



HAL
open science

From Smart Life to Smart Life Engineering: a Systematic Mapping Study and Research Agenda

Elena Kornyshova, Rebecca Deneckere, Eric Gressier-Soudan, John Murray,
Sjaak Brinkkemper

► **To cite this version:**

Elena Kornyshova, Rebecca Deneckere, Eric Gressier-Soudan, John Murray, Sjaak Brinkkemper. From Smart Life to Smart Life Engineering: a Systematic Mapping Study and Research Agenda. 15th International Baltic Conference on Digital Business and Intelligent Systems (DB&IS), Jul 2022, Riga, Latvia. 10.1007/978-3-031-09850-5_13. hal-03663346

HAL Id: hal-03663346

<https://hal.science/hal-03663346>

Submitted on 21 Dec 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

From Smart Life to Smart Life Engineering: a Systematic Mapping Study and Research Agenda

Elena Kornyshova¹, Rebecca Deneckère², Eric Gressier-Soudan¹, John Murray³, Sjaak Brinkkemper⁴

¹ Conservatoire National des Arts et Métiers, France,

² Université Paris 1 Panthéon Sorbonne, France

³ San José State University, California, USA

⁴ Utrecht University, Netherlands

elena.kornyshova@cnam.fr, rebecca.deneckere@univ-paris1.fr,
eric.gressier_soudan@cnam.fr, john.murray@sjsu.edu,
S.Brinkkemper@uu.nl

Abstract. The development of new digital technologies and their omnipresence impact the everyday life of people and intend to contribute to a so-called Smart Life. Numerous Smart Life applications and technologies relate directly to individuals and their life (Smart health, Smart buildings, Smart cities, etc.), but also indirectly through professional applications (Smart manufacturing, Smart grids, Smart farming, etc.). We assert that these applications have common foundations, and several design principles could be established to contextualize the development of Smart Life applications, thus, to introduce the field of Smart Life Engineering. We foresee the domain of Smart Life and Smart Life Engineering as an independent research domain that would contribute to the sharing or reuse of efforts to develop and maintain Smart applications. However, there is no common agreement on the concept of Smart Life and the associated methods and technologies. Thus, this paper provides a systematic view of the existing literature on Smart Life and its decomposition into sub-domains using systematic mapping study and presents a research agenda for Smart Life and Smart Life Engineering.

Keywords: Smart Life, Smart Life Engineering, Smart Technologies, Systematic Mapping Study, Research Agenda.

1 Introduction

The term *Smart* is an old English word that originated in the 13-14th century with the meaning quick, active, and clever in relation to sharp humor or words [1]. Since then, it became a synonym for intelligent, quick, and fashionable [2]. In the early 1970s, the adjective Smart began to be used to mean devices that behaved as if they were guided by intelligence. With the emergence of ubiquitous wireless computing, we can really speak of *smartification* in many domains [3]: all kinds of devices and human activity get equipped with computational and intelligent features: Smart phone, Smart city,

Smart energy, Smart car, and Smart manufacturing.

The rise of Smart applications and technologies in different scientific domains articulates a need for a more encompassing understanding of *Smart* that can function as a fundamental theoretical concept: what does it mean? And also, what does it not mean? The concept of Smart object was already introduced in 1998 by Kallman and Thalmann [4]. Recently all these terms seem to be bundled under the umbrella topic of *Smart Life*. However, there is no precise definition of what Smart Life entails. Many papers exist and contribute to expanding the knowledge about parts of this field, but there is still no clear explanation of what it is called exactly *Smart Life* and, by extension, what can then be called *Smart Life Engineering (SLE)*. Engineering of Smart Life applications is now widespread in many domains. But the extent to which the engineering of Smart Life applications differs from regular information systems remains not investigated.

Numerous works exist to present research agendas in Smart-related fields. For instance, Smart cities future research is given in [5-8], but the whole number of the related research papers is about 40. The same for Smart grids, Smart home, and many other Smart fields.

The main research goal is *to define and characterize Smart Life and Smart Life Engineering and to summarize the existing work on this topic*. Smart Life is a concept emerging from a plethora of studies on Smart cities, Smart devices, Smart energy, and so on. However, there is no real consensus about the scope and contents of this new domain. In [9], we suggested a taxonomy of contemporary Smart applications and analyzed their evolution. In this work, on top of a clear definition of Smart Life, we will identify research topics, methods, and technologies used in this domain to describe and delineate the different elements of SLE. In addition, we define a Smart Life research agenda to identify the key issues remaining in this field.

We present our research method mainly based on a Systematic Mapping Study methodology in section 2, and in sections 3 and 4 we detail and discuss the obtained findings with regards to the Smart Life definition, Smart Life topics, and technologies used in this field. We end the paper with a set of research directions in a Smart Life and Smart Life Engineering research agenda in section 4, and we conclude the paper in section 5 with prospects of our research.

2 Research Method

The lack of a theoretical framing in the domain of Smart Life motivated us to conduct a Systematic Mapping Study (SMS) [10]. SMS relies on well-defined and evaluated review protocols to extract, analyze, and document results. We selected this type of research methodology as it is a useful product to describe the existing research in a particular field of study and allow the identification of knowledge gaps, which will help in the definition of a specific research agenda for this new field of study. We follow the process presented in [10] with a five-step review that includes the definition of research questions, the conducting search for primary studies, the screening of papers, the keywording of abstract, and finally the data extraction and mapping of studies. The review is completed by an evaluation of each step's outcome. Furthermore, we provide an additional characterization framework for the study context.

Step 1: Definition of research questions. The goal of a systematic mapping study is to provide an overview of a particular research area. The need for this review has been outlined in the introduction and we identify the research questions to help in shaping the review protocol.

Our research goal is to systematize the existing work about Smart Life and characterize Smart Life and Smart Life Engineering. To attain the main research goal, we defined three following research questions (RQ):

RQ1. How can Smart Life be defined?

RQ2. What are the different topics in application domains covered by Smart Life?

RQ3. What methods and technologies are used for various Smart Life applications?

Step 2: Conducting a search for primary studies. This step is composed of the selection of the primary studies with the identification of search key terms, guided by the main research question. In order to avoid excluding any studies in this emerging context, we only used the search string TITLE-ABS-KEY(“Smart Life”), thus the search term “Smart Life” applied on title, abstract, and keywords. We extracted initially 121 studies from the years 2011 to 2021 (incl.) from the Scopus API (which includes databases from Elsevier, Springer, ACM, IEEE, etc.). The year 2011 was chosen as the term “smart life” began to appear more often in the literature at that time. Seven papers were identified as secondary sources and were used to describe the existing state of the art on Smart Life.

Steps 3 and 4: Screening of Papers and Keywording of Abstract. Since we used our primary search criteria on title and abstract, this resulted in the selection of some irrelevant studies (primarily in the health domain) which we then deleted from our dataset, using our inclusion/exclusion criteria, which led us to use 71 sources in our SMS¹. The inclusion and exclusion criteria are presented in Table 1.

To complete the answer to RQ2, we conducted another study to obtain the largest set of Smart topics and their evolution. As the number of papers in Scopus with the keyword “Smart” is more than 126 000, we reduced the search to the state-of-the-art and research agenda-related articles to obtain 2410 sources with DOIs. Based on the title and, if needed, on the abstract, we excluded 69 sources not relevant to Smart Life topics papers, obtaining 2341 papers². Table 2 presents the inclusion and exclusion criteria for this additional study.

Step 5: Data extraction and Mapping of studies. In this last step of the SMS study, we analyze the results obtained, answer the research questions, and draw some conclusions about Smart Life (see section 3). Firstly, we analyzed the obtained sources according to years, paper type, and field of science. For RQ1, we checked the papers to discover the existing definitions of Smart Life and summarized the found concepts. For RQ2, we identified Smart topics and classified them. During the additional study, we identified topics for all papers and classified them into macro-topics

¹ The complete list of the papers of this SMS is given in Appendix A, available at <http://cri-dist.univ-paris1.fr/smart-life/Appendix%20A%20-%20SMS%20on%20Smart%20Life.pdf>. All sources from this list have their references starting with “A”.

² The complete list of these papers is available at <http://cri-dist.univ-paris1.fr/smart-life/Appendix%20B%20-%20Smart%20SoA%20and%20Research%20Agenda%20by%20topic.pdf>.

regarding to their nature. For RQ3, we extracted the used technologies and methods in the field of Smart Life.

In order to minimize the impact of the validity threats that could affect our study, we present them with the corresponding mitigation actions, as preconized in [11]:

Descriptive validity: It seeks to ensure that observations are objectively and accurately described. At this end, we unified the concepts and criteria we used in the study, and we structured the information to be collected with a data extraction form to support a uniform recording of data and to objectify the data extraction process.

Table 1. Inclusion/exclusion criteria for the study on Smart Life.

Selection Criteria	Criteria Description
Inclusion criteria	Title/Abstract/keywords include key term “smart life”: Search string TITLE-ABS-KEY(“smart life”). The paper is published after 2011. From the abstract it is clear that a contribution towards Smart Life is made.
Exclusion criteria	The source is not a research paper (blog, presentation, etc.). The source is secondary (literature review only). The source is not in English or French.

Table 2. Inclusion/exclusion criteria for the study on Smart topics.

Selection Criteria	Criteria Description
Inclusion criteria	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	The source is not a research paper (erratum, retracted, etc.). The source is related to an abbreviation SMART, like, 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”.

Theoretical validity: It depends on the ability to get the information that it is intended to capture. We started with a search string and applied it to a library including the most popular digital libraries on computer sciences and software engineering online databases. A set of inclusion and exclusion criteria have been defined. Two researchers studied the papers. They were working independently but with an overlap of studies to identify potential analysis differences. We combined two different search methods: an automatic search and a manual search (backward and forward snowballing), to diminish the risk of not finding all the available evidence. The choice of English sources should be of minimal impact concerning the discard of other languages.

Generalizability: This validity is concerned with the ability to generalize the results to the whole domain. Our set of research questions is general enough to identify and classify the findings on Smart Life, its topics, and technologies.

Interpretive validity: This validity is achieved when the conclusions are reasonable given the data. To this end, at least two researchers validated every conclusion.

Repeatability: The research process must be detailed enough in order to ensure it can be exhaustively repeated. We detailed this protocol sufficiently to allow us to repeat the followed process. The protocol as well as the results of the study are presented in this paper, so other researchers can replicate the process and corroborate the results.

3 Results of the Systematic Mapping Study

In this section, we sum up the results obtained during SMS. The initial study of the relevant sources on Smart Life shows the growing interest in this topic. We can observe the almost continual increase since 2011 and completely regular progression since 2016 of the number of papers on Smart Life (See Figure 1.).

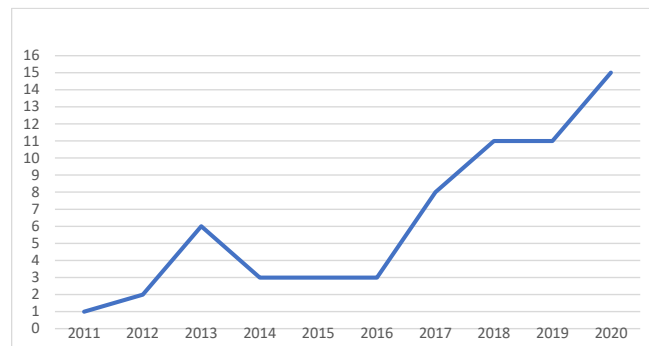


Fig. 1. Growth of the number of papers on Smart Life (without 8 papers for the first half of 2021 for data consistency).

Paper Type. We categorized these papers according to the type of research approaches introduced by Wieringa et al. [12] (See Table 3.). We can see that a third of the papers are validation research papers (35,2%), presenting novel techniques with an experimental setup. Another third represents philosophical papers (32,39%) dealing with new ways of looking at existing things by structuring the field in a way or another. The last third contains all the other types of research, with a good representation of solution proposals a very few evaluation, opinion, or experience papers.

Fields of Science. We characterized the papers with regards to the fields of science publishing on Smart Life. For this purpose, we used the classification FOS (Fields of Science and Technology) of OCDE [13] as the most recognized classification of the scientific fields. When dealing with multi-disciplinary journals or conferences, we picked the field based on the paper content. The results are given in Table 4.

Table 3. Categorization in Paper Contribution Types.

Research approach type	Number of papers	Ratio (%)	References
Validation research	25	35,2%	[A12][A13][A15][A16][A19][A21][A27][A28][A31][A35][A38][A40][A41][A43][A44][A45][A51][A56][A58][A6][A64][A65][A69][A70][A9]
Evaluation research	2	2,81%	[A10][A29]
Solution proposal	16	22,53%	[A1][A11][A17][A25][A26][A3][A4][A49][A54][A57][A60][A62][A63][A66][A68]
Philosophical papers	23	32,39	[A14][A18][A2][A20][A22][A23][A30][A32][A33][A34][A39][A46][A48][A5][A50][A52][A53][A55][A59][A61][A67][A7][A71]
Opinion papers	4	5,63%	[A24][A36][A42][A47]
Experience papers	1	1,4%	[A37]

Table 4. Fields of Science and Technology.

Field of Science and Technology	Number of papers	Percentage	References
Natural sciences	34	47,9%	
Biological sciences	1	1,4%	[A22]
Computer and information science	30	42,3%	[A1][A3][A4][A5][A7][9][A12][A14][A15][A17][A24][A25][A29][A30][A32][A33][A35][A36][A39][A43][A44][A49][A55][A57][A58][A64][A65][A66][A67][A70]
Mathematics	1	1,4%	[A11]
Physical science	2	2,8%	[A48][A6]
Engineering and technology	30	42,3%	
Electrical engineering, Electronic engineering, information engineering	20	28,2%	[A8][A10][A16][A18][A19][A20][A23][A26][A27][A28][A37][A40][A41][A45][A52][A54][A56][A60][A68][A69]
Environmental engineering	3	4,2%	[A2][A51][A59]
Material engineering	5	7,0%	[A13][A21][A31][A34][A42]
Mechanical engineering	2	2,9%	[A46][A61]
Medical and Health sciences	1	1,4%	
Medical biotechnology	1	1,4%	[A50]
Social sciences	6	8,4%	
Economies and business	2	2,8%	[A53][A63]
Media and communication	4	5,6%	[A38][A47][A62][A71]

The most published research works in the area of Smart Life are fields related to ICT (computer and information science and information engineering). However, other fields are also interested in this research topic. During the characterization, we observed that the current Field of Study and Technology categorization does not take several new technologies into account. For instance, sensors appear in this classification only with relation to medical fields, however, sensors are now omnipresent and are used in civil engineering, agricultural sciences, psychology, and so on.

Smart Topics. Several topics were extracted from the first SMS (see Table 5). Some topics appear several times but absolutely none of them stand out of this set with a spectacular proportion of references. We can then conclude that this domain covers many fields of research and is still evolving with new terms appearing regularly.

Table 5. Topics Identified from Smart Life related Literature.

Number of references	Topics
6	Smart home [A22][A41][A43][A44][A57][A8]
5	Smart HCI [A15][A19][A35][A38][A70], Smart city [A17][A20][A55][A59][A67], Smart communication [A1][A11][A50][A64][A7]
4	Smart service [A30][A32][A46][A49], Smart device [A23][A31][A4][A56]
3	Smart localization [A12][A6][A66], Smart application [A14][A39][A62]
2	Smart appliance [A25][A42], Smart environment [A21][A69], Smart health [A36][A60], Smart manufacturing [A10][A53], Smart monitoring [A40][A63], Smart sensor [A13][A51], Smart transport [A48][A52], Smart vehicle [A18][A26], Smart object [A33][A58]
1	Smart assistant [A68], Smart bin [A27], Smart building [A2], Smart carpet [A3], Smart family [A71], Smart farming [A37], Smart life cycle management [A61], Smart luggage [A54], Smart market [A28], Smart mirror [A45], Smart product [A16], Smart project [A47], Smart sound [A65], Smart system [A24], Smart textile [A34], Smart university [A29], Smart web [A5], Smart navigation [A9]

Existing State-of-the-Art Works. To analyze the state-of-the-art of this domain, we first studied the seven secondary research papers. Most of them mention smart life but focus on different sub-topics of this field. In [14], the authors present a systematic literature review on IoT application for energy consumption and discuss future research directions. [15] details a state-of-the-art perspective on Security in Internet-of-Things (IoT). The third work [16] contains a state-of-the-art overview of IoT usage for Smart cities and classification of smart technologies that were applied. [17] presents a thorough catalog of computer technologies from the viewpoint of artificial intelligence. In [18], the concept of machine to machine (M2M) is studied to define the current research on this field, describe its technical features and present the key aspects under which M2M technologies can function. The last paper specifies an integrative study about IoT, an operational view, their benefits, and corresponding problems [19].

Only one retrieved paper [20], entitled “Smart Technologies for Smart Life”, deals with a problem corresponding to our purpose. In this paper, the author describes a state-of-the-art synopsis focused on Smart technologies. She gives several definitions, lists different concepts related to Smart technologies by year, and suggests a classification of Smart technologies in general. From the additional study on Smart topics, we then identified a systematic literature review on Smart systems [21]. In this work, the authors concentrate on the concept of smartness, enumerate several related definitions, and provide a set of primary characteristics of Smart systems.

So summarizing, we may truthfully state that none of the existing works focuses on the definition, systematic review, or future trends in the field of Smart Life.

4 Findings

We detail the findings in the following sub-sections according to the defined RQ.

4.1 Smart Life Definition

In the existing literature, the concept of Smart Life is often linked to the Internet of Things (IoT). IoT has made revolutionary changes in human life and enables the exchanges of information in a wide variety of applications such as Smart buildings, Smart health, Smart transport, and so on, which can be unified into a single entity referred to as Smart Life [15][22]. A step beyond is in [23], where this new entity of IoT is characterized as a new lifestyle. Smart Life connects all IoT microdevices and microsensors under wireless communication grids [24]. This widely spread idea of a connection of all embedded devices around us to the internet has the potential to change our lives and the world, to enable us to live a Smart Life in a Smart world [19]. IoT then becomes an indispensable technology to improve the quality of life for human beings [25], [26] and people want to live a Smart Life [27].

However, Smart Life is not reduced to IoT. The key concept of Smart Life is the data use and processing to improve our living. Each artefact processing data is smart even if it is not connected. In addition, “Being smart” should not be confused with “being digital” as infrastructures and technologies are the means, not the end, enabling a set of services that affect deeply life [28]. IoT objects and devices collect every possible data about a user, but their final goal is to make intelligent use of such data to support this user [29]. These intelligent devices will drive people into Smart Life, becoming the new innovative direction of the internet [30].

In a thorough analysis of the studied literature, we did not find any consistent definition of Smart Life. Even the notion of smart is understood rather differently between sub-fields and even inside fields. For instance, different notions of Smart object could be found in [31][32], but there is no common agreement on the notion of Smart object. In this paper, we try to overcome this drawback by analyzing the development of the notion of Smart Life with regards to its structure and the definition of different smartness degrees to better specify the concept of Smart.

Smart Life Structure. From the structure point of view, we foresee Smart Life using the systemic approach [33]. The core element of Smart Life is a so-called *Smart Artefact*, the term we selected to avoid intermingling with already established terms such as a Smart object or Smart thing. Smart artefacts correspond to any standalone device with a program and a capability to store and process data. Smart artefacts of the same or similar functional usage form a *Smart Application*. Smart applications could be identified at different levels of granularity from detailed and concrete (e.g., a Smart lighting system including several sensors about the home environment and people positions in a home) to more global ones (such as a Smart home application covering different aspects: lighting, heating, windows management, and so on). Smart artefacts could belong to two or more smart applications, like Smart lighting systems could be found in Smart home, Smart factory, or Smart city. Each Smart application is a system of Smart artefacts, which means that it should have at least one emergent property [34]. Emergent properties correspond to features of the whole system and that system elements do not have, like all components of a car should be put together in a certain manner so this car could run. Smart life, in its turn, is composed of various Smart applications, thus Smart Life is a system of systems. In its simplest form is Smart Life a combination of at least two Smart applications, that requires coordination based on the input and analysis of emergent properties. This system-oriented vision of Smart Life is illustrated in Figure 2.

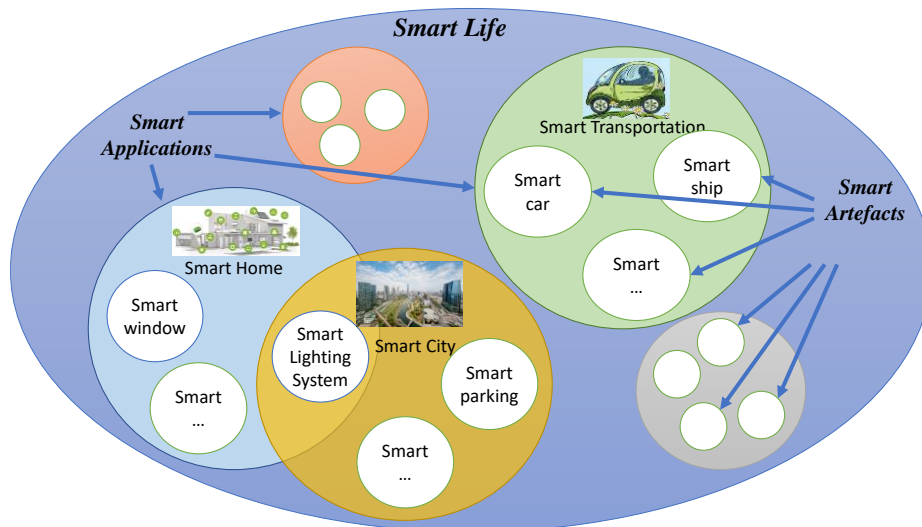


Fig. 2. System-Oriented Vision of Smart Life.

Smartness Degree. To understand better the nature of Smart Life, we go in deep into the definition of the term “Smart”. We define the degree of smartness depending on data integration and processing type. The first axis reflects different levels of consideration of data coming from the environment and users. Data complexity varies from the embedded sensors data (immediate environment) to data from the distant environment in addition to the sensors data, and, finally, to data on users’ well-being and

state. The second axis shows how data are processed from non-AI processors to AI-based processors (expressing the processor complexity). We distinguish three degrees of smartness: *smart*, *intelligent*, and *sentient*.

- **Degree 1 of Smartness – Smart:** is a capability to process data and to adapt its functioning.
- **Degree 2 of Smartness – Intelligent:** is a capability to process data and to adapt its functioning with the usage of AI (smart + AI).
- **Degree 3 of Smartness – Sentient:** is a capability to process data coming from users about his/her feelings, emotions, physical state, and so on. The notion of sentience came from the field of animals' rights protection and is quite new to the field of ICT. It is already used to qualify the evolution of artificial intelligence of machines [35] or to introduce requirements for human-aware information systems and technologies [36].

To illustrate this proposal, we position the smartness degrees according to the two axes (data complexity and processing complexity) and give some examples (Fig. 3).

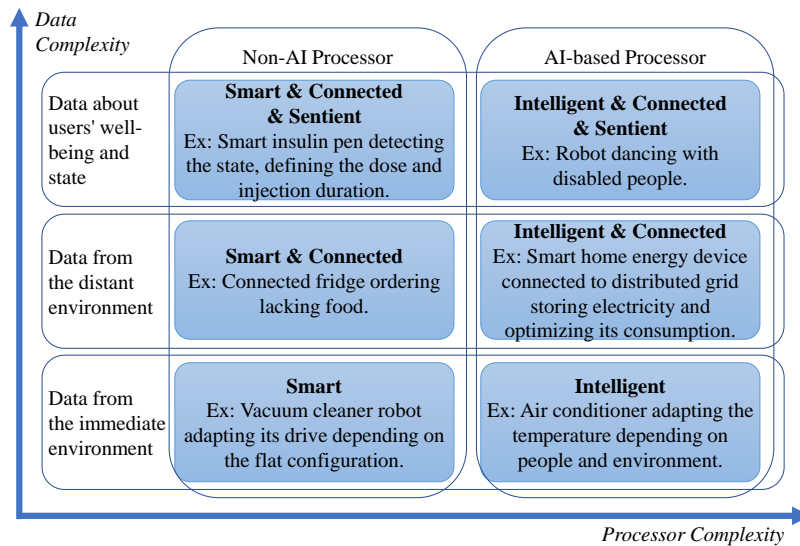


Fig. 3. Smartness Degrees according to Data and Processor Complexity.

We can summarize the main definitions of our proposal as follows:

- **Smart Artefact** is any autonomous and stand-alone artefact provided with a data processor when data is obtained, stored, processed, and used to trigger actions of the artefact in the environment. A Smart artefact could be connected or not. For example, a Smart artefact can be a Smart watch, Smart window, Smart toy, Smart antenna, and so on.
- **Smart Application** is a system of connected Smart artefacts, and possibly other Smart applications. Thus, it corresponds to a set of artefacts with a common goal.

For instance, a Smart city application can be composed of a Smart parking application, a Smart energy application, and so on. A Smart home can be composed of a Smart TV, a Smart fridge, a Smart assistant, and so on. A Smart application should contain at least two Smart artefacts.

- **Smart Life** is defined as the domain that embraces all Smart applications and Smart artefacts for the purpose of an enriched experience from the personal, societal, environmental and enterprise perspectives [9]. Smart Life can be seen as the societal domain that unifies all in initiatives to apply Smart artefacts and applications in any setting. We also use the term of Smart Life as a comprehensive scientific research domain that includes all research areas with studies into Smart technology, artefacts, and applications.
- **Smart Life Engineering** as the use of scientific principles to design, build, implement and evolve Smart Life applications. SLE can therefore be seen as overlapping with the domain of Information Systems Engineering, but it also has a broad set of links with research domains in Wireless Network Technology, Artificial Intelligence, Urban Geography, Logistics, Medical Technology, etc.

Note, that in these definitions, the perspective of the distributed ownership or multi-stakeholder arrangements does not appear. Smart Life usually deals with a variety of technologies, a variety of development approaches, a multitude of modeling and coding. Furthermore, the individual or human perspectives is not included. We relate these viewpoints in chapter 5 when describing the research agenda.

4.2 Smart Life Topics

A set of topics was considered on the 71 SMS papers. The “smart” term is used for a lot of many different things, but our study was not including enough papers to be consistent on this specific question. As a result, we made another study to identify which are exactly the “smart” topics, not restraining ourselves only to the Smart Life topics but more generally to the “smart” term. Based on the titles analyses, we identified 775 different formulations of Smart topics quite detailed like Smart grid, Smart energy, Smart energy system, Smart energy management system, etc. To deal with this huge number of topics, we grouped them by macro-topics (i.e., we grouped the above-mentioned energy-related topics with several others within a macro-topic “Smart grid, Smart microgrid, Smart energy, Smart meter”. Another example is “Smart transportation, Smart road, Smart bridge, Smart mobility, Smart vehicle” including Smart airport, Smart train, Smart ship, etc. The evolution of Smart macro-topics is shown in Table 6.

As a reminder, this additional study contains papers only on state-of-the-arts and research agendas, thus, the current quantity and growth of these research themes are impressive. As we can see, the most popular topics are Smart energy-, Smart city-, and Smart home-related. This study allowed us to identify very specific emerging Smart artefacts, like Smart toys, Smart socks, Smart guns, but also Smart applications like Smart earth, Smart space exploration, Smart fishery, Smart pest management, and so on.

The situation presented in Table 6 drastically confirms a need for a systematization of knowledge in order to make life smarter.

Table 6. Large Study on Smart Topics.

Macro-topic	1986	1990	1996	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total				
smart application																		1					1	1		1	2		6				
smart charging																				1			1			3	1			6			
smart city																			1	3	2	5	9	19	33	42	93	77	85	5	375		
smart clothing, smart shoes																1		1					1			3	1	7	1	1	16		
smart contract																								2	4	8	13	22	2	51			
smart device, smart object, smart well								1		1			1	2	1	3	1	2	1	1	5	6	6	5	9	14	26	17	19	16	137		
smart drug, smart drug delivery																			2				1	1	1		1	2	5	14			
smart environment, smart water management								1							1	1				2	2	2	2	4	3	6	10	14	16	64			
smart factory, smart manufacturing and other business-related smart topics																															166		
smart farming, smart agriculture	1	1							1																					2	88		
smart grid, smart microgrid, smart energy, smart meter																																656	
smart healthcare																																106	
smart home, smart building																																230	
smart learning, smart education																																27	
smart lighting system																																5	
smart material, smart structure, smart surface, smart textile																																170	
smart methodology																																2	
smart phone																																22	
smart sensor																																22	
smart service																																6	
smart society, smart world, smart growth																																	36
smart space exploration																																1	
smart sport																																5	
smart survey																																7	
smart system	1																															14	
smart technology																																19	
smart tourism																																	14
smart transportation, smart road, smart bridge, smart mobility, smart vehicle																																	48
smart university, smart campus																																	17
smart waste management																																	11
Total	2	1	2	2	2	4	2	5	1	2	3	6	11	11	17	18	25	63	71	72	94	160	172	266	401	438	473	17	2341				

4.3 Smart Life Technologies

As IoT is the core of Smart Life, a lot of diverse technologies are used in this field. Smart objects of course (devices, sensors, and so on), but also some single-board computers. Networks are envisioned in different ways to improve the data communication with GPS, 5G, or even NFC protocol. Sometimes the data collection is handled on social media instead of Smart objects and some specific software can help in the process. Table 7 shows the repartition of these technologies in our study papers.

Different kinds of deep learning or machine learning techniques are used, such as regression algorithms [A17][A60], standardization methods [A48], neural networks [A35], clustering [A57], Hidden Markov models [A69], recommendation systems [A65] or decision support tools [A58] to cite the widely known ones.

Table 7. Smart Technologies.

Type	References
Smart objects and sensors	Smart phones [A35][A21][A65][A10][A68][A12]; Devices [A62][A56][A49][A26]; Specific sensors [A3][A39][A6][A51][A54][A27][A41]; Bluetooth beacons [A66][A12]; Cameras and robot sensors [A9][A15]; RFID [A38]
Single-board computers (arduino and raspberry)	[A21][A45][A41][A9]
Networks and protocols	5G [A50]; Wireless sensor network [A8]; GPS [A66][A62][A12]; NFC [A66][A12][A8]
Social media / Social networks	Social media [A60][A8]; Context [A65][A8]
Software	Applications [A14][A62][A68][A43]; Blockchain [A7]

5 Smart Life and Smart Life Engineering Research Agenda

In the research agenda, we define four perspectives for Smart Life and Smart Life Engineering research: technological, methodological, organizational, and societal (See Fig. 4). Different research agendas in particular Smart technologies or applications can be found in other works, for instance [5][6] for Smart cities, e.g.

Technological challenges. Smart applications generate all sorts of data that is of interest to other applications (it does not make sense to build a central data archive). The necessity to manage a huge amount of data implies multiple issues: How can secure and privacy-aware access to data be granted and obtained for various applications? How can high-level information wishes be expressed in distributed queries over a variety of applications? An appropriate distributed infrastructure should be defined accordingly.

In addition, Smart applications require devices, resources, and energy, which are scarce and need careful implementation and a recycling perspective. Thus, other questions should be highlighted: Can we identify Smart Life methods for Green IT and ensure sustainable development?

Thus, we define the following SLE technological challenges: developing shared but secure and privacy-aware access to data, developing efficient distributed infrastructure, considering Green IT, considering sustainability, and so on.

Methodological challenges. Smart Life is already applied in a lot of projects, sometimes successfully, sometimes not. The Information Systems Engineering field has brought about many strong conceptual modeling techniques (class diagrams, process models, object-orientation, state-transaction graphs). What conceptual modeling techniques provide the most effective modeling of Smart applications? Situational Method Engineering [37] focuses on formalizing the use of methods for systems construction using organization-, project-specific and context-aware methodological approaches. Would these approaches be suitable for Smart Life applications? Would it be possible to use these methods to provide a real-time adaptation of Smart Life applications?

Next to scientific reporting, a huge variety of application projects have been reported in the popular press and industrial magazines. What are the key factors of success? How can we objectively obtain the essential contributions of contextual factors in different cases? Early estimations of explicit and implicit values of Smart applications projects are often vague and debatable. How different value-modeling techniques can assist in Smart Life projects quantification?

In this manner, a first list of methodological challenges for SLE comprises: defining common methods for SLE, defining quality criteria and value models, providing context awareness of SLE, providing real time adaptation, etc.

Organizational challenges. When multiple Smart applications build up a large-scale Smart Life experience, there is a variety of stakeholder groups (e.g., citizens, entrepreneurs, city officials) that have different interests in the data, products, and services sharing. How can multi-stakeholder policies be organized and communicated? How can governmental and democratic representations assist in the elicitation of views and strategies for the future?

Smart artefacts and applications in real-life settings are usually owned by different stakeholders, who have their own budgets, plans, and Information and Communication Technologies infrastructures. Bringing these parties together in various Smart Life projects requires careful communication and planning across organizations. How agile engineering approaches can engage distributed owners in a SLE project? How investments in facilities and resources can be shared in complex beneficiary dependencies, where long-term costs and benefits are not balanced among stakeholders?

We then define the following preliminary set of organizational challenges for SLE: defining policies for smart applications governance, defining policies for distributed ownership engagement, defining policies for data, products, and services sharing, etc.

Societal challenges. The propagation of Smart Life applications raises questions related to ethics and well-being issues. The issue of system accessibility is becoming critical. While organizations are promoting guidelines for making some websites more usable by people with disabilities, almost no attention is being paid to other types of smart prod-

ucts and embedded systems. How can we build Smart systems that will reason coherently over the type of ethical dilemmas that we humans have to deal with?

Engineering of Smart Life artefacts and applications should not only provide means to attain their main functional purposes, but also contribute to users' well-being. Many current technologies cause addiction or depression, for instance, social media induce the FOMO (Fear Of Missing Out) syndrome (discussed in [38]) which could increase the risk of becoming depressive. How the well-being of users can be considered during all engineering phases starting from requirements elicitation?

The most important SLE societal challenges include ensuring machine ethics, developing Smart Life applications consciousness, providing sentient systems, providing system accessibility, and so on.



Fig. 4. Research Agenda for Smart Life and Smart Life Engineering.

6 Conclusion and Future Works

In this paper, we studied the existing literature on Smart Life using the Systematic Mapping Study methodology and we investigated this field in order to systematize the existing knowledge. We discovered a very large, and continuously growing, set of Smart topics ranging from very established (like Smart energy, Smart material, Smart city, and so on) to emerging ones (like Smart airport, Smart toy, or Smart gun) and from very practical (like Smart waste bin system and Smart self-power generating streetlight) to more conceptual (like Smart earth and Smart world). We believe that a huge scientific effort should be made to optimize these fields to make life smarter. For us, this effort should be done through the definition of common methods, techniques, and tools, thus by the development of a new field, Smart Life Engineering. Thus, we elaborated a research agenda towards this field.

In our future research, we foresee focusing on methodological aspects of SLE. Our

first goal will be to identify different opportunities for optimizing the research effort between different fields and sub-fields of Smart Life.

References

1. Online Etymology Dictionary, www.etymonline.com (2021).
2. Oxford Dictionary, Oxford University Press, www.oxfordlearnersdictionaries.com (2021).
3. Schuh, G., Zeller, V., Hicking, J., Bernardy, A.: Introducing a methodology for smartification of products in manufacturing industry. *Procedia CIRP*, 81, 228-233 (2019).
4. Kallman, M., Thalmann D.: Modeling Objects for Interaction Tasks. *Proc. Eurographics Workshop on Animation and Simulation*. Springer. pp. 73–86 (1998).
5. Gopinath B., Kaliamoorthy M., Ragupathy U.S., Sudha R., Nandini D.U., Maheswar R.: State-of-the-Art and Emerging Trends in Internet of Things for Smart Cities. In: *Challenges and Solutions for Sustainable Smart City Development*, Cham (2021).
6. Echebarria, C., Barrutia, J. M.; Aguado-Moralejo, I.: The Smart City journey: a systematic review and future research agenda, *Innovation: The European Journal of Social Science Research*, 34:2, 159-201 (2021).
7. Bohloul, S.M.: Smart cities: A survey on new developments, trends, and opportunities, et al., *Journal of Industrial Integration and Management*, Vol. 05, No. 03, pp. 311-326 (2020)
8. Ali, H., Qazi, R., Shah, M. A.: Smart Cities: Methods, Encounters & Hunt for Future - Survey, 25th International Conference on Automation and Computing, pp. 1-6 (2019).
9. Kornysheva, E., Deneckere, R., Sadouki, K., Gressier-Soudan, E. and Brinkkemper, S. Smart Life: Review of the Contemporary Smart Applications. In 16th International Conference on Research Challenges in Information Science, Barcelona, Spain (2022).
10. Petersen, K., Feldt, R., Mujtaba, S., and Mattsson, M.: Systematic mapping studies in software engineering. In 12th Intl Conference on Evaluation and Assessment in Software Engineering, volume 17 (2008).
11. Pinciroli F., Justo J., Zeligueta L., Palma M.: Systematic Mapping Protocol - Coverage of Aspect-Oriented Methodologies for the Early Phases of the Software Development Life Cycle (2018).
12. Wieringa, R., Maiden, N. A. M., Mead, N. R. & Rolland, C.: Requirements engineering paper classification and evaluation criteria: a proposal and a discussion, *Requir. Eng.* 11(1), 102–107 (2006).
13. Revised field of science and technology (FOS) classification in the Frascati manual, OCDE (2007).
14. Wang, D., Zhong, D., Sourì, A.: Energy management solutions in the Internet of Things applications: Technical analysis and new research directions. *Cognitive Systems Research*. 67, 33–49 (2021).
15. Harbi, Y., Aliouat, Z., Harous, S., Bentaleb, A., Refoufi, A.: A Review of Security in Internet of Things. *Wireless Personal Communications*. 108, 325–344 (2019).
16. Tai-hoon Kim, T., Ramos, C., Mohammed, S.: Smart City and IoT. *Future Generation Computer Systems*. 76, 159–162 (2017).
17. Yamane, S.: Deductively verifying embedded software in the era of artificial intelligence = machine learning + software science. 2017 IEEE 6th Global Conference on Consumer Electronics, GCCE 2017 (2017).
18. Severi, S., Sottile, F., Abreu, G., Pastrone, C., Spirito, M., Berens, F.: M2M technologies: Enablers for a pervasive internet of things. *EuCNC 2014 - European Conference on Networks and Communications* (2014).

19. Baruah, P.D., Dhir, S., Hooda, M.: Impact of IOT in Current Era. Proceedings of the International Conference on Machine Learning, Big Data, Cloud and Parallel Computing: Trends, Perspectives and Prospects, COMITCon 2019. 334–339 (2019)
20. Mizintseva, M.F.: Smart Technologies for Smart Life. Lecture Notes in Networks and Systems. 155, 653–664 (2021).
21. Romero, M., Guédria, W., Panetto, H., Barafort, B.: Towards a Characterisation of Smart Systems: A Systematic Literature Review, In Computers in Industry, Vol 120 (2020).
22. Benhaddi, M.: Web of goals: A proposal for a new highly smart web. Proceedings of the 19th International Conference on Enterprise Information Systems. 2, 687–694 (2017).
23. Chen, Y.S., Chou, J.C.L., Chen, W.R.: Long-term strategic development application by a two-stage expert-based AHP model for the internet plus era: A leading TFT-LCD manufacturer case. Journal of Applied Science and Engineering. 21, 361–374 (2018).
24. Lee, S.H., Lee, J., Jung, J., Cho, A.R., Jeong, J.R., Dang Van, C., Nah, J., Lee, M.H.: Enhanced Electrochemical Performance of Micro-Supercapacitors Via Laser-Scribed Cobalt/Reduced Graphene Oxide Hybrids. ACS Applied Materials and Interfaces. 13 (2021).
25. Cho, Y., Lee, S., Hong, J., Pak, S., Hou, B., Lee, Y.W., Jang, J.E., Im, H., Sohn, J.I., Cha, S., Kim, J.M.: Sustainable hybrid energy harvester based on air stable quantum dot solar cells and triboelectric nanogenerator. Journal of Materials Chemistry A. 6 (2018).
26. Ho, Y., Sato-Shimokawara, E., Wada, K., Yamaguchi, T., Tagawa, N.: Developing a life rhythm related human support system. IEEE International Symposium on Industrial Electronics. 894–899 (2015).
27. Sharma, K., Tayal, S.: Indian smart city ranking model using taxicab distance-based approach. Energy Systems. (2019).
28. Coccoli, M., Guercio, A., Maresca, P., Stanganelli, L.: Smarter universities: a vision for the fast changing digital era. J. Vis. Lang. Comput. 25, 1003–1011. Elsevier (2014).
29. Yoon, I., Ng, G., Dong, X., Duan, H., Aggarwal, A., Shah, R., Ku, G.: SuperCaly: Smart life assistance by integrating a calendar app with location tracking, media organization and social connection. 2017 IEEE 7th Annual Computing and Communication Workshop and Conference, CCWC 2017. (2017).
30. Fu, J.: Intelligent hardware somatosensory design. Proceedings - 2016 6th International Conference on Instrumentation and Measurement, Computer, Communication and Control, IMCCC 2016. 331–334 (2016).
31. González García, C., Meana Llorián, D., Pelayo García-Bustelo, B.C., Cueva Lovelle, J.V.: A review about Smart Objects, Sensors, and Actuators, International Journal of Interactive Multimedia and Artificial Intelligence, Vol. 4, N°3 (2017).
32. Liu, X., Baiocchi, O.: A comparison of the definitions for smart sensors, smart objects and Things in IoT, In: IEEE 7th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), pp. 1-4 (2016).
33. Thagard, P.: Computational philosophy of science. MIT press (1993).
34. Nikolaev, M. Y., Fortin, C.: Systems thinking ontology of emergent properties for complex engineering systems, In: Journal of Physics: Conference Series, 1687 012005 (2020).
35. Husain, A.: The Sentient Machine: The Coming Age of Artificial Intelligence, Scribner, USA (2017).
36. Kornysheva, E., Gressier-Soudan, E.: Introducing Sentient Requirements for Information Systems and Digital Technologies. In EMCIS 2021, Dubai, United Arab Emirates (2021)
37. Henderson-Sellers B., Ralyté J., Ågerfalk P.J., Rossi M.: Situational Method Engineering, Springer (2014).
38. Kreps, D., Rowe, F. and Muirhead, J. ‘Understanding Digital Events: Process Philosophy and Causal Autonomy’, in HICSS 2020, Maui, Hawaii, USA, pp. 1–10 (2020).