source | <1 % |
| 17 | Submitted to Rochester Institute of Technology<br>Student Paper | <1 % |
| 18 | Submitted to Northeast Wisconsin Technical College<br>Student Paper | <1 % |
| 19 | Submitted to Sunway Education Group<br>Student Paper | <1 % |
| 20 | Submitted to University of Maryland, Global Campus<br>Student Paper | <1 % |
| 21 | Submitted to Lynn University<br>Student Paper | <1 % |
| 22 | omdia.tech.informa.com<br>Internet Source | <1 % |
| 23 | Submitted to Montclair State University<br>Student Paper | <1 % |
| 24 | Narendran Ramasenderan, Vinesh Thiruchelvam, Umar Saeed, Krishna Ravinchandra, Chew Kai Ze, Siva Kumar Sivanesan. "Autonomous navigation system | <1 % |

with weight detection for autonomous loose fruit collector", AIP Publishing, 2024
Publication

| | | |
|---|---|---|
| 25 | Submitted to UC, Irvine<br>Student Paper | <1 % |
| 26 | Submitted to Unity Christian High School<br>Student Paper | <1 % |
| 27 | Submitted to University of Reading<br>Student Paper | <1 % |
| 28 | arxiv.org<br>Internet Source | <1 % |
| 29 | bioengineer.org<br>Internet Source | <1 % |
| 30 | www.ncbi.nlm.nih.gov<br>Internet Source | <1 % |
| 31 | Fatima Canseco-Lopez, Artur Serra, Marta Martorell Camps. "Opening Our Innovation Ecosystems to All: The INTEGER Project Case Study", Sustainability, 2025<br>Publication | <1 % |
| 32 | Submitted to Tias Business School B.V.<br>Student Paper | <1 % |
| 33 | Submitted to Oral Roberts University<br>Student Paper | <1 % |
| 34 | Submitted to University of Florida<br>Student Paper | <1 % |
| 35 | Submitted to Westcliff University<br>Student Paper | <1 % |
| 36 | www.globalchamber.org<br>Internet Source | <1 % |

| | | |
|---|---|---|
| 37 | Submitted to The Community School of Naples<br>Student Paper | <1 % |
| 38 | Submitted to University of Sunderland<br>Student Paper | <1 % |
| 39 | Submitted to Washington State University System<br>Student Paper | <1 % |
| 40 | www.plymouth.ac.uk<br>Internet Source | <1 % |
| 41 | Submitted to De La Salle University - Manila<br>Student Paper | <1 % |
| 42 | Submitted to Florida International University<br>Student Paper | <1 % |
| 43 | en.wikipedia.org<br>Internet Source | <1 % |
| 44 | Kanungo, Avnish. "Human in the Loop: An Approach to Optimize LLM Based Robot Task Planning", Purdue University<br>Publication | <1 % |
| 45 | Submitted to Molloy College<br>Student Paper | <1 % |
| 46 | Submitted to Cambridge International Examinations (CIE)<br>Student Paper | <1 % |
| 47 | Submitted to Royal Holloway and Bedford New College<br>Student Paper | <1 % |
| 48 | www.arcweb.com<br>Internet Source | <1 % |
| 49 | "Security Standardisation Research", Springer Science and Business Media LLC, 2025 | <1 % |

Publication

| | | |
|---|---|---|
| 50 | Submitted to Kaplan College<br>Student Paper | <1 % |
| 51 | developer.nvidia.com<br>Internet Source | <1 % |
| 52 | www.zemplee.com<br>Internet Source | <1 % |
| 53 | Submitted to BB9.1 PROD<br>Student Paper | <1 % |
| 54 | Birger Becker, Sebastian Kochanneck, Hartmut Schmeck. "Test Beds for Component Integration in Energy Systems", 2019 IEEE 4th International Workshops on Foundations and Applications of Self* Systems (FAS*W), 2019<br>Publication | <1 % |
| 55 | Submitted to Elizabeth School of London<br>Student Paper | <1 % |
| 56 | Submitted to George Mason University<br>Student Paper | <1 % |
| 57 | Submitted to Middlesex University<br>Student Paper | <1 % |
| 58 | Pita Jarupunphol, Wipawan Buathong. "Potential Use of Smart Kitchen Management Application (SKM)", 2018 22nd International Computer Science and Engineering Conference (ICSEC), 2018<br>Publication | <1 % |
| 59 | Submitted to Singapore Institute of Technology<br>Student Paper | <1 % |
| 60 | Submitted to TAFE Queensland Brisbane<br>Student Paper | <1 % |

| | | |
|---|---|---|
| 61 | Submitted to Wageningen University<br>Student Paper | <1% |
| 62 | ebin.pub<br>Internet Source | <1% |
| 63 | lunarhub.co<br>Internet Source | <1% |
| 64 | www.lotusflow3r.com<br>Internet Source | <1% |
| 65 | community.intersystems.com<br>Internet Source | <1% |
| 66 | homeautotechs.com<br>Internet Source | <1% |
| 67 | tessis.ro<br>Internet Source | <1% |
| 68 | Submitted to Erasmus University of Rotterdam<br>Student Paper | <1% |
| 69 | Guerra, Carlos Daniel Simões Jorge. "IoT Home Automation With Mobile Devices Vision", ISCTE - Instituto Universitario de Lisboa (Portugal), 2025<br>Publication | <1% |
| 70 | Johnson, Meredith Dentice. "Industrial Robotic Automation: Motivational Drivers and Safety Considerations for Implementation and Use", The University of Wisconsin - Milwaukee<br>Publication | <1% |
| 71 | medium.com<br>Internet Source | <1% |
| 72 | pidora.ca<br>Internet Source | <1% |

| | | |
|---|---|---|
| 73 | pure.eur.nl<br>Internet Source | <1 % |
| 74 | www.cybrary.it<br>Internet Source | <1 % |
| 75 | Submitted to University of Lancaster<br>Student Paper | <1 % |
| 76 | enicbcmed.eu<br>Internet Source | <1 % |
| 77 | frw.studenttheses.ub.rug.nl<br>Internet Source | <1 % |
| 78 | metalphoto.com<br>Internet Source | <1 % |
| 79 | online-journal.unja.ac.id<br>Internet Source | <1 % |
| 80 | storables.com<br>Internet Source | <1 % |
| 81 | theairlab.org<br>Internet Source | <1 % |
| 82 | www.ageinplacetech.com<br>Internet Source | <1 % |
| 83 | www.ajiet.edu.in<br>Internet Source | <1 % |
| 84 | www.science.org<br>Internet Source | <1 % |
| 85 | www.vpnunlimited.com<br>Internet Source | <1 % |
| 86 | "Decide Better", Springer Science and Business Media LLC, 2025<br>Publication | <1 % |

| | | |
|---|---|---|
| 87 | Anubha Anubha, Daviender Narang, Ankit Raj. "chapter 8 AIoT-Enabled Smart Homes Solution to Security, Comfort, and Energy Efficiency", IGI Global, 2025<br>Publication | <1 % |
| 88 | Submitted to CITY College, Affiliated Institute of the University of Sheffield<br>Student Paper | <1 % |
| 89 | Sabrina Sauer. "User innovativeness in living laboratories : everyday user improvisations with ICTs as a source of innovation", 'University Library/University of Twente', 2013<br>Internet Source | <1 % |
| 90 | Sokratis Vavilis, Fotis Michalopoulos, Harris Niavis, George Misiakoulis et al. "Chapter 3 ERATOSTHENES Project Integrated Solution", Now Publishers, 2025<br>Publication | <1 % |
| 91 | Submitted to Victoria College<br>Student Paper | <1 % |
| 92 | iksadyayinevi.com<br>Internet Source | <1 % |
| 93 | lpppipublishing.com<br>Internet Source | <1 % |
| 94 | networks.imdea.org<br>Internet Source | <1 % |
| 95 | staceyoniot.com<br>Internet Source | <1 % |
| 96 | westoahu.hawaii.edu<br>Internet Source | <1 % |
| 97 | wikizero.com<br>Internet Source | <1 % |

| | | |
|---|---|---|
| 98 | www.fzi.de<br>Internet Source | <1% |
| 99 | Kawalpreet Kaur, Amanpreet Kaur, Yonis Gulzar, Vidhyotma Gandhi. "Unveiling the core of IoT: comprehensive review on data security challenges and mitigation strategies", Frontiers in Computer Science, 2024<br>Publication | <1% |
| 100 | Giovanni Diraco, Gabriele Rescio, Pietro Siciliano, Alessandro Leone. "Review on Human Action Recognition in Smart Living: Sensing Technology, Multimodality, Real-Time Processing, Interoperability, and Resource-Constrained Processing", Sensors, 2023<br>Publication | <1% |
| 101 | Laura Quadros Aniche, Jurian Edelenbos, Alberto Gianoli, Rochelle Caruso et al. "Contextualizing and generalizing drivers and barriers of urban livings labs for climate resilience", Environmental Policy and Governance, 2024<br>Publication | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | Off | Exclude matches | Off |
| Exclude bibliography | Off | | |