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Rébecca Deneckère, Elena Kornyshova, Kaoutar Sadouki, Sjaak Brinkkemper

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Chapter 2

Taxonomy of the Scientific Domain of Smart Life



Rébecca Deneckère, Elena Kornyshova, Kaoutar Sadouki,
and Sjaak Brinkkemper

Abstract The field of Smart Life represents a large spectrum of various application domains coming from very established ones as Smart energy and Smart home to very recent ones as Smart environment, Smart airport, or Smart Earth. We observed a substantial growth in the scientific literature with over 126,000 papers containing “Smart” in their titles in 2021. Despite this huge number, we did not identify a detailed classification of these fields in the existing literature. There is still a notable gap in the classification and systematization of these fields. To address this, we developed a generic taxonomy for Smart applications by conducting a systematic mapping study focused on state-of-the-art and research agenda-oriented papers (2341 scientific publications in total).

Keywords Smart Life · Smart domain · Taxonomy

2.1 Introduction

There is a huge number of scientific publications in the various Smart domains. In 2021, more than 126,000 papers containing the term “Smart” in their titles were extracted from the scientific databases. In front of this quantity of scientific works, we decided to reduce our scope to state-of-the-art- and research agenda-oriented

R. Deneckère

Centre de Recherche en Informatique, Université Paris 1 Panthéon-Sorbonne, Paris, France

e-mail: rebecca.deneckere@univ-paris1.fr

E. Kornyshova (✉) · K. Sadouki

Centre d’Études et de Recherche en Informatique et Communications, Conservatoire National des Arts et Métiers, Paris, France

e-mail: elena.kornyshova@cnam.fr; kaoutar.sadouki@lecnam.net

S. Brinkkemper

Department of Information and Computing Sciences, Utrecht University, Utrecht, the Netherlands

e-mail: s.brinkkemper@uu.nl

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papers. The motivation behind was to target more established sub-fields of Smart Life as the presence of this kind of publication can testify.

We discovered that the number of scientific literature reviews in Smart Life-related topics is also important and growing continuously. For instance, for the period from 1986 to the beginning of 2022, we identified 891 literature reviews on Smart industries, 384 on Smart cities, 191 on Smart homes, and 190 on Smart healthcare, to cite the most widespread ones.

Most of these state-of-the-art works deal with a particular sub-topic in the Smart domain: IoT application for energy consumption (Wang et al. 2021), security in Internet of Things (IoT) (Harbi et al. 2019), IoT usage in Smart cities with a classification of Smart technologies (Tai-hoon et al. 2017), computer technologies from the viewpoint of artificial intelligence (Yamane 2017), machine-to-machine usage (Severi et al. 2014), and so on. Despite the explosion of literature reviews in Smart domains, we noted an absence of research dedicated to the classification, organization, and systematization of these fields.

We undertook a systematic mapping study (Petersen et al. 2008) to explore and structure the scientific domain of Smart Life. Our main goals were to elaborate a taxonomy of Smart Life applications, which does not exist yet in the current literature and to understand the evolution of these applications and related concepts.

To elaborate on these goals, we established two research questions:

- *RQ 1: How can Smart applications be classified?*
- *RQ 2: How have these applications evolved through time?*

The objective of this chapter is to identify the existing Smart applications and taxonomize the scientific domain of Smart Life. We elaborated a generic taxonomy of applications around Smart Life to answer the first question. The second one is detailed in Chap. 3 of this book. Our results were partially presented in Kornysheva et al. (2022a, b).

In this chapter, we explain our research method in Sect. 2.2. We highlight the obtained results in Sect. 2.3 and each of the Smart domains in Sects. 2.4–2.7. Clusters are explained in Sect. 2.8. We conclude in Sect. 2.9.

2.2 Research Methodology

We adopted a systematic mapping design (Petersen et al. 2008) to explore the Smart Life field of research. Systematic mapping studies (SMS) share similarities with other systematic reviews (like SLR—systematic literature review—synthesizing the existing research in established fields), except in their broader inclusion criteria to select a wider range of research papers. SMS are intended to map out topics within a field classification rather than synthesize study results. Our study is focused on consolidating existing work in the Smart Life domain, following the process outlined in Petersen et al. (2008), which includes five steps: definition of research

questions, finding papers, screening papers, classification scheme definition, and data extraction.

2.2.1 Step 1: Definition of the Research Questions

The objective of this chapter is to identify existing Smart applications and taxonomize the scientific domain of Smart Life. Thus, we focus on the first question (the second question is answered in Chap. 3):

- *RQ 1: How can Smart applications be classified?*

2.2.2 Step 2: Finding Papers

This step focuses on identifying a set of papers based on a relevant search string. We conducted our search and selected papers from the SCOPUS scientific database using the SCOPUS Search API in November 2021. (This database includes all “articles being published in virtually all scholarly journals of any significance in the world.”)

Initially, we conducted a broad search for papers containing the term “Smart” solely in the title, yielding over 126,000 papers. Consequently, we limited our search to secondary research papers such as state of the arts and research agendas. This narrowed search resulted in obtaining 2410 sources with DOIs. The inclusion criteria related to the search string are given in Table 2.1.

2.2.3 Step 3: Screening Papers

We analyzed the titles and, when necessary, the abstracts and content of papers. We excluded 69 sources that did not represent research papers or were irrelevant to Smart Life topics. We obtained 2341 papers.¹ In Table 2.1, we summarize the exclusion criteria employed to compile the final list of papers.

¹ The complete list of these papers is available at http://cri-dist.univ-paris1.fr/rcis22/RCIS2022_Appendix%20A%20-%20references%20list.pdf

Table 2.1 Inclusion/exclusion criteria for the study on Smart topics

Selection criteria	Criteria description
Inclusion criteria (2410 sources identified)	The title includes the term “smart” and at least one of the terms “research agenda,” “state of the art,” “review,” or “survey”: Search string: TITLE(smart) AND (TITLE(“research agenda”) OR TITLE(“State-of-the-art”) OR TITLE(review) OR TITLE(survey))
Exclusion criteria (2341 sources selected)	The source is not a research paper (erratum, retracted, etc.)
	The source is related to an abbreviation SMART, for instance, SMART (stroke-like migraine attacks after radiation therapy) syndrome.
	The source mentions the term “smart,” which is used in its ordinary sense, like “working smart and hard”

2.2.4 Step 4: Classification Scheme Definition

The goal of this step in the SMS is to determine the classification scheme to be applied to the acquired results. To answer the defined research questions, we grouped all relevant papers according to the Smart application category and the year of publication of the paper (the second criterion will be presented in detail in the next chapter).

2.2.5 Step 5: Data Extraction

For each paper, we identified the main topic based on the title and abstract (and content if required). Within the identified topics, we observed that they concerned either applications or artifacts. We focused only on applications. We grouped these applications in categories related to their main usage, like Smart industry, Smart healthcare, Smart agriculture, and so on. Finally, we grouped these categories into four Smart domains: persons, society, environment, and enterprises. Thus, we obtained a taxonomy composed of a hierarchy of Smart applications.

2.2.6 Validity Threats

Qualitative research relies on subjective, interpretive, and contextual data. Therefore, we analyzed the potential biases that could jeopardize the validity of our research. Thomson (2011) proposes five categories of validity. To mitigate the impact of validity threats on our study, we present them along with the corresponding mitigation actions as follows.

Descriptive validity (accuracy of the data). We standardized the concepts and criteria utilized in the study and structured the information to be collected through a data extraction form, ensuring a consistent recording of data.

Theoretical validity (ability to get the information that it is intended to capture). We used a search string and implemented it across a library encompassing the most popular digital repositories in computer sciences and software engineering. We established a set of inclusion and exclusion criteria. To mitigate the risk of overlooking available evidence, we employed two distinct search methods: an automatic search and a manual search (backward and forward snowballing). The decision to focus on English sources aimed to minimize the impact on disregarding other languages.

Generalization validity (ability to generalize the results). Our set of research questions is sufficiently broad to identify and classify the findings related to Smart applications.

Evaluative validity (conclusions reasonable given the data). Two researchers independently examined the papers, with an overlap in their studies to identify potential variations in analysis. Every conclusion was validated by at least two researchers.

Transparency validity (repeatability of the research protocol). The research process protocol is sufficiently detailed to ensure it can be thoroughly replicated.

2.3 Four Main Domains of the Smart Applications Taxonomy

Many applications have interconnections, yet a systematic structuring is necessary. To address this, we studied the subjects covered by the 2341 selected papers of the SMS (). Initially, we adopted a bottom-up approach by looking the titles of all papers. However, when titles proved insufficient in identifying the application field, we extended our examination to include abstracts. If further clarification was required, we looked into the content of the papers.

We assigned each paper a classification of 1–3 levels of applications (e.g., Smart energy → Smart grid → Smart grid communication). This classification was applied to all papers except those addressing Smart artifacts, technologies, or systems without a clear association with a concrete application field. An expert carried out the assignment of each paper to a Smart application. In cases where the alignment of a topic with a Smart domain was not straightforward, a more in-depth analysis involving two or more experts was conducted to reach a consensus.

After qualifying the papers, we structured them within a taxonomy using a top-down approach. This involved categorizing the major fields of Smart Life, such as Smart home, Smart city, Smart industry, Smart healthcare, etc. and organizing the identified application fields within these major fields. Considering the number of major application fields, we organized them into four Smart Life domains: Smart applications for persons, Smart applications for environment, Smart applications for society, and Smart applications for enterprises (Fig. 2.1).

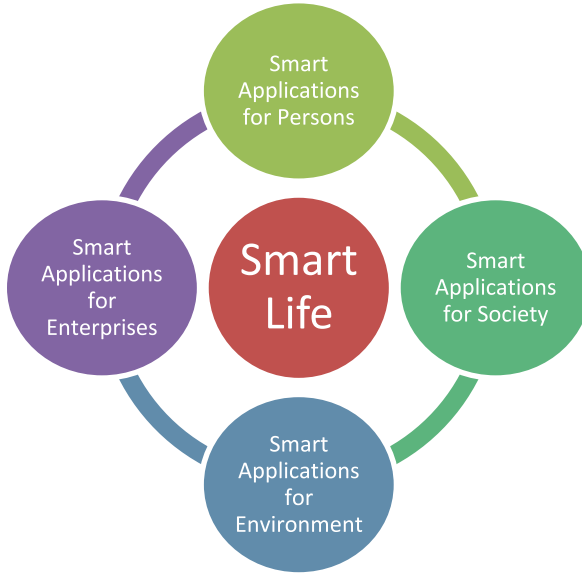


Fig. 2.1 Smart Life domains

- *Smart applications for Persons* contain applications focused on the personal Life of humans, like Smart healthcare, Smart home (Smart living), Smart welfare, etc. (see Sect. 2.4)
- *Smart applications for Environment* include various topics related to the study and preservation of the environment: Smart natural resource management, Smart earth, Smart disaster management, and Smart space exploration (see Sect. 2.5).
- *Smart applications for Society* deal with various not-for-profit aspects of human life in groups, including Smart city and Smart village. It also includes applications related to the management of people living in groups, such as Smart citizenship, Smart state, Smart policing, and so on (see Sect. 2.6).
- *Smart applications for Enterprises* concern applications in the for-profit sectors, covering three basic domains: Smart agriculture, Smart industry, and Smart service industry. This category also covers applications related to Smart transportation and Smart business management (see Sect. 2.7).

We detail the sub-categories in the following sections.

2.4 Smart Applications for Persons

In our study, we found three categories of Smart applications belonging to this domain: Smart healthcare, Smart home, and Smart welfare (Fig. 2.2).

Fig. 2.2 Smart Life applications for persons

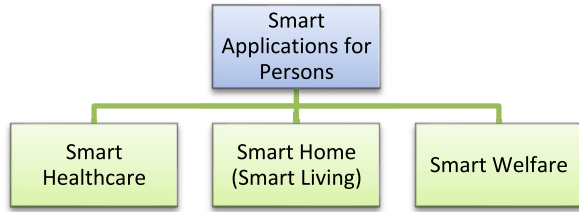
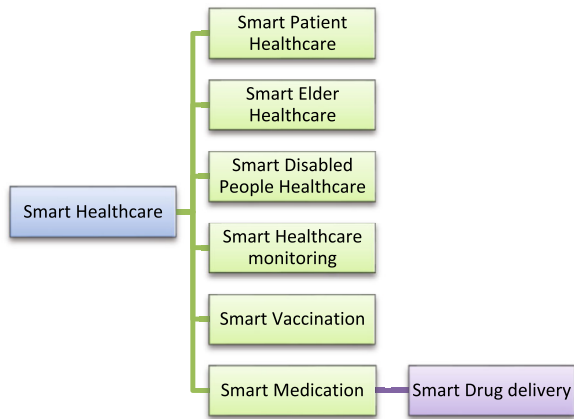


Fig. 2.3 Smart Life applications for Smart healthcare



2.4.1 *Smart Healthcare*

Smart healthcare does not have a unique definition. Yin et al. (2018) define Smart healthcare as that besides clinical usage; it utilizes implantable and wearable medical devices to gather, store, and process various types of physiological data during daily activities. However, our SMS allows us to identify six categories of Smart healthcare applications, as shown in Fig. 2.3.

Smart Patient Healthcare There are a lot of studies about technologies linked to the care of patients, especially for specific needs. For instance, Moraitou et al. (2017) look into the needs of vulnerable groups that need nursing for a long period of time and offer a review on the main technological, psychological, ethical, and economic challenges raised by the implementation of a Smart health caring home.

Smart Elder Healthcare Information technologies in geriatric healthcare are needed, due to rapidly ageing societies. Zhao et al. (2021) propose a review aiming to examine the extent, variety, and characteristics of existing Smart concepts and feasible healthcare technologies in nursing home settings. Demiris and Hensel (2008) look into Smart homes-needed features to consider older or disabled people.

Smart Disabled People Healthcare In the same way, there are works looking into specific technological needs for disabled people. For instance, Jamwal et al. (2020)

aim to explore the impact of Smart home and communication technology on the outcomes of people with disabilities and complex needs.

Smart Healthcare Monitoring Yusuf et al. (2020) define a health monitoring system as a system that allows patients to monitor the health-related problem to avoid further complications that could result in loss of life.

Smart Vaccination Andries et al. (2014) propose to use the current repertoire of devices used in RNA synthetic biology to propose programmable “Smart vaccines” that will revolutionize the field of RNA vaccination.

Smart Medication Medication can be identified and delivered with the help of Smart artifact. We found a subset of these Smart applications specifically addressing the delivery of drugs, essentially insulin for diabetic people.

Smart drug delivery: These artifacts are able to deliver drugs to people. For instance, Smart insulin pens, which automatically delivers insulin to people as a continuous subcutaneous infusion, were being used by 375,000 people with type 1 diabetes in 2008 (Zisser et al. 2008).

2.4.2 Smart Home (Smart Living)

The aim of the Smart home is to improve the quality of life for its residents through automating household tasks, such as energy management, security surveillance, and so on (Alaa et al. 2017). Smart home is defined in Lutolf (1992) as “the integration of different services within a home by using a common communication system. It assures an economic, secure, and comfortable operation of the home and includes a high degree of intelligent functionality and flexibility.” Smart home applications can be categorized into several other type of applications, as shown in Fig. 2.4.

Smart Home Management

Smart Home Water Management. Water management is possible by real-time monitoring of water level and quality. Real-time water level monitoring can significantly reduce wastage of water due to overflow from tanks. The water management system can also help detect water leaks in a Smart home by analyzing water levels during different hours of the day (Singh and Suhaib 2020). Different Smart water frameworks, including definition and architecture, are proposed, as in (Li et al. 2020).

Smart Home Temperature Management. It groups all the applications that help regulate the temperature in a Smart home system. Malekpour et al. (2020) address these applications by studying Smart thermostats, a device which has the capability to remotely control the set points as well as to adjust set point schedules of the temperature system. In some cases, it can also monitor occupant behavior and learn from this behavior for improved operational efficiency and occupant comfort.

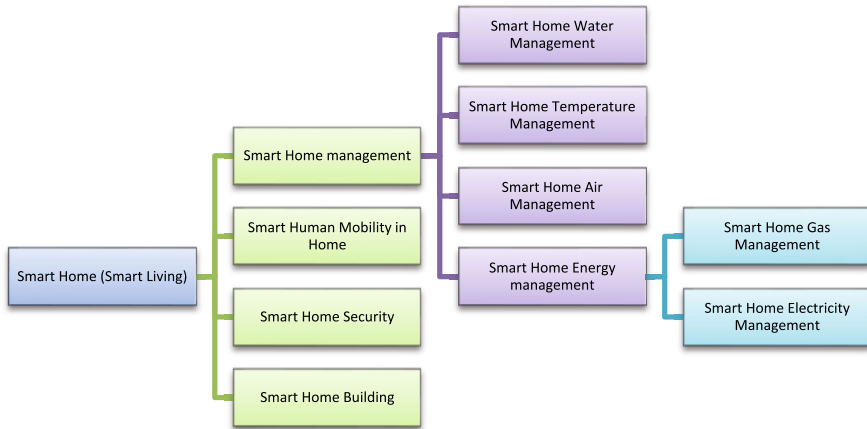


Fig. 2.4 Smart Life applications for Smart home (Smart living)

Smart Home Air Management. On the same way as water or temperature, air can be controlled by the use of sensors. Guyot et al. (2018) provide a literature review on Smart ventilation used in residential buildings, based on energy and indoor air-quality performance.

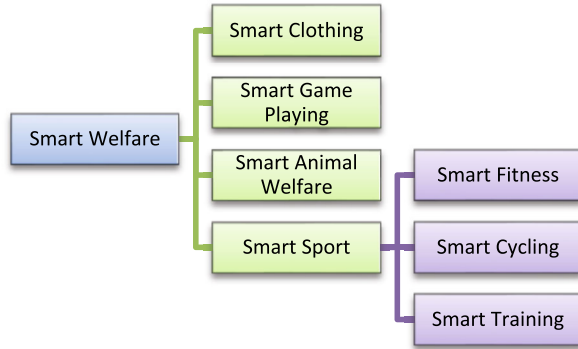
Smart Home Energy management. Various system components such as hardware elements, software algorithms, network connections, and sensors need to collaborate to offer diverse services in a Smart home environment. Energy management at the household level must consider reducing environmental impact while supporting human lifestyles (Komninos et al. 2014). We can find two different kinds of energy management specific to a Smart home system: *Smart home gas management* and *Smart home electricity management*.

Smart Human Mobility in Home Smart homes can integrate considerations for human mobility within the residence environment. For example, the use of Smart wheelchairs can lead to a seamless user experience and enable control over all household appliances (Leaman and La 2017).

Smart Home Security There is a range of security issues in a Smart home management (Lin and Bergmann 2016). Yan et al. (2021) focus on four aspects of Smart home security, Smart devices, cloud platforms, mobile applications, and communications, and summarize the attack and defense methods. Aljanah et al. (2021) specifically study the solutions offered about how to authenticate a large number of heterogeneous and possibly resource-constrained devices in a secure and efficient manner.

Smart Home Building In Smart home buildings, it is possible to manage household appliances such as lighting, air conditioning, fans, washing machines, TVs, refrigerators, security systems, and so on. Through the application of artificial

Fig. 2.5 Smart Life applications for Smart welfare



intelligence, these systems can also achieve self-control and monitoring capabilities (Shaker 2020).

Smart Welfare Smart welfare is about how Smart technologies can be applied to enhance the life quality of a person with the help of devices and sensors. Figure 2.5 shows the different types of Smart welfare applications.

Smart Clothing Smart clothes embed Smart wearables into garments. Fernandez-Carames et al. (2018) propose the paradigm of “Internet of Smart clothing,” which envisions a world where Smart garments communicate with each other, with the objects on their environment, and with remote servers on the Internet in order to provide advanced services.

Smart Game Playing Costa et al. (2018) present the application of proxemics in digital games to enhance game-mediated interactions within Smart ecosystems.

Smart Animal Welfare Animal welfare refers to an assessment of whether animals are healthy, free of pain and suffering, and positively stimulated in their environment. Smart technologies can also be used for animal welfare, as studied in (Jukan et al. 2017), for instance.

Smart Sport Smart sport refers to the integration of advanced technologies and data-driven solutions in the realm of sports to enhance performance, training methodologies, and overall athlete experience. This paradigm leverages innovations such as wearables, sensors, analytics, and connectivity to collect and analyze real-time data, providing valuable insights for athletes, coaches, and sports organizations.

Smart Fitness. Smart fitness is divided into three categories: fitness trackers (including wearable and non-wearable sensors), movement analysis, and fitness applications (Farrokhi et al. 2021). The aim is to enhance training performance in a fitness environment.

Smart Cycling. These applications offer interactions between traffic participants, to help communicate the cyclist’s intentions to others or to enhance playfulness and social cohesion, on and beyond the cycle path. Smart cycling technologies offer

possibilities to be in touch with people who are not sharing the road with you, and a ride can be recorded, “re-lived,” and shared in improvised social networks (Nikolaeva et al. 2019).

Smart Training. With the increase of participation trends in mass sporting events, as well as the involvement of people in sporting activities, there is a need for systems/applications that can guide, help, and support people in enjoying their activities. Modern technology is revolutionizing the way athletes maximize their performance and compete on a higher level than ever before (Rajsp and Fister 2020).

2.5 Smart Applications for Environment

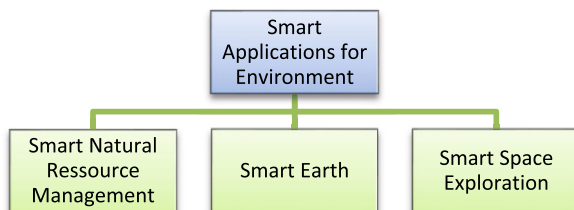
This domain encompasses three types of applications, those dedicated to natural resource management, those focused on Smart Earth solutions, and those geared towards space exploration, as shown in Fig. 2.6.

2.5.1 Smart Natural Resource Management

The management and preservation of natural resources are paramount in today’s world, driven by the pressing need for sustainability and environmental stewardship. Within this context, Smart technologies are playing an increasingly crucial role in revolutionizing how we approach resource conservation and management. This section looks into several key Smart applications focused on natural resources, highlighting innovative solutions that harness technology to address critical challenges in water management, climate engineering, forestry, and air quality, as shown in Fig. 2.7.

Smart Water Management Efficient water management has emerged as a significant concern for numerous countries and water industries. Researchers are leveraging ICT to develop self-learning systems, which possess the capability to enhance water management efficiency (Gupta et al. 2020a). We can distinguish two

Fig. 2.6 Smart Life applications for environment



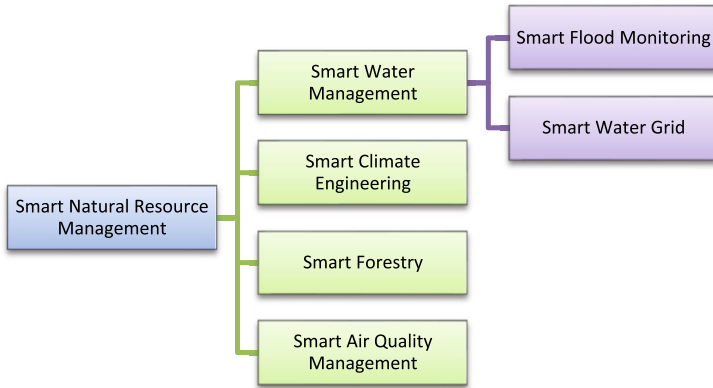


Fig. 2.7 Smart Life applications for Smart natural resource management

types of Smart water management systems: Smart flood monitoring and Smart water grids.

Smart Flood Monitoring. Smart technology is used to determine the accurate level of flooding of land, which is ordinarily dry in nature, and the connected phones are able to give the forecasting information to the affected people to prevent the unnecessary loss caused by this natural hazard (Subashini et al. 2021).

Smart Water Grid. There is a need for water management, measures to control water scarcity and a way to conserve water (Behera and Pradhan 2019).

Smart Climate Engineering Global warming represents one of the most significant challenges humanity faces. To achieve climate goals, technologies such as CO₂ capture and storage and CO₂ capture and utilization are crucial for mitigating hard-to-avoid CO₂ emissions (Wang et al. 2020).

Smart Forestry It is based on digital forestry, using cloud computing, Internet of Things, mobile Internet, big data, and other new generation information technology. It can promote the coordinated development of forestry resource management and ecosystem construction (Zou et al. 2019).

Smart Air Quality Management Air quality is a huge and pressing global issue, leading to over 7 million annual deaths according to the World Health Organization. Access to air quality information allows individuals to make informed decisions, yet analyzing this data and implementing effective solutions remains challenging. Efficient methods for analyzing big data are crucial to reveal hidden insights and address the invisible impacts of air pollution effectively (Iskandaryan et al. 2020).

2.5.2 *Smart Earth*

Smart Earth is a set of environmental applications of the Internet of Things but articulated across a much wider range of ecosystems and land use types (Bakker and Ritts 2018). Smart Earth technologies use terrestrial, aquatic, and aerial sensors, satellites, and monitoring devices.

2.5.3 *Smart Space Exploration*

Over the last century, the progress of space exploration has imposed demanding requirements on payloads and increased the spacecraft complexity, with the result of a constant rise in their average launch mass, but space industries and agencies are currently more interested in very small satellites with launch masses below 10 kg (nanosatellites, picosatellites, femtosatellites). Niccolai et al. (2019) discuss about the result of this miniaturization process with the design of integrated miniaturized components into a common substrate of *silicon wafer* layers. It gives the possibility of creating a single component-satellite, capable of generating and distributing power, exchanging heat with the environment, communicating, and hosting a payload, with subsystems assembled in a 20 mm × 20 mm × 3 mm monolithic integrated circuit.

2.6 Smart Applications for Society

The integration of advanced technologies into urban environments has given rise to the concept of “Smart cities,” representing a significant subset of Smart applications for society. This section explores the multifaceted initiatives within the domain of Smart applications for society, as shown in Fig. 2.8.

This domain contains a wide set of Smart applications, some widely known, such as Smart city or Smart education, or a bit less studied, like Smart state or Smart citizenship.

2.6.1 *Smart City*

As defined in Washburn et al. (2009), the realization of a Smart city is about integrating software services and applications to improve regular city services and ease and facilitate the life of citizens. In Chamee (2020), Smart city is “a city that collects and utilizes data gathered from distributed sensors and video cameras that connect everything from trash bins to streetlights.”

Fig. 2.8 Smart Life applications for society

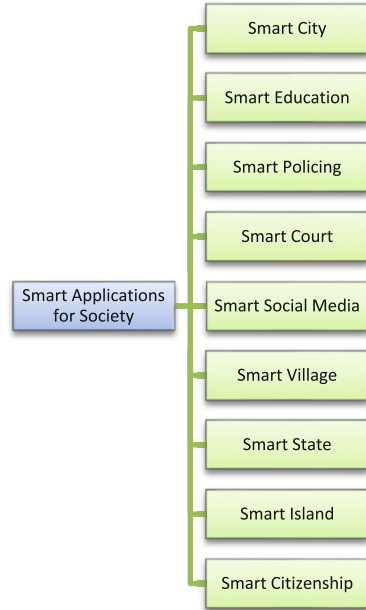
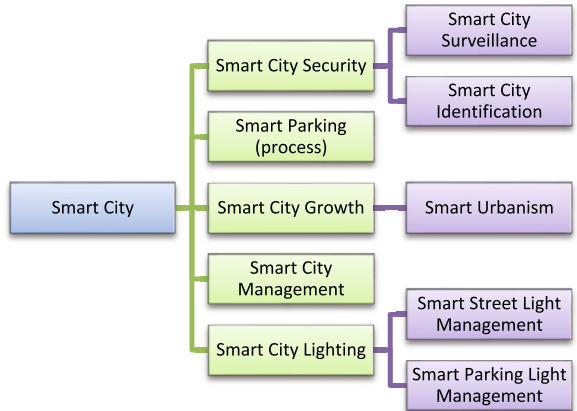


Fig. 2.9 Smart Life applications for Smart city



To provide more specific examples, the concept of Smart city concept is employed to address challenges in urban cities by providing a high-quality living environment for citizens (Al-Ani et al. 2019). Therefore, within the taxonomy, the Smart city application domain contains applications addressing issues as security, urban growth, lighting, parking, and more (see Fig. 2.9).

Smart City Security The dependence on ICT makes Smart cities prone to cyberattacks (Alibasic et al. 2017). We identify two main categories of Smart

applications relative to Smart city security: Smart city surveillance and Smart city identification.

Smart City Surveillance. Smart cities enhance residents' lifestyle by offering efficient infrastructure and improved security. Continuous surveillance, often a repetitive and monotonous task, can diminish the performance of human guards over extended periods, and the use of the huge amount of data can help increase this performance (Thakur et al. 2021).

Smart City Identification. An essential component of Smart cities is their surveillance infrastructure, which necessitates intelligent techniques for analyzing video footage from surveillance cameras (Behera et al. 2020).

Smart Parking (The Parking Process) Smart parking sensors and technologies assist drivers in finding vacant parking slots while they are on the way to their destination (Zulfiqar et al. 2021).

Smart City Growth Smart growth aims to enhance housing affordability and diversity. However, one of the goals of Smart growth, compact development, restricts land development and presents challenges for affordability (Addison et al. 2013). Smart growth-related planning practices, including growth management policies and urban design tools like transit-oriented development and urban infill, can influence housing markets significantly.

Smart Urbanism. The tightening integration of urban systems, coupled with increased coordination in urban domains, enables the provision of more holistic views and synoptic city intelligence to give a better understanding of urban life (Bibri 2019).

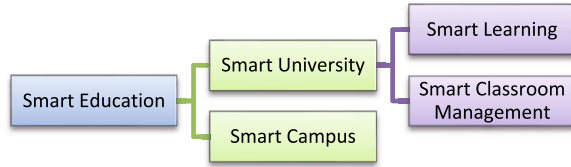
Smart City Management The concept of Smart cities involves comprehensive city organization and management through technology. It is built and sustained by integrating technologies like sensors, electronics, and networks. The primary motivation behind investigating Smart city services is to enhance city services for citizens and improve their overall quality of life (Al-Smadi et al. 2019).

Smart City Lighting Lighting systems play an important role in the evolution process of Smart cities, thanks to their ability to affect city life at night along with people's mood and behavior (Scorpio et al. 2020).

Smart Street Light Management. Smart street light management refers to a networked system of streetlights equipped with sensors, actuators, and communication infrastructures to illuminate roads, highways, parking areas, and public spaces efficiently. Addressing environmental concerns and aiming to reduce electricity costs, utilizing these applications with real-time monitoring and energy efficiency features benefits municipalities, utility companies, and city residents alike (Mahoor et al. 2020).

Smart Parking Light Management. With the rise in population, there is a corresponding increase in the number of vehicles on roads, necessitating the development of sustainable and efficient parking solutions. However, continuous lighting in these

Fig. 2.10 Smart Life applications for Smart education



areas is not resource-efficient. To address this, integration of automated lighting that activates only when a vehicle is detected, thus combining Smart parking with automated lighting for a practical, sustainable, and efficient solution (Shastry et al. 2020).

2.6.2 Smart Education

Conventional teaching methods, involving classroom instruction followed by independent student exercises, are being supplanted by modern learning approaches, including distance learning, mobile learning (m-learning), personalized learning, flipped and blended learning, social collaborative learning, and game-based learning, among others (Demir 2021). Figure 2.10 shows the sub-taxonomy for Smart education.

Smart University The concept of Smart university encompasses a thorough modernization of educational processes, leading to enhanced quality across various university activities such as education, research, and commercial endeavors. This transformation includes the adoption of technologies like Smart boards, screens, and ubiquitous wireless Internet access, redefining the educational landscape with advanced tools and connectivity (Tikhomirov et al. 2015).

Smart Learning. This modern education approach is using technology integration for enhanced learning outcomes by combining Smart devices and pedagogies, to prioritize personalized and adaptive learning experiences (Wong and Li 2021).

Smart Classroom Management. Installing Smart devices and emerging trending technologies help teachers focus on student’s learning process in place of wasting time in taking attendance for a large group of students, transforming traditional classrooms into Smart classrooms (Gupta et al. 2020b).

Smart Campus Similar to the goal of a Smart city, which is to make the quality of life of its population increase, the purpose of a Smart campus is also about how the quality of life of university stakeholders can be improved (Imbar et al. 2020).

2.6.3 *Smart Policing*

Smart policing refers to the application of data-driven approaches by police authorities. Afzal et al. (2020) present a framework to show the connections between Smart use of data and police approaches and strategies to show how Smart policing can be an area of increased interest in digital government and public management research.

2.6.4 *Smart Court*

A Smart court is characterized by the automation and digitization of judicial procedures, forming part of a comprehensive set of reforms aimed at establishing a more precise and consistent judiciary. In Smart courts, certain tasks may be automated using programs, potentially incorporating learning algorithms but not necessarily all. The essence of Smart courts lies in the interaction between human judges and the technology that supports them in their work during this partially automated digital judicial process (Papagiannas 2021).

2.6.5 *Smart Social Media*

Smart social media refers to a set of practices and approaches used to optimize the use of social media in an intelligent and effective manner. This involves leveraging advanced technologies, algorithms, and analytical tools to enhance the management, engagement, and relevance of content on social media platforms. The goal is to achieve more meaningful results in terms of visibility, interaction, and conversion through a strategic and thoughtful approach to social media (Lia et al. 2021).

2.6.6 *Smart Village*

The notion of a Smart village involves leveraging technology to address interconnected challenges such as financial exclusion, poverty, hygiene, and education, presenting an empowering approach to uplift underserved communities through improved access to power, education, and entrepreneurial opportunities (Kaur and Parashar 2021).

2.6.7 *Smart State*

There are evident trends indicating increased inter-organizational collaboration, information sharing, and integration, paving the way for what could be termed as a Smart State. Gil-Garcia (2012) delves into the promises and challenges already identified in government information sharing and integration initiatives. The case study of the Brisbane city is studied in Hertz (2016); it evaluates the Smart State strategy's effectiveness, analyzes barriers to knowledge-based urban development, explores limitations in public policy development for urban planning, and presents lessons learned to enhance frameworks for intelligent urban planning in the context of global economic development.

2.6.8 *Smart Island*

The European Union has clearly outlined priorities for sustainable and low-carbon energy systems, highlighting the significant role of islands. These islands are seen as ideal locations to develop and test innovative strategies and solutions, which can then be applied to accelerate the transition to sustainable energy systems on the mainland (Groppi et al. 2021). Smart island applications are then good tests for techniques that deal with such solutions in the insular contexts.

2.6.9 *Smart Citizenship*

To effectively develop Smart cities, it is crucial to involve citizens as integral participants. They play key roles as users, decision-makers, consumers, and sources of valuable data and information (Tadili and Fasly 2019). Smart citizenship includes Smart voting (see Fig. 2.11).

Smart Voting. In democratic countries, the voting system plays a major role during elections. Electronic voting machines can be used, but they need more manpower, are time-consuming, and also less trustworthy. For avoiding misconceptions during elections, there are lot of advanced techniques that are being proposed using various methods (Deepika et al. 2017).



Fig. 2.11 Smart Life applications for Smart citizenship

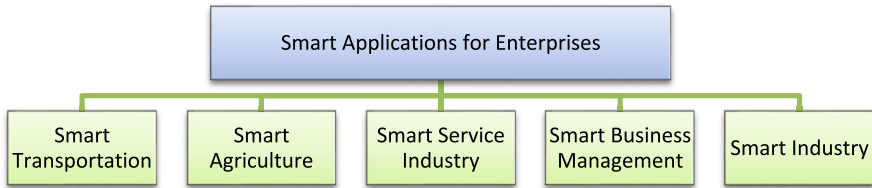


Fig. 2.12 Smart Life applications for enterprises

2.7 Smart Applications for Enterprises

This domain contains applications about transportation, agriculture, service industry, business management, and industry, as shown in Fig. 2.12.

2.7.1 Smart Transportation

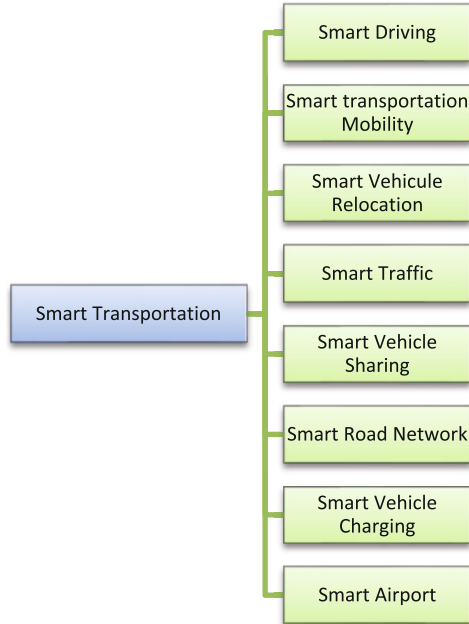
Smart transportation refers to the integration of advanced technologies, data analytics, and intelligent systems to enhance the efficiency, safety, and sustainability of transportation networks. It optimizes traffic flow, improves public transit systems, enhances vehicle safety, and reduces environmental impact. Smart transportation aims to create a seamless, interconnected, and data-driven mobility ecosystem for the benefit of both commuters and the overall transportation infrastructure. The Smart transportation field includes several topics illustrated in Fig. 2.13.

Smart Driving Smart driving refers to a conscientious and environmentally friendly approach adopted by drivers in response to the growing emphasis on climate change in social and political discussions (Young et al. 2011). While traditional ergonomics research has predominantly concentrated on enhancing vehicle safety and performance efficiency, the evolving landscape demands a shift toward the development of systems that actively promote eco-conscious driving behavior. Smart driving integrates technological solutions, behavioral insights, and ergonomic considerations to contribute to sustainable and environmentally responsible transportation practices.

Smart Transportation Mobility Smart mobility, a crucial element of Smart cities, has the potential to alleviate traffic congestion, reduce commute times, lower road accidents, and offer passengers the flexibility to personalize their journeys. Planning Smart mobility solutions ranks among the foremost challenges faced by major cities globally, necessitating deliberate actions supported by advanced technologies (Biyik et al. 2021).

Smart Vehicle Relocation Traditional car-sharing systems require users to pick up and return cars at designated stations, whereas free-floating systems establish a geo-

Fig. 2.13 Smart Life applications for Smart transportation



fence around the city center, allowing users to hire and drop cars directly at or near their desired locations without visiting a station (Hermann et al. 2014).

Smart Traffic The increasing number of vehicles on roads and limited capacities are making traffic networks increasingly complex and challenging, resulting in congestion and traffic jams that significantly impact the economy, environment, and human health. As a result, there is a strong motivation to develop new traffic management systems to address these issues effectively (Merrad et al. 2016).

Smart Vehicle Sharing Transport and urban planners are focused on creating policies that improve service access for transportation activities, ensuring convenient and affordable public transportation, integrating all modes effectively, ensuring safety, and developing transport infrastructure. The initial cost of fully autonomous vehicles may be prohibitive, leading to their introduction in the public market as shared-fleet services initially. On-demand mobility, incorporating both car-sharing and ride-sharing, along with automation, especially in integrated demonstrations like shared autonomous vehicles, are presented as sustainable solutions to urban mobility challenges (Golbabaei et al. 2021).

Smart Road Network The management and maintenance of road infrastructures require extensive data on their maintenance history and current condition. There is a growing need to improve the efficiency of managing and maintaining road infrastructures. In recent years, several promising technologies have emerged to address various identified challenges in this area (Carneiro et al. 2018).

Smart Vehicle Charging The transportation sector is currently grappling with challenges related to its reliance on oil-based energy models. Electric mobility represents a crucial step toward sustainability in contemporary society. The integration of plug-in electric vehicles into electrical distribution networks stands to benefit all stakeholders by enhancing system efficiency both technically and economically. Smart charging technology plays a pivotal role in achieving this ambitious objective (Garcia-Villalobos et al. 2014).

Smart Airport Smart airports enhance both passenger and airport experiences by employing technologies, sensors, and processors, to maintain an inclusive and continuous connection between passengers and various services, accessible anytime and anywhere within the airport ecosystem (Alansari et al. 2019). They establish a real-time communication framework that enables seamless responsiveness and analysis. Unlike traditional setups, passengers at these airports experience unified check-in processes, with all crucial information centralized.

2.7.2 *Smart Agriculture*

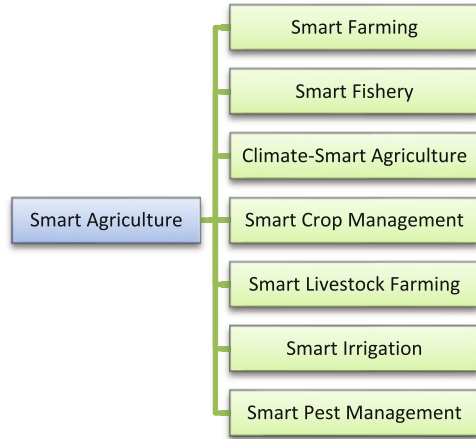
Smart agriculture refers to the use of advanced technologies, including the Internet of Things, sensors, data analytics, and automation, to optimize various aspects of farming processes. The goal is to enhance efficiency, productivity, and sustainability in agricultural practices by collecting and analyzing real-time data, enabling informed decision-making, and promoting resource optimization. Smart agriculture encompasses a range of applications, from precision planting and irrigation to livestock monitoring and crop management, ultimately contributing to more intelligent and resource-efficient farming practices. The sub-topics of Smart agriculture are shown in Fig. 2.14.

Smart Farming The increase of the global population and its subsequent surge in food demand pose challenges to agricultural production. Concurrently, decreasing rural workforce and rising production costs further compound the challenges faced by the agricultural sector. In response to these complexities, the concept of Smart farming, using the Internet of Things, emerges as a farm management solution. Smart farming employs IoT to address contemporary issues in food production, enhancing efficiency and sustainability (Navarro et al. 2020).

Smart Fishery Smart fishing spans various domains, as the assessment of the economic aspects of commercial fleets, electronic monitoring of catch and bycatch, identification and prediction of fishing grounds, and the simulation of fishing vessel behavior (Ebrahimi et al. 2021).

Climate-Smart Agriculture The literature contains numerous projections regarding the impact of climate change on agriculture, particularly on crop, livestock, and fishery production sectors. Understanding the scale of these impacts is crucial for

Fig. 2.14 Smart Life applications for Smart agriculture



informing adaptation strategies and developing policies that promote climate-Smart agriculture (Zougmoré et al. 2016).

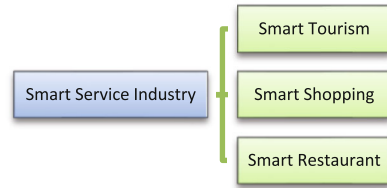
Smart Crop Management In the context of Smart agriculture, contemporary farming increasingly relies on new technologies. IoT farmers can remotely monitor their crops and equipment using smartphones and computers (Mekala and Viswanathan 2017). Crop production in agriculture is influenced by numerous factors including climate, geography, biology, economics, history, politics, socio-economic conditions, and agro-ecological zoning. Intelligent agro-ecological zoning plays a crucial role in this context, aiming to accurately suggest and predict crops that optimize production yields (Chetan et al. 2021).

Smart Livestock Farming The future of livestock farming is marked by precision, sustainability, and intelligence. By harnessing modern information technology, precision livestock farming addresses traditional farming challenges, paving the way for modernization and stimulating sustainable growth within the livestock sector (Zhang et al. 2021).

Smart Irrigation In most parts of the world, the lack of efficient irrigation methods leads to wastage or excessive use of irrigation water. Installation of Smart water irrigation systems can prove useful for saving water, time, and cost (Issaka et al. 2018).

Smart Pest Management Insect pests pose a significant threat to global agricultural crop yield and quality. Efficient and accurate monitoring of insect pest populations is vital for prediction and control measures. The emergence of Smart pest monitoring, driven by advancements in artificial intelligence theories and technologies, aims to enhance the automatic and intelligent collection of crucial crop insect pest data (Li et al. 2021).

Fig. 2.15 Smart Life applications for Smart service industry



2.7.3 *Smart Service Industry*

The concept of a “Smart service industry” encapsulates a diverse array of applications that include cutting-edge technologies to enhance customer experiences, improve operational efficiency, and drive sustainable practices across various sectors, from data-driven insights in tourism to streamlined shopping experiences and optimized restaurant operations, as shown in Fig. 2.15.

Smart Tourism Smart tourism denotes the growing reliance of tourism stakeholders on emerging information and communication technologies for substantial data transformation, leading to enhanced tourist experiences, heightened destination competitiveness, and improved sustainability. The application of software and analytics to analyze and predict tourist behaviors represents a notable trend among practitioners, ultimately benefiting tourists, industry players, and destinations alike (Ye et al. 2020).

Smart Shopping Smart shopping includes consumers’ efforts to minimize the expenditure of time, money, or energy while maximizing the hedonic and utilitarian value derived from the shopping experience (Green Atkins and Youn-Kyung 2012).

Smart Restaurant Accurate demand forecasting plays a pivotal role in the effectiveness of a restaurant’s yield and revenue management system, a critical aspect for both independent restaurants and larger restaurant chains (Lasek et al. 2016).

2.7.4 *Smart Business Management*

To ensure the sustainability of their businesses, various companies, especially for small and medium-sized enterprises (SMEs), must embrace the Internet as a crucial element in designing new business model values, enhancing customer experiences, and bolstering internal capabilities that support key operations. Companies need to leverage information and communication technology in their business operations to remain competitive and meet evolving market demands (Rozmi et al. 2021).

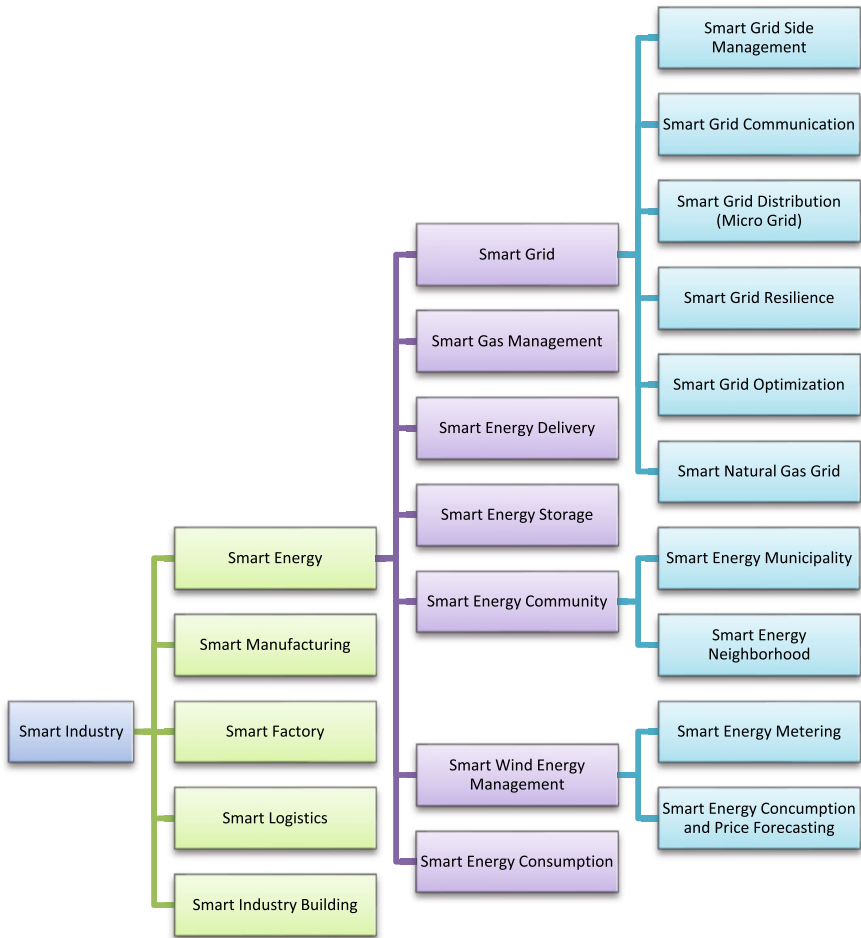


Fig. 2.16 Smart Life applications for Smart industry

2.7.5 Smart Industry

A “Smart industry” application refers to an application to manufacturing and production that integrates IoT advanced technologies to optimize processes, improve efficiency, and enhance decision-making. We can find several kinds of applications related to Smart industry, especially Smart energy ones, as shown in Fig. 2.16.

Smart Energy Being the most widespread in the manufacturing sector, Smart energy applications have a significant impact on sustainability and the environment. These include renewable energies such as solar, wind, hydropower, and biomass,

as well as Smart grids, catalysis industry advancements, and innovations in power storage and distribution (Rangel-Martinez et al. 2021).

Smart Grid. The term “Smart grid” typically refers to a technology class enabled by two-way communication techniques. These techniques facilitate real-time data transfer, essential for control systems to enhance efficiency, reliability, and flexibility (Abdelwahab et al. 2019). We can distinguish six different types of Smart grid applications: for side management, for communication, for distribution (micro-grid), for resilience, for optimization, and for natural gas.

Smart Gas Management. Smart gas management includes various applications related to the handling of gas resources. For example, Smart gas sensing integrates physical and chemical material sciences, electronic circuits, statistics, chemometrics, communication networks, and machine learning methods. The general process of Smart gas sensing technology includes sensing materials and sensor arrays, signal processing for drift compensation and feature extraction, and gas pattern recognition technology based on machine learning, as outlined by Feng et al. (2019).

Smart Energy Delivery. In energy-related sectors, direct interaction between utility providers and consumers from residential, industrial, and commercial sectors is crucial. The integration of digital computation and communication technologies ensures secure, efficient, and reliable electricity delivery and information exchange among power generators, utility companies, and electric power consumers (Reka and Dragicevic 2018).

Smart Energy Storage. Energy storage technologies are central in today’s context, spanning from low-capacity mobile storage batteries to high-capacity batteries linked with intermittent renewable energy sources (Sufyan et al. 2019).

Smart Energy Community. Community energy storage represents a new generation of energy storage important to Smart grids. Its placement at the grid’s edge and proximity to customers provide significant advantages over storage located at substations (Sardi and Mithulananthan 2014). We can identify two types of Smart energy community applications, those aiming to help municipality and those addressed to the neighborhood.

Smart Wind Energy Management. Given that renewable energy sources depend on weather conditions beyond human control, there is a growing need for new functionalities within electricity networks (Xing et al. 2013). The study and integration of wind power are crucial aspects of Smart wind energy management applications. Two different kinds of Smart applications related to Smart wind energy management can be identified: for energy metering and for energy consumption and price forecasting.

Smart Energy Consumption. There is a gradual increase in electricity demand, but establishing new power plants for electricity generation is challenging due to stringent pollution control policies and increased government awareness of environmental preservation. To address this challenge, sufficient profiling of electricity consumption can be used to explore alternative methods for managing

electricity loads in the future while utilizing existing generation capacity (Ahmad et al. 2018).

Smart Manufacturing In response to the growing demand for highly customized products and smaller lot sizes, companies must rapidly adapt to new market opportunities to thrive in a competitive environment, underscoring the importance for manufacturers to cultivate approaches fostering dynamism, flexibility, and reconfigurability at the factory level (Alemão et al. 2021).

Smart Factory Quite close to Smart manufacturing, Smart factories focus on the transformation of factories into smarter, more efficient, safer, and environmentally sustainable environments results from the amalgamation and integration of production technologies, devices, information and communication systems, and data in network infrastructures. Illustratively, in a Smart factory, the capabilities of flexibility and re-configurability in production, coupled with enhanced customer interaction for understanding their needs, enable the customization of goods and services with cost efficiency comparable to mass production (Strozzi et al. 2017).

Smart Logistics Smart logistics enables the intelligent implementation of an integrated logistics system through real-time processing and comprehensive analysis of logistical information. It enhances end-to-end visibility; optimizes logistics processes including transportation, warehousing, and distribution; and provides efficient information services. Smart logistics not only contributes to significant time and cost savings but also holds the potential to mitigate environmental pollution associated with logistical activities (Song et al. 2021).

Smart Industry Building Buildings are evolving toward interactive features that can dynamically adjust to users' needs and changing conditions, be it external factors like climate and grid prices or internal factors such as occupants' requirements. This transition reflects a shift from unresponsive buildings to highly efficient ones capable of energy consumption, production, storage, and distribution (Al Dakheel et al. 2020).

2.8 Clusters

In addition to this main taxonomy, we've discovered the existence of generic clusters that have relevance across multiple areas; thus, they are applied across various Smart applications. We can cite Smart energy and Smart transportation clusters.

Smart energy can be seen as an independent application domain within the Smart industry. However, its presence extends beyond this application, making appearances in other fields such as Smart city, Smart home, etc. In case of Smart cities, energy applications are vital, as energy management systems enhance energy economics, consumption efficiency, grid stability, and reliability. The residential sector significantly impacts global energy consumption and offers flexibility in adjusting consumption patterns, helping address major global challenges (Mahmood

et al. 2021). For Smart homes, energy applications allow to reduce environmental impact and supports lifestyles. They push residents to participate in the energy market and addresses technical aspects like peak shaving, load shifting, and strategic conservation while also having significant socioeconomic impacts (Amer et al. 2014).

Another identified cluster is Smart transportation, which designates applications specifically associated with the transportation and mobility field. For instance, Smart transportation applications in Smart cities include Smart electric vehicles. Smart vehicle charging could be applied in Smart cities to monitor the flow of electric vehicles. They involve a wide range of technologies from road and rail vehicles to surface and underwater vessels and even electric aircraft (Shuai et al. 2016). It allows to contribute to the overall efficiency and resilience of Smart cities.

Smart transportation also contributes to the energy distribution in the grid, for instance, through the charging of electric vehicles. To ensure the sustainability, reliability, and efficiency of the electric-power distribution grid, it is essential to develop and implement Smart charging techniques. By integrating Smart transportation with Smart energy solutions, it is possible to promote sustainable mobility while optimizing energy distribution and usage (Igbinovia et al. 2016).

2.9 Conclusion

In this chapter, we presented a classification of Smart Life applications by means of a unique taxonomy. We conducted a systematic mapping study based on 2341 publications to define this Smart application taxonomy.

We observed the introduction of some more special concepts in the literature, even if they are not fully implemented yet.

- *Smart Earth* is defined as an innovative approach to environmental monitoring in (Bakker and Ritts 2018).
- *Smart island* aims to classify current Smart-related methodologies in the urban context and assess their potential applicability to islands (Desogus et al. 2019).
- The concept of *Smart State* (Gil-Garcia 2012) aligns with the notion of “knowledge-based urban development.”
- Kaur and Parashar (2021) provide a literature review on the use of blockchain technology in *Smart villages*.

Finally, the term Smart world appeared in the literature (Kumari et al. 2020) (Liu et al. 2019) as a unifying term encompassing various Smart applications. For instance, Liu et al. (2019) define a Smart world as “an attractive prospect with comprehensive development of ubiquitous computing involving penetrative intelligence into ubiquitous things.” In our perspective, this term corresponds with our vision of Smart Life.

In developing the taxonomy for Smart Life applications, we deliberately excluded 328 sources only focused on Smart artifacts, Smart technologies, and

Smart systems without clear associations with specific application domains. Additionally, the taxonomy omits Smart infrastructure-related applications as we consider them as transversal issues (infrastructure can be found in almost all major Smart applications fields).

This taxonomy will not be a static structure; it will evolve just like taxonomies in other domains. We plan to develop our taxonomy by extracting a classification of the Smart artifacts and link them to the Smart applications and Smart domains identified in this taxonomy. We also plan to carry out a bibliometric study to explore the relationships between the Smart applications. Finally, we also intend to pursue investigations into the variety research challenges in the field of Smart Life and Smart Life Engineering. Our main goal is to discover whether a common methodological basis could be identified in the field of Smart Life and its engineering approaches.

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