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Health–Related ICT Solutions of Smart Environments for Elderly–Systematic Review

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ABSTRACT By improving the quality of life and extending the length of life, Western society is becoming an increasingly ageing population with a higher proportion of seniors. From another point of view, there is a critical shortage of care staff, both in hospitals and for in-home care. Thanks to new technology trends such as Smart Homes and Smart Furniture, there is an opportunity for increased support for seniors by utilizing new technologies. This paper presents the current trends and possibilities in applying smart information and communications technology (ICT) solutions for in-home care concerning diseases in old age. The paper consists of a systematic review according to the PRISMA methodology of the available literature in Web of Science, IEEE Xplore, PubMed, Springer, and the Espacenet patent database. Publications report the usage of some types of artificial intelligence and their implementation and non-intrusive sensing technologies. The patents review identified solutions with a focus on monitoring the state of older adults and mobility improvement. Existing ICT smart solutions must address the following issues: (1) ease-of-use; (2) invisibility and disuse that isolate older adults; (3) privacy and security; (4) affordability of technology in terms of cost; and (5) supporting elderly individuals to stay in their homes or move in different environments independently. There is a significant gap between a large number of scientific publications and commercial solutions. The existing products reflect the specifics of the diseases in a rather wider context instead of the fulfilment of exact needs. It is often stated that such devices can be used across diseases, but the direct connection and benefits for the disease is still rather weak. The challenge remains to tap the existing potential of a large number of innovative ideas on the market and improve the quality of life.

INDEX TERMS Respiratory diseases, senior citizens, technology, smart, air quality sensors.

I. INTRODUCTION

The demographic changes in developed countries are specific to the ageing population, and higher age is associated with many chronic diseases. Currently, we are witnessing a trend of creating superior technology that can be applied to many domains, including health and social care. Tools such as sensors, digital devices, and applications are already emerging as aids that seniors can use, often in their home settings, and enable augmented communication and better monitoring for caregivers.

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Such smart solutions need to be based on the Smart Homes idea [1], but they need not be so complex that they are obtrusive for users [2]–[8]. Thus, they need to substitute, or even improve, existing communication between the user (older person) and responsible person (e.g., descendant). There is already one existing platform, known as Smart Furniture [9]–[12], that covers all of the mentioned issues. It brings some standardization but at the same time provides enough freedom to implement new ideas that may not be too complex, as Smart Homes are in most cases but will provide the right solution. Last but not least, the final (market) price of the solution must be low enough to be an alternative or add-on to existing models of communication between older people

and descendants [13]. Integrated information and communication technology (ICT) solutions that would improve healthy and safe ageing of elderly people play an important role in this area [14]–[16]. The potential of these solutions is also seen in the possible reduction of health and social expenses.

At the same time, it is an area supported by a great deal of finance in developed countries aiming to not just improve the quality of life (QoL) [17] but also ensure the sustainability of care for which there is a continually increasing financial burden [18]. Among other things, this is strongly related to demographic development and the ageing of the population [19].

The trends in demographic crisis determine the need to apply ICT solutions for home care concerning old-age-related diseases. Ageing of the population, the onset of chronic diseases, and the development of ICT solutions are interconnected processes requiring systematic approach based on experience both from academia and industry. The use of ICT solutions can improve the QoL of older adults by supporting independent living at home while reducing health and social expenses. Therein lies the motivation for this research, i.e., to provide current trends on smart homes and ICT solutions and answer these research questions: What are the described ICT solutions for the most frequent diseases? Are the current state of knowledge and deployment of technology in practice consistent?

For this purpose, a literature review and patent analysis was performed.

The objective of the paper is to analyse and present the current trends and possibilities for applying smart information and communications technology (ICT) solutions for social care concerning diseases in old age. The research papers cover ICT solutions related to the World Health Organization (WHO)'s top 10 chronic diseases that are behind the most deaths globally. The patent analysis includes health-related ICT solutions with a granted patent application. This combined analysis provides a comprehensive understanding of health-related ICT solutions of smart homes for the elderly population, from both an academic and an industrial perspective.

The paper covers the research gap from two perspectives. From an academic perspective, it summarizes the health-related ICT solutions of smart environments for the elderly population with the potential to expand innovation development. From an industrial perspective, it provides a patent analysis related to the subject matter in order to promote the development of practical applications. Thus, this systematic review of health-related ICT solutions may be useful for both the academic and industrial communities as well as other stakeholders interested in this contemporary and attractive field in order to recognize the research gaps and recommend new research directions.

This paper is structured as follows. After the introduction in the first section, section 2 covers the theoretical background for this research. The methodology is outlined in section 3 while section 4 and 5 provide the results analysis and discussion of the reviewed literature and patents along with research limitations and implications. At the end, the sixth section provides a conclusion to the paper and provides open research areas for the future activities.

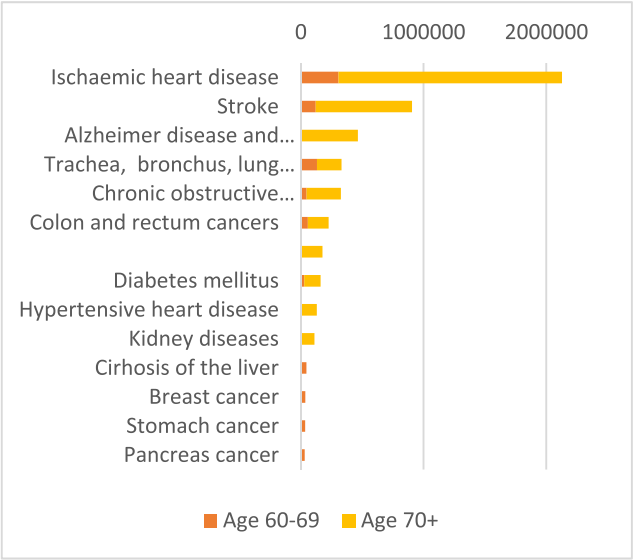

FIGURE 1. Top 14 most frequent diseases by WHO causing the most deaths in European region in 2016 in age group 60+ (merged by groups 60-69 and 70+) (Source: http://www.who.int/gho/mortality_burden_disease/causes_death/top_10/en/).

II. THEORETICAL BACKGROUND

A. OLD-AGE-RELATED DISEASES

The human life span has continued to increase due to many reasons [20]–[24]; meanwhile, ICTs are developing at a fast pace and affect each aspect of human life. Although often perceived as an obstacle to participation by older adults, ICTs may help them maintain independence and improve their quality of life. The most frequent diseases causing the most deaths in the European region in 2016 in the 60+ age group according to WHO are shown in Figure (Fig. 1).

Many deaths worldwide can be attributed to stroke and ischaemic heart problems. The two illnesses are the leading causes of death around the world during the last 1.5 decades. In 2016, the two collectively accounted for 15.2 million deaths globally while chronic obstructive pulmonary disease resulted in the loss of 3 million lives. Lung cancer led to another 1.7 million deaths. Over 1.6 million lost their lives to diabetes during the same period, a number that jumped up from 1 million in the year 2000. During the 2000-2016 period, dementia-related deaths increased by 50%. It became the fifth most prominent cause of deaths around the world, jumping from the 14th position in the year 2000. In terms of communicable illnesses, lower respiratory infections led to three million deaths during 2016, causing the most deaths globally. A decrease of approximately one million deaths was observed during the same period for diarrhoeal issues. However, this disease still caused the deaths of 1.4 million people. Similar trends were also observed for tuberculosis, with deaths falling during the given period; however, its status

as a deadly killer remained unchanged as it is still listed among the top 10 diseases killing people around the world, registering 1.3 million deaths globally. While it used to be a top killer, HIV/AIDS is no longer as lethal. In 2000, the disease killed 1.5 million people, a number that has fallen to one million since.

B. HEALTH-RELATED NEEDS OF OLDER ADULTS

According to the previous subsection, ageing induces age-specific chronic diseases (e.g., cardiovascular diseases, Alzheimer's disease, diabetes mellitus, etc.) which increase the demand for support and care in everyday life. Independent living of older adults under complex disease patterns implies being able to perform different activities regardless of age-specific limitations. As the interpretation of independent living depends on individual's health conditions and (un)affected skills, the main issue of how to support it refers to age-specific limitations. This issue demands a holistic concept focusing on the QoL of older adults [25]. Good health not only improves the QoL of older adults and their family members but also facilitates social and economic development by increasing the human resources accessible within a social community[26]–[29] [27]-[30]. Older adults can make an important and valuable contribution to the community if they follow steps for healthy ageing accounting for many different life aspects as described in [30]–[34], even with the support of health-related ICT solutions.

In this regard, certain ICT solutions may support independent living of older adults within their home even while facing some health obstacles. Even so, the needs of older adult have not been adequately assessed. To understand these needs, it is necessary to explore the acceptance of health-related ICT solutions of older adults.

Health is a basic need of all people, and especially seniors. Health is closely connected to physical activities, which can be planned, recorded and associated with health factors such as blood pressure, weight, etc. In this sense, physical activities can be considered as a type of prevention and component of healthcare at home. In addition to prevention, healthcare includes early detection of age-related diseases (e.g., heart diseases, diabetes, cancer, dementia, etc.). Moreover, there is a need to overcome the physical health obstacles related to old age (e.g., fall-related injuries, mobility impairments, etc.).

However, older adults do not easily adapt to health-related ICT solutions for home care. Moreover, it is not favourable for their well-being to be placed into an unknown living environment, as they may only feel comfortable when surrounded by familiar places, people and things. Therefore, it is important to recognize the ICT solutions that may help to maintain independent living of older adults within their homes despite facing some health obstacles.

C. BEST PRACTICES FOR HEALTH-RELATED ICT SOLUTIONS

Many health-related ICT solutions are proposed with the purpose of prolonging and providing aid for the independent and active living of seniors in their homes. In line with this purpose, these ICT solutions are intended to satisfy the needs of older adults and caregivers and improve well-being and QoL [35].

Different technologies are used to build ICT solutions with user-friendly configuration and management that can be integrated with smart environments at home, at work, in a social community, etc. These technologies include various functions, which can be controlled by sensors and devices, communication and connectivity, and cloud and analytics and integrated with living environments to support individual needs and independence. They provide older people with control over the time and the place for monitoring their health conditions. Furthermore, they decrease the stress on hospitals and other care institutions while making a significant contribution towards managing several health conditions.

In this regard, ICT solutions of smart homes for the elderly population may be categorized in relation to the context of use: (1) resident activity monitoring [36]–[46] and (2) resident health monitoring and/or managing [38], [44], [47]–[57]. They give older adults the opportunity to use wearables and/or environmental sensors and devices which are intended to monitor and/or manage various health conditions, i.e., ischaemic heart disease [47], stroke[39], [49], [50], [58], Alzheimer's disease and other dementia [4], [34], [36], [37], [41]–[46], [48], [59], chronic obstructive pulmonary disease [34], [52], [53], [60] diabetes mellitus [38], [55]–[57], and physical disabilities [51]. With this approach they can improve the coordination among caregivers, emergency response teams, and intervention effectiveness, which contributes to cost savings and better QoL for older people living with chronical conditions.

The summary above shows that existing ICT solutions have a twofold purpose, i.e., (1) prolonging and supporting the independent living of older people [37]–[40], [44], [45], [47], [49]–[51], [55], [57], [58], [60] and (2) providing help and simplifying activities for caregivers [38], [41]–[44], [46], [48], [52], [53], [56]. The ultimate goal is to build a smart ecosystem based on technological infrastructure including the following components: (1) sensors and devices; (2) connectivity and communications; (3) services and application; (4) security and privacy; and (5) data management and analytics [61]. Although each technological component is important for optimal operation of the future smart ecosystem, sensors and devices are key integrating technologies connected with smart living environments that assist people in activity and health monitoring and in managing well-being and healthcare. In this regard, wearable technologies are becoming an important part of everyday life as they are associated with daily life activities. Although wearable sensors represent the most suitable avenues for both deployment and acceptance of technology in larger scale setups, the current main issue is the unwillingness to adopt technology for privacy and security concerns [62]. Another issue may be the exhaustion of using a wearable. There is demand for a decent balance in terms of accessing and/or sharing such data versus privacy and

security underpinnings. Additionally, there is an intention to personalize them and make them more pervasive and multi-functional [63]–[66].

D. IMPORTANCE OF HEALTH-RELATED ICT SOLUTIONS ANALYSIS

Changes in population structure, chronic disease frequency, personalized care demands, and financial pressure require a new, integrated approach to healthcare that has the potential to enhance the quality, efficiency, and security of healthcare services in terms of aiding one with their daily chores, activity and health monitoring, accessing medical and emergency systems, etc. Building a smart home plays an important role in such an integrated approach as many older people are adopting ICT solutions more than ever in order to age in the most independent manner achievable [34], [63], [67], [68].

These ICT solutions should be understood through some formalized analysis. This paper seeks to analyse health-related ICT solutions occurring in the smart homes for the elderly population within scientific parameters. There are three possible options for doing this, i.e., (1) analysing the marketplace, (2) examining the various ICT solutions through a literature review, or (3) evaluating the patenting activities [69]. A marketplace analysis would soon be outdated as many health-related ICT solutions have passed through research and development. A literature review related to health-related ICT solutions would be skewed towards the academic perspective rather than the industrial and practical perspective [70]. The most cost-effective, data-driven predictor of the marketplace of health-related ICT solutions can be reached by patent analytics [71].

To address these shortcomings, our analysis combines the literature review and patent analytics, similar to [72]. The literature review on health-related ICT solutions of smart homes for the elderly population is based on exploring the frontiers of a subject. In contrast, the patent analysis is closely connected to the industrial application of ICT solutions, thereby promoting the practical development of smart environment for the elderly population. This choice fills the knowledge gap of academia and industries in the subjects of smart environments or the elderly population, similar to [73]. We expect to gain a reproducible, measurable, and unbiased analysis of health-related ICT solutions of smart environments for the elderly population.

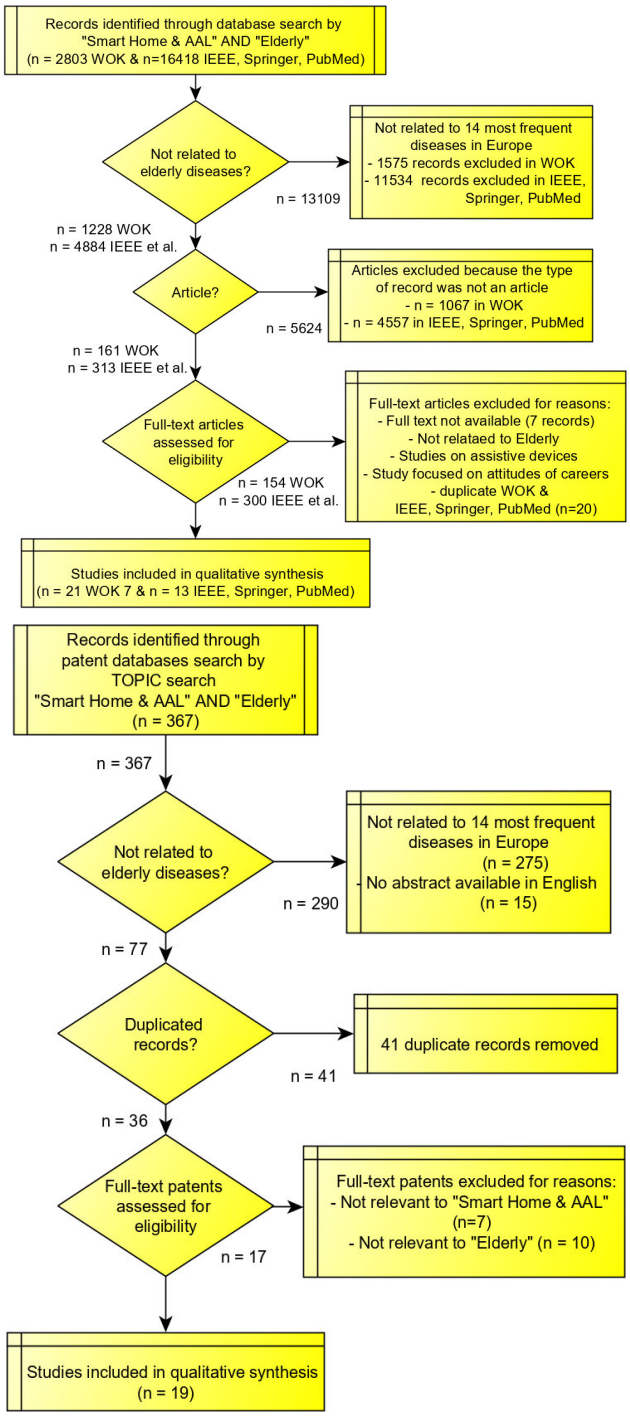

FIGURE 2. Publication (upper) and patent (lower) search process.

III. METHODS

A. SEARCH STRATEGY

Our search of scientific and research sources focused on scientific sources as well as on intellectual property (IP) patents.

The scoping review was conducted for research papers based on PRISMA guidelines [25]. The literature search was undertaken between 1 September 2019 and 13 February 2020 to find peer-reviewed, published work alongside conference papers produced in English. The search considered articles indexed in Web of Science, IEEE Xplore, Springer and PubMed that were published between 1990 and 2018. The keywords included ''Smart Home & AAL area'' in connection with ''Elderly''. The keywords were added to journal and database searches. The references of the retrieved articles were examined for appropriate articles that the original search may have overlooked; thus, several other results were added.

Additionally, we used a semi-automated search framework [74]. The engine automatically scans papers published between 1990 and 2018. The keywords included

in the automated search were ''Working after a Stroke'', ''Smart environments'', ''Intelligent environments'', ''Ambient Assisted Living'', ''Enhanced Living Environment'' and ''Smart homes''. After that, the articles that were returned by the search engines of IEEE Xplore, Springer and PubMed were analysed by the framework [74] using additional properties reflecting the diseases listed in the figure (Fig. 1). The results selected by the framework were then manually screened, and the relevant articles were selected for a more thorough manual review.

Patent searching was performed in the Espacenet, PatentInspiration and Google Patent databases with the same time range as the article search, from 1.1.1990, until December 2018 for the application date. The search strategy focused on patents concerning smart home with a connection to the elderly population. Because of the importance of diseases in the elderly population, we search for a connection to the most frequent diseases in the elderly population using 14 specific different keywords reflecting the diseases listed in the figure (Fig. 1).

B. ARTICLE AND PATENT SELECTION AND DATA COLLECTION

1) ARTICLES – DATA COLLECTION

As for the original search for ''Smart Home & AAL area'', the exact search string used was as follows: ''SMART ENVIRONMENTS or Intelligent ENVIRONMENTS or Smart Home or Smart indoor or Smart Room OR AAL OR Ambient Assistive Living OR Enhanced Living Environment''. We received 58,701 results from the ISI WOK database for the topic search (title, abstract or keywords) and 7,027 results for the title-only search string.

As the goal was the need to survey smart solutions for the elderly population, we searched for ''Smart Home & AAL area AND Elderly'' where we used the exact string ''ELDERLY OR Older OR OLD OR senior''. The structure of the records covered 2,803 records by topic search and 717 records by title search. The final results are summarized in the table (Table 7), where they are structured according to the 14 most frequent reasons for death in the elderly population (60+ group, as shown in figure (Fig. 1)). Finally, from 717 records 193 records of the ''article'' type were considered for the analysis, where only 163 records remained when we combined them with 14 diseases. We found full-text documents for 154 articles, which were screened; then, 21 records were selected as a result and fully analysed (table 7 - appendix).

The general procedure is described in the figure (Fig. 2).

For the IEEE Xplore, Springer and PubMed databases, the semi-automated framework for literature reviews returned 16,418 articles. The articles were then additionally analysed using a list of predefined properties such as ''Cancers'', ''Chronic bronchitis'', ''Ischaemic heart disease'', ''Respiratory Disease'', ''Smart capabilities'', ''Stroke'' and their synonyms. From the 16,418 articles, 11,534 articles were found to not be related to any disease, 4,557 articles were not relevant or were other types of records, and 313 articles were briefly manually reviewed by 4 different people. From those articles 20 articles were selected from which 7 were found to be duplicates with the previous selection. The remaining 13 articles were included in the review.

2) PATENTS – DATA COLLECTION

A search of patents by patent databases (ESPACENET, Patent Inspiration and Google) with ''Smart Home & AAL area'' was executed with the exact search string as following: ''(SMART AND ENVIRONMENTS) OR (Intelligent AND ENVIRONMENTS) OR (Smart AND Home) OR (Smart AND indoor) OR (Smart AND Room) OR AAL OR (Ambient AND Assistive AND Living) OR (Enhanced AND Living AND Environment)''. We received 70,705 results from the patent databases for the topic search (title or abstract or claims) and 58,217 for the title-only search string. A combination with the elderly topic was executed with the string ''ELDERLY OR (Older AND people) OR (OLD AND people) OR seniors OR senior''. The structure of records covered 367 records in the topic search for both 'Smart' and 'Elderly' keywords and 249 records in the topic search for the keyword 'Smart' and title search for 'Elderly'. The final results are summarized in the table (Table 8), where they are structured according to the 14 most frequent reasons of death in the elderly population (60+ group, as shown in figure (Fig. 1)). Finally, when 367 records from the topic search was combined with these 14 most frequent reasons, we obtained 92 records of which only 77 had available abstracts of the patent application. After removing 41 duplicates, 36 remaining patent applications were fully analysed. After the full-text analysis 17 patents were removed, and 19 were included in the synthesis presented in the table (Table 8 - appendix).

The applicant countries covered China (9), United States (7), Canada (1), Taiwan (1), and Korea (1).

C. DATA EXTRACTION AND STUDY QUALITY EVALUATION

The analysis was conducted based on a combination of impact factors of the publications considering reviews and original articles (denoted as articles in the remainder of the text) and patent applications (as patents). Articles and patents were included in the selection and review.

During the last 20 years (until 2013), the patent activity, which was infrequent, oscillated with patent applications in H04L12/00 ''data switching networks'', G06Q50 ''Systems or methods specially adapted for specific business sectors'' and H04L29 Arrangements. Nevertheless, since 2013 a significant growth can be detected from fig xxx where in the last four years the patent activity has focused mainly on G08B21 ''Alarms responsive to a single specified undesired or abnormal condition'' and similar G08B25 ''Alarm systems in which the location of the alarm condition is signalled to a central station''. These alarm patents can be achieved by the expansion of new technologies, sensors, machine learning and high-quality video

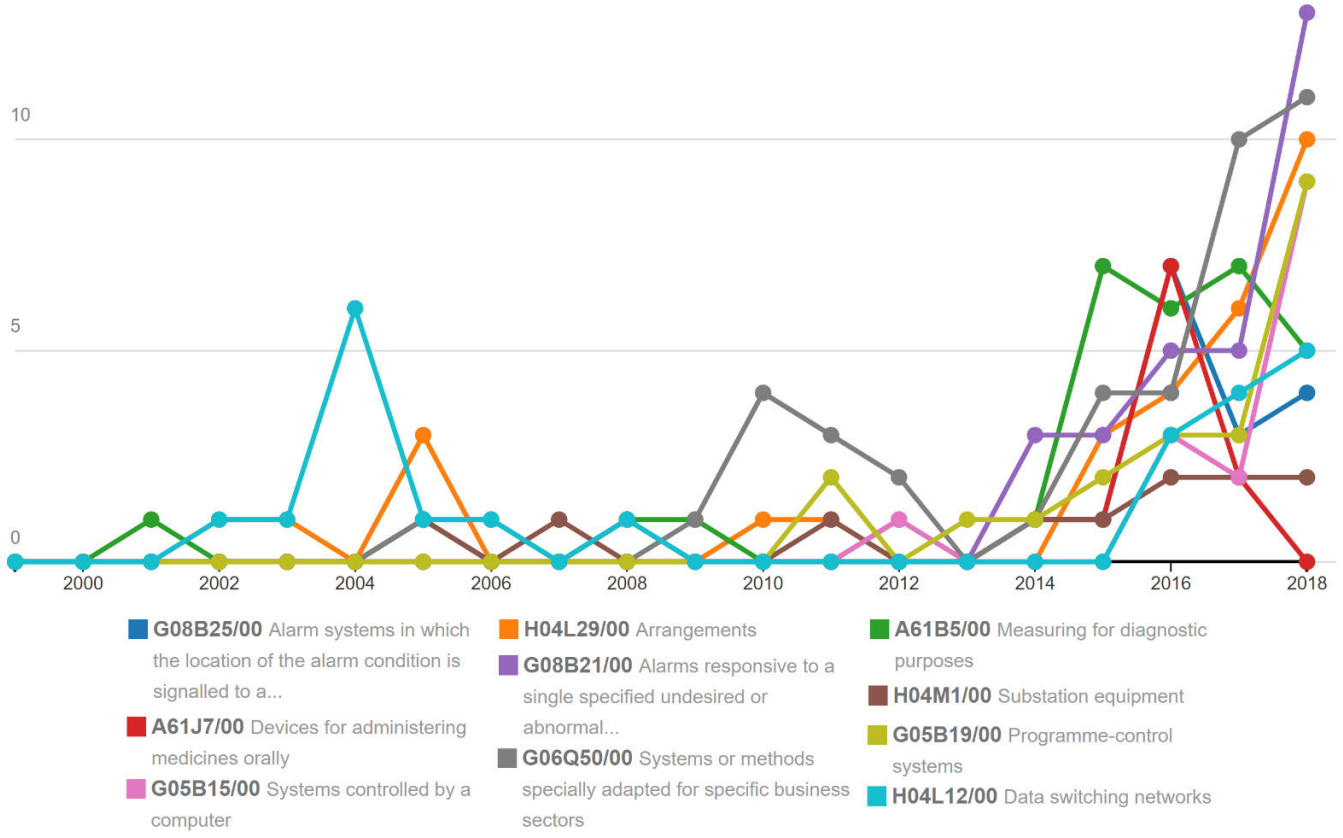

FIGURE 3. IPC code evolution in time for ICT solutions AND elderly keywords (367 patents).

cameras. The next significant group is A61J7 ''Devices for administering medicines orally'' and A61B5 ''Measuring for diagnostic purposes'' with possible use for the elderly population to help them with independent living. The last group with two IPC sub-codes is represented by G05B15 ''Systems controlled by a computer'' and the similar G05B19 ''Programme-control systems'' as computer-based systems for monitoring a ubiquitous environment or Smart Home.

It is evident that most of the technologies discussed in the scientific literature (in articles) were established early on or before 2009. Nevertheless, keywords such as activity recognition, classification, ontology, mild cognitive impairment and perception have been frequently used since 2014. For example, ''activity recognition'' is connected to sensors, elderly, care, dementia and Alzheimer's disease, recognition and independent living. From the newest connections IoT, algorithm, recognition, behaviour and ''machine learning'' can be highlighted. It is evident that the last trend is focused on using machine learning for activity recognition based on sensor data and recognition.

During recent years (2017-2018) the significant trend lay in applying algorithms, behaviours and IoT to the elderly population and e-health from 2016. Behaviour can be named as a growing example, and it is connected to activity recognition, AAL, care, Smart Homes and independent living. This trend corresponds with the growing possibilities for detecting many activities from online video sources; thus, real-time AAL solutions are becoming real at present.

The following inclusion and exclusion criteria were established.

1) INCLUSION CRITERIA

- Ordinary results in a 20-year window: 1998–2017.
- Reviewed full texts of articles or patents in English.
- The aim is to analyse the current state of the art and potential of different types of smart homes and assisted living or perceptions of future potential users.
- The output of the articles was both descriptions of specific Smart Home solutions and the analysis of the state of the solution and the efforts to address the elderly population, as well as with any of the 14 most frequent types of diseases causing death in Europe (EU-28).
- Addressed the use of technology in environments that included seniors with complicated needs
- Addressed the complicated needs of seniors, including physical and mental problems they may face; included technology that has been applied to support independence for seniors, at least as a pilot; and considered data collection and communication challenges.
- Sample included seniors who needed constant care, such as permanent monitoring and chronic conditions

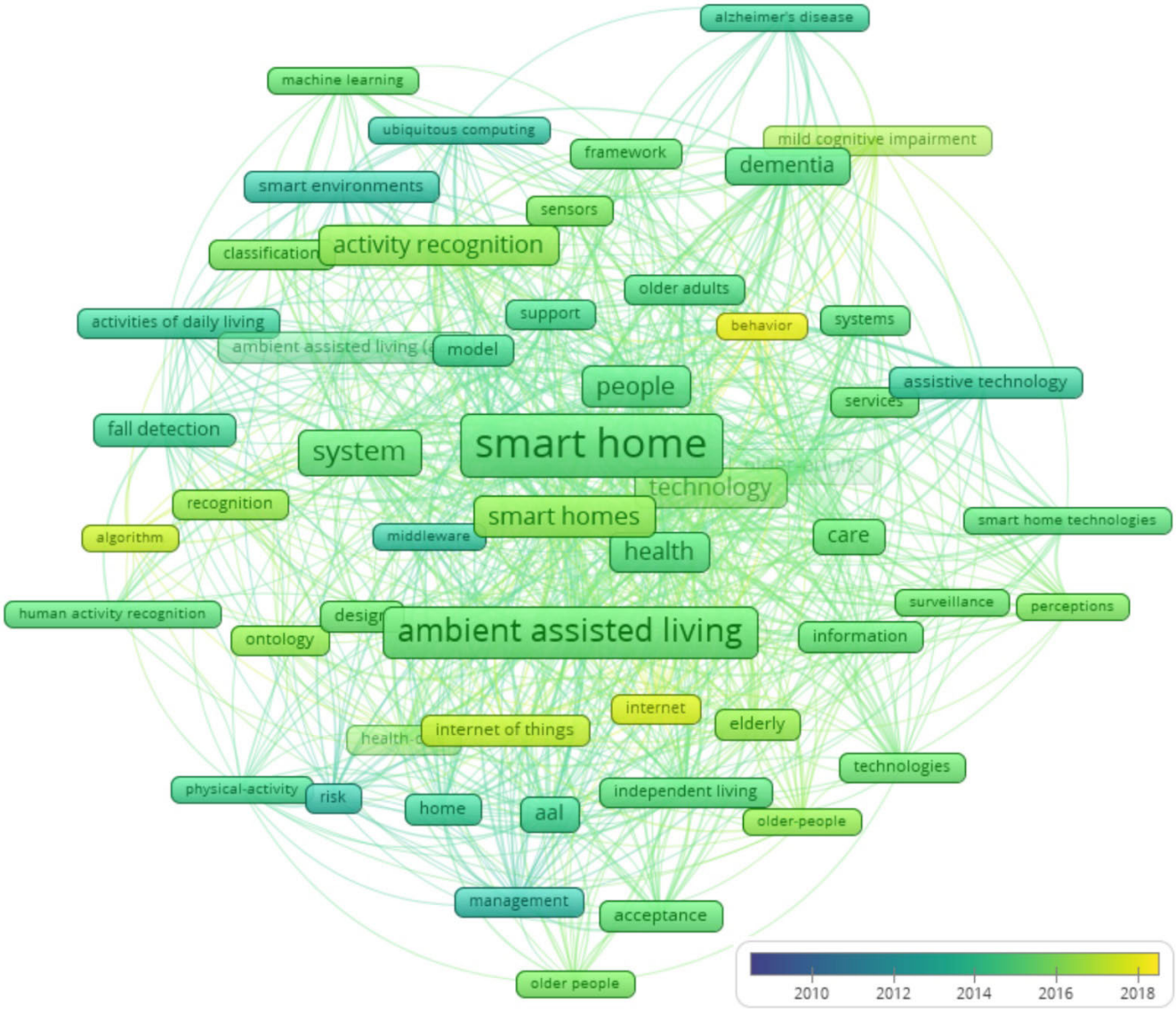

FIGURE 4. Cluster analysis of keywords from records with article type from ISI WOK database for the years 2009-2018 (421 articles). The most frequent keywords with more than 8 connections among each other.

and were afflicted with chronic issues that restrict their capacity for ADL1 and IADL2.

- If the work only looked at conditions such as heart problems or diabetes, the paper was included only if it discussed the sample subjects' restrictions in terms of IADL or ADL or both due to physical, psychosocial or mental impairments and at home.
- Works that included any study method or design with negative or positive outcomes.

2) EXCLUSION CRITERIA

The articles and patents that we gradually eliminated from the analysis had the following specifics:

- A language other than English.
- Papers that offered a review of any sort, meta-analyses, theoretical papers, notes from conferences, and any other form of literature review.
- Studies that were not related to health elements and instead looked at home-based technology aimed at other aspects such as home security or energy efficacy.
- Works that looked at assisting tools such as wheelchairs, walkers, hearing aids, etc.
- Papers that were not available or only available with an abstract.
- In the case of diabetes, studies that were conducted focusing on better self-management without linking to the elderly population.
- Studies addressing medical devices and related clinical trials.
- Furthermore, articles on mental perceptions of ICT perception were also excluded.
- When the study was focused on attitudes of careers.
- Focus on industry and production of ICT solutions.

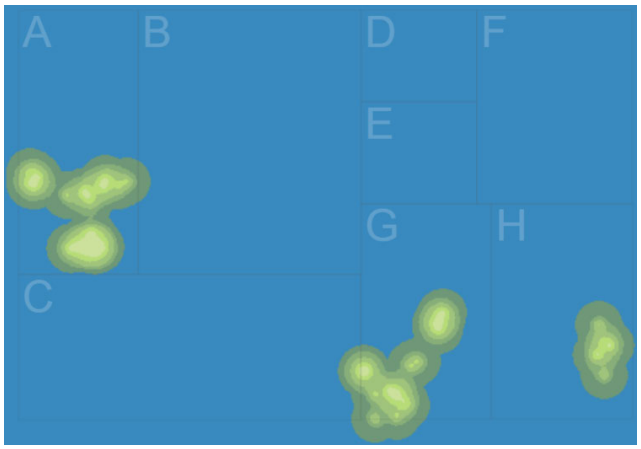

FIGURE 5. IPC patent map. Patents in the results are located in A: Human Necessities, G: Physics, H: Electricity.

- **A61B5/00 (5 patents, 18%)** Measuring for diagnostic purposes
- **G06F3/00 (4 patents, 14%)** Input arrangements for transferring data to be processed into a form capable of being handled by the computer
- **H04M1/00 (3 patents, 11%)** Substation equipment
- **A61N7/00 (3 patents, 11%)** Ultrasound therapy
- **A61N1/00 (3 patents, 11%)** Electrotherapy
- **G06Q10/00 (2 patents, 7%)** Administration
- **G06F19/00 (2 patents, 7%)** Digital computing or data processing equipment or methods
- **A61N5/00 (2 patents, 7%)** Radiation therapy
- **A61N2/00 (2 patents, 7%)** Magnetotherapy
- **A61M21/00 (2 patents, 7%)** Other devices or methods to cause a change in the state of consciousness

FIGURE 6. IPC codes (Main groups) of 19 results in the patent pool.

- A focus on solutions in developing countries where there are conditions different from those of developed countries, a similar economic level and an ageing population.

3) LIMITATIONS

Some relevant articles could have been unintentionally left out of this review due to the specificity of the search strings. Additionally, some empirical studies may not have been identified in this literature review because only English peer-reviewed published papers were analysed. Most of the analysed articles considered technological maturity from the R&D or prototype level; only one of them analysed the final product. Original research in cooperation with the corporate environment would need to be conducted to ensure the analysis of the final products.

IV. RESULTS

In the systematic review 34 articles and 19 patents were included, and the objective, effect and technology in relation to the diseases are described.

automatic · average · certain · characteristic · chinese
close · common · complete · digital · direct · effective
environmental · equal · final · full · functional · general
human · individual · initial · intelligent · local
long · medical · mobile · multiple · negative
new · normal · old · original · personal · physical
proper · real · red · related · remote · respiratory
secondary · several · short · smart · sound · special
standard · synchronous · third · whole · wireless

FIGURE 7. Patent text analysis using a tag cloud for adjectives in patent applications. Summary of the 50 most-used adjectives mentioned in selected patents (in Title, abstract, claims) with selected adjectives for analysis.

smart	digital	mobile	intelligent	individual	personal	Terms	Patents
●	●	●	●	●	●	6	4
●	●	●	●	·	●	5	1
●	●	·	●	●	●	5	2
·	●	●	●	●	●	5	2
·	●	●	·	●	●	4	1
●	·	●	●	·	·	3	1
●	·	·	●	·	●	3	1
●	·	·	·	●	·	2	2
●	·	·	·	·	●	2	1
·	·	·	●	·	●	2	1
·	·	●	·	·	·	1	1
·	·	·	●	·	·	1	2

FIGURE 8. Combination analysis for patent pool for selected adjectives where all 19 patents are covered by these selected adjectives.

A. ANALYSIS OF RESEARCH PAPERS

Regarding research papers most of the summarized articles are connected to Alzheimer's disease and other dementias (14x), diabetes mellitus (7x) and stroke (7x) while the other diseases are represented by only 1 to 3 articles which use some ICT solution to help the elderly population with specific diseases (Table 1).

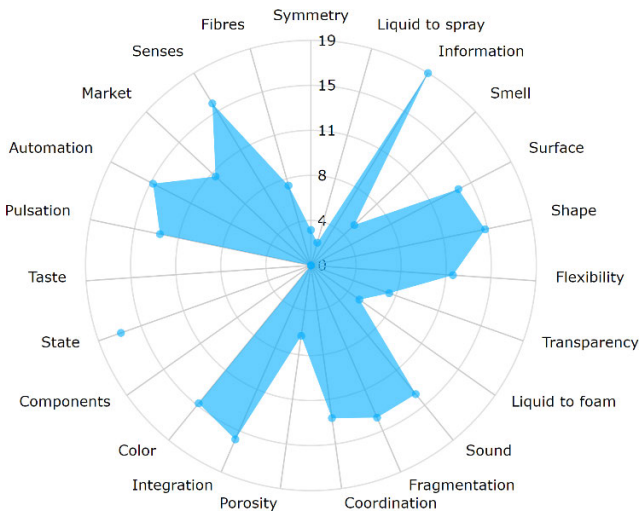

FIGURE 9. Evolutionary potential showing which properties were explored in the 19 patents in our pool [124].

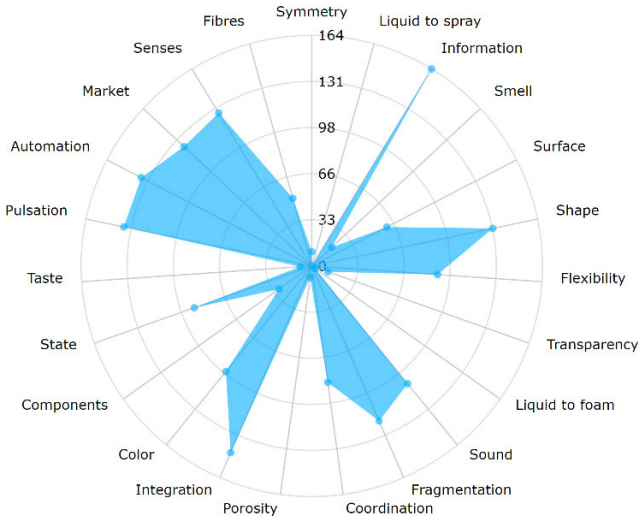

FIGURE 10. Evolutionary potential in 185 patent citations [124].

As there is a logical need to monitor patients with any kind of dementia [36], [43], [46], a number of articles, studies and research projects have been undertaken during recent years. Ambient Assistive Living (AAL) technologies [45] as well as Smart Home systems [34],[46],[51], [53] are widely suggested as a useful ICT solutions to help patients with dementia as well as to caregivers. Monitoring is performed by passive and active IR motion sensors [43] which have been found to be suitable solution in cases where more independent living is possible in the elderly population. When more precise patient monitoring is needed, video monitoring systems are widely used [36], [60].

Several articles also evaluate the possible use of ICT technologies as a part of AAL [47], [58], [49], [41], [45], including how elderly and patients can work with these Smart ICT technologies as such tablets, touch screen devices, and thermostats. Hwang *et al.* 2015 [45] concluded that AAL technologies must be created or developed to be customizable, flexible and possibly featuring a DIY capability that can augment or help care, experiences and relationships. A requirement for constant user involvement during the development and implementation process, constant training and support throughout system use and transfer between the real and the virtual world especially when using ICT technologies in old age was confirmed also by Muuraiskangas *et al.*, 2012 [47].

QoL and well-being are also connected to comfort in the elderly environment. Air conditioning system control for places where multiple users lived is also suggested by Tartarini *et al.*, 2017 [41]. The problem of agitated behaviours from setting the temperature within a community impacts not only the person exhibiting the said actions but also those around them, i.e., residents in close proximity. It also impacts care delivery for all involved. The authors suggests setting only a limited number of indoor air temperature variations to reduce agitation.

One trend is also to use multicomponent interventions and smartphones/PDAs, whereas wearables, biosensor devices, and computer systems as the sole technological solution are not in vogue now. This indicates an ability to use ICT technologies in elderly living environments, including smartphones, wearables and any devices they can have [55].

We performed an in-depth analysis regarding the technological aspect of the suggested solutions. It is essential to know whether the sensing technologies used are invasive (in terms of privacy and personal space) (Table 2). Additionally, we reviewed the consideration of Smart technologies which are becoming increasingly popular as they are continually being improved. Novel methods based on machine learning are known to be used in many different aspects of AAL and medical informatics where they give promising results [97], [98]. The user interface is another aspect that we considered in the analysis. With the increased usage of mobile devices, we also see an increased number of applications that use them. Furthermore, for impaired people, voice recognition modules are one of the possible solutions that are taken into consideration. Next, one of the essential aspects of any solution is the user. Which user type is the solution intended for: the doctor, the caregiver, or the patient or older person? We also reviewed the technological maturity of the solution in terms of the state of development. Finally, we reviewed if the authors considered the acceptance and satisfaction of the proposed solution by the users.

Most of the solutions use web or mobile applications with several of them considering speech recognition to process user input. Depending on the application, a large part of the solutions consider non-invasive sensors which are commendable; in addition, the inclusiveness of Smart capabilities is a trend, especially in newer publications. Almost all of the solutions consider the older adult or the patient as a user. Many of them are intended to be collaboratively used by the older adult and the caregiver. However, some of them also include healthcare providers. In almost all publications, the state of development is at the R&D or prototype level which is understandable considering the nature of the problems. Most of

TABLE 1. Summary of studies in relation to the most frequent reasons of death in European region.

KIND OF DISEASE	STUDY	OBJECTIVE	METHODS	MAIN FINDINGS	LIMITATIONS	MARKETED SOLUTIONS
Ischemic heart disease	Muuraiskangas et al., 2012 [47]	To implement a virtual coach that can help users participate actively in reaching out to people and educating them on starting and maintaining substantial relationships.	30 participants; interview - how they expected to perform a short task. Services and Applications are used with help of Mobile devices | Tablet (touch screen devices)	Use of ICT in old age requires constant involvement of users during the development and implementation process, constant training and support throughout system use and transfer between the real and the virtual world.	Ambient Assisted Living (AAL) research project is aimed at finding a solution to ridding one of loneliness by use of technology that is easy to use, such as a tablet.	
	Hervás et al 2013 [75]	To develop an end-to-end software application that uses mobile phones to monitor risk of heart diseases	Software development, evaluation and reporting. Uses mobile phones with Bluetooth communication with sensors. High response speeds and rule-based decision support integrated system.	Authors have developed and evaluated an end-to-end solution for monitoring that can be used by patients, caregivers and doctors and uses mobile devices such as smart-phones	Not very high reported acceptance rate by the aged population. Only 69%.	
	Kaňtoch 2018 [76]	To develop a method of automatic recognition of sedentary behaviour related to cardiovascular risk based on quantitative measurement of physical activity.	Develop method based on data from multimodal sensors and machine learning algorithms for activity recognition and validate using experimental protocol.	Smart shirts and machine learning approaches can achieve high accuracy in detection of sedentary behaviour	Limited set of activities can be detected, additional research is needed for different states. Not all behaviours are detected with equal accuracy and some are ambiguous (like standing and sitting still)	Smart Sofa solution [77] for household, for posture monitoring which enable furniture shape change. Smart BED solution [78], [79] with heart rate, temperature, sleep monitoring and breath rate monitoring.
Stroke	Lavoie et al., 2015 [49]	Study looked at how effective a self-administered care through smart tablet could augment verb naming skills	ABA multiple baseline design was implemented so that the CP's performance could be compared to three equivalent sets for stimuli. Use of sensors and devices | Mobile devices | Smart Tablet	Graphemic cueing therapy was conducted over a period of three weeks and resulted in an augmented level of the aforementioned activity, as opposed to the untrained set and the baseline.	Small sample size, necessity of confirmation of this results.	
	Hayward, et al., 2015 [50]	Authors suggested - self-administered, Home-based Smart Arm training.	A pretest–posttest follow-up, single-case, mixed-method study using multiple component system, environmental sensors, and computer-training programme.	Smart Arm training may offer a feasible option for people with stroke with severe paresis to undertake self-administered upper-limb rehabilitation at home.	Not a final product, study is a base for next development.	VirtualGym: A Kinect-based system for elderly exercising at home [32].
	Ocepek, et al., 2013 [51]	To allow seniors and people with disabilities to use and check multiple assistive technologies and solutions so that they may become more independent	Canadian Occupational Performance Measure (COPM) and the Functional Independence Measure (FIM) using environmental sensors of Smart Home IRIS - technological solutions that compensate some kinds of disabilities and thereby improve the QoL of persons with disabilities.	The treatments in the Smart Home IRIS appeared to contribute to higher occupational performance and satisfaction with performance and higher functional independence of persons with disabilities and elderly people.	The number of Assistive Technology ATs in the statistical models was only considered.	Smart BED solution [78], [79] for household with heart rate, temperature, sleep monitoring and breath rate monitoring providing foot warming, bed shape change and lightning control. Google Nest Yale Smart lock [80] for household use with lock and voice recognition feature.
	Arcelus et al., 2009 [39]	Measurement the duration of Sit-to-Stand (SiSt) unobtrusively and automatically using a pressure sensor array.	25 participants monitored by Sensors and devices | Environmental sensors | Video camera | Pressure sensor array under a bed mattress and a floor plate beside the bed.	Adults both young and old who were in good health come up with shorter SiSt, registered at 2.31 and 2.88, respectively. However, people who had suffered a stroke or hip fracture registered 5.00 and 3.32, respectively.	Small sample	Smart BED solution [78], [79] for household with heart rate, temperature, sleep monitoring and breath rate monitoring providing foot warming, bed shape change and lightning control.
	Pastorino et al. 2014 [81]	To evaluate a platform for personalized rehabilitation within the CogWatch framework with the intent of fostering independence in activities of daily living in patients with apraxia and action disorganization syndrome	36 participants divided into 3 groups Monitoring using Cameras, sensors, Kinect device, servers, web application and interface.	A robust system from technical point of view, users reported ease of use and 75% of them would favour using the system in their own home	Several technical problems with the sensor communication reliability reported and clinical results not included in the study.	
	Oliver et al. 2018 [82]	To build a system for cognitive rehabilitation that allows users to use it at their convenience.	A group of 20 therapists were questioned to evaluate the system of head-set for emotion detection, Kinect V2, Glove vibrotactile sensor, Servers and Web based services with client application for both therapists and patients.	The system provides greater autonomy for therapists and patients but doesn't replace the therapists.	The study was made on 20 random conveniently chosen therapists. Further study is needed for patient's satisfaction.	Smart BED solution [78], [79] for household with heart rate, temperature, sleep monitoring and breath rate monitoring providing foot warming, bed shape change and lightning control.
Alzheimer disease and other dementias	Alberdi, et al., 2018 [40]	Detection of multimodal symptoms that are often found to be impaired in AD	Longitudinal Smart Home data for 29 older adults with average duration of >2 years. Mobility, cognition and mood were evaluated every six months by use of sensors, devices, environmental sensors, and machine learning software in Java.	All mobility, cognition, and depression symptoms can be predicted from Activity-aware Smart Home data. Based on Smart Home data, regression models was created to predict symptoms, measured by the tests and a feature selection analysis was performed.	Model can improve sensitivity by including additional longitudinal data and by further improving strategies.	Happie Home automation system [83], [84] is provided to facilitate senior care, as well as to facilitate care for individuals suffering from Alzheimer's disease or other dementias. A home control unit is provided that is connected to, and interfaces with, a combination of health equipment, smart home appliances, a smart medicine cabinet, a smart pantry, wearable sensors, motion detectors, video cameras, microphones, video monitors, speakers, smart thermostat, lighting, floor sensors, bed sensors,
	Tartarini et al., 2017 [41]	To determine the specific correlation between indoor air temperature and agitation of nursing home residents with dementia.	21 residents, living in 1 nursing home, were assessed for a 10-month period using the Cohen-Mansfield Agitation Inventory (CMAI). Environmental sensors iButtons (Maxim Integrated - small, cylindrical data logging devices 17.5 mm in diameter and 6 mm deep) was used.	Agitated behaviours not only affected the person manifesting them but were found to be disruptive for other residents and the delivery of care. Agitation can, therefore, be potentially reduced by limiting the range of indoor air temperature variations	Low number of participants. Corrections of residents positions indoor by caregivers when not precis location by indoor positioning system.	

TABLE 1. *(Continued.)* **Summary of studies in relation to the most frequent reasons of death in European region.**

						smoke detectors, glass breakage detectors, door sensors, and other perimeter sensors.
	Hattink et al., 2016 [42]	Integration of three previously developed AT systems into one modular, multifunctional system	Controlled trial with pre- and post-test measures across three countries (Germany, Netherlands and Belgium)	All participating people felt that Rosetta was a truly helpful introduction and would prove useful for care in the future.	The system had not detected falls of participants three times. In one case person continued moving while on the ground.	
	Rudicz et al., 2015 [37]	Study of speech-based interactions between mobile robotic platform called ED, along with every one of the senior adults that presented with AD	A set of experiments, such as finishing a daily activity in a home environment that is simulated. ED intended to assist with daily activities by visual monitoring and verbal prompts in cases of difficulty.	Seniors who presented with AD had a higher likelihood of ignoring a robot, and account for approximately 40 percent of these types of behaviours when dealing with it.	Not all nonverbal and semi verbal strategies was taken into account – thus problem with non-formal promotions of elderly	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	Lyons et al., 2015 [43]	Patterns of intra-individual variation detected in each of these areas was used to predict outcomes such as low mood, loneliness, and cognitive function.	System of strategically placed sensors in over 480 homes. Collecting data for up to 8 years. oRCAt Ch Platform design with several types of sensors, wireless passive IR motion sensors in each room. Wireless magnetic contact sensors also placed on the outside doors and the refrigerator.	Home-based monitoring provides a method for tackling one of the greatest challenges across the spectrum of dementing diseases from pre-symptomatic to manifest disease. Upgrades included IR sensors (by ZigBee).	Due to the large use of passive IR and contact sensors - difficulty of distinguishing between individuals if more than one person in the home. Low fidelity of recognizing and distinguishing between activities recorded.	
	Cavallo et al., 2015 [44]	Demonstration of effectivity and acceptability of developed innovative domiciliary smart sensor system with an AAL approach for providing domiciliary assistance to patients with AD.	15 sociomedical operators and 14 patients with AD were directly involved. Monitoring using sensors and mobile devices, video cameras, bed and easy chair monitoring systems, door monitoring tool, personal localization system, and personal posture monitoring system.	During the experimentation, the acceptability, utility, usability, and efficacy of this system were evaluated by operators and patients as quite positive.	Small sample	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	Hwang et al., 2015 [45]	Design, development, testing, and evaluation of the caregiver interface artefacts as triggers to facilitate envisioning of AAL support and unpack the situated, idiosyncratic context within which AAL aims to assist.	Experiment with 6 participants, patients and caregivers using sensors and mobile devices.	Suggestion that AAL should be designed to support solutions that complement tacitly improvised care strategies and enable them to try, observe, and adapt to solutions over time. In this way, an ICP could decide which activities to entrust to AAL support. AAL technologies should be designed to be flexible, customizable, and potentially with "do-it-yourself" (DIY) capabilities to complement care routines, relationships, and experiences.	Small sample	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	Lotfi et al., 2012 [46]	Solution to support independent living of the elderly population by means of equipping their homes with a simple sensor network to monitor their behaviour.	Case study: Can system detect abnormality within the behaviour of an occupant living in a real environment in 6 months. Home automation sensors are used, while neural networks are set to predict the future values of the activities for each sensor.		Only 3 motion sensors and 2 door contact sensors. (movement and door entry point)	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	Sacco et al., 2012 [36]	The aim of the study is to propose a Daily Activity Scenario (DAS) score that detects functional impairment using ICTs in AD and Mild Cognitive Impairment (MCI) compared with Normal Control group (NC).	64 participants over 65 years old were included: 16 AD matched with 10 NC for protocol 1 and 19 MCI matched with 19 NC for protocol 2. Video monitoring system (VMS) is used to obtain a quantifiable assessment of IADLs in AD and in MCI - Two fixed monocular video cameras (eight frames per second).	This study outlines the interest of a novel tool coming from the ICT world for the assessment of functional impairment in AD and MCI. The derived DAS scores provide a pragmatic, ecological, objective measurement which may improve the prediction of future dementia	Short duration of the scenario. Only the relative position of the participant in the room is automatically processed by computer vision algorithm. Automatic recognition of IADL remains in progress.	
	Wai et al., 2008 [48]	Design, development, and preliminary deployment of a smart wireless continence management system for dementia-impaired elderly or patients in institutional care settings such as nursing homes and hospitals.	Trial in a nursing home after conducting several experiments in the laboratory in order to prove the usefulness and importance of this system. Mote wireless platform used for deployment of large quantities of wetness sensors with wider coverage with dramatically less complexity and cost - an intelligent signal relay mechanism.	Preliminary results from a trial in a local nursing home are promising and can significantly improve the quality of care for patients.	When the wetness sensor was not being put in the optimal position of the diaper, the detection rate would be lower as there is limited contact between the wetness sensor and the urine.	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	Mahoney et al. 2015 [86]	To build an assistance system for aiding caregivers in dressing people with Alzheimer, with automatic detection of clothes and suggestion system to aid dressing.	25 caregivers for people with Alzheimer and 10 people for control for the evaluation of the system in controlled laboratory settings.	Promising overall functionality and high acceptance with caregivers.	Needs increased accuracy in clothes detection. Care recipients weren't included in the study.	Panasonic Mirror solution [87] for household with skin condition detection and recommendation which product to use by using image processing,
	Lazarou et al. 2016 [88]	To propose a system for monitoring of activities in problematic living areas and give automated feedback and health related observations to improve quality of life	4 homes had installed various sensors such as wearables, object motion, presence, sleep utility usage and other for distance monitoring of patients and health pattern analysis and detection, data visualization.. The collected data is combined with clinical data and visualized.	Overall usage of the system improved the scores of the monitored neuropsychological assessment. The abnormalities detection was crucial for assessing the current situation, driving interventions and evaluate improvements.	Detection of abnormalities is not synced and requires notes from the patients/users in order to be able to match activities with abnormal sensor readings	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.
	López-de-Ipiña et al. 2013 [89]	To perform analysis of features in Spontaneous Speech and Emotional Response oriented to pre-clinical evaluation for the definition of appropriate tests for early AD diagnosis	Evaluation of machine learning algorithms performance on existing dataset consisted of 20 AD patients and 20 normal patients for control group, where date are taken from speech recording in home environments.	Promising results for early AD diagnostics based on speech.	The reported results are only for the dataset, no field testing is performed	Google Nest Yale Smart lock [80] for household use with lock and voice recognition feature.
	Griol et al. 2016 [90]	Evaluation of a framework for multimodal interactive system that uses a conversational agent	Evaluation of the user experience by caregivers and randomly selected test users by mobile application, speech recognition, and context-aware application.	High satisfaction of caregivers and selected users. The proposed framework and application are able to provide to the user a large combination of input and output modalities to communicate with the system which makes the system especially useful for older adults and people with impairments.	The article lacks a comprehensive evaluation with people with Alzheimer	IKEA solution [85] focusing on range of household smart items such as lightning control, wireless charging, wireless speakers, etc.

TABLE 1. *(Continued.)* **Summary of studies in relation to the most frequent reasons of death in European region.**

Chronic obstructive pulmonary disease (COPD)	Johnson et al., 2014 [60]	The KSERA (Knowledgeable Service Robots for Ageing) project integrates Smart Home technology and a socially assistive robot to extend independent living for elderly people, in particular those with COPD.	User studies using sensors and devices, robotic services, person- and self-localization, person-aware navigation, speech recognition and generation, robot gestures, emulated emotions, eye contact and joint attention, and audio video communication.	The results showed that (1) the KSERA system and Nao robot are likeable, (2) the attitude towards the Nao robot is highly correlated with the attitude towards the system, and (3) communication through a robot is preferred over interaction with the individual technical elements of a Smart Home.		Hyundai Livart solution [91] is focusing on Living room, kitchen where it clean the air by UV LED – Violeds solution Infurma Actiu Smart chair [92] for SoHo use with posture, air quality, temperature, humidity, lighting and noise levels monitoring updating design of Smart chair.
Lower respiratory infections	Sun et al., 2014 [52]	Developed a non-contact vital sign monitoring system (Vital-CUBE).	System was tested by 16 subjects (22±3 years old) using sensors, environmental sensors, phone with virtual network, and radar. Users can immediately and conveniently access measurement data. Randomized control trials.	The Vital-CUBE measurements exhibited a strong positive correlation with those of the reference contact-type sensors (ECG: r = 087, p<001; respiratory effort belt: r = 091, p < 001)	Small sample size	Hyundai Livart solution [91] is focusing on Living room, kitchen where it clean the air by UV LED – Violeds solution
	Demongeot et al., 2002 [53]	Concept of Health Smart Home designed to follow dependent people at home in order to avoid the hospitalization, limiting hospital sojourns to short acute care or fast specific diagnostic investigations.	Not full description of system design. Using of sensors and devices, environmental sensors and sensors set.	We can follow the cardio-respiratory state by measuring the intensity of the respiratory sinusal arrhythmia in order to quantify the integrity of the bulbar vegetative system. Need to carefully watch abnormal symptoms (e.g., arterial pressure or presence of plasma proteins) in the expired air flow for early detecting hypertension/pulmonary oedema.	Not evaluated within Home environment.	Hyundai Livart solution [91] is focusing on Living room, kitchen where it clean the air by UV LED – Violeds solution
	Marques et al. 2018 [93]	Indoor air quality system for monitoring PM air particles inside rooms and buildings	Design of prototype and evaluation in indoor environments with iDust hardware component that connects to servers and communicates with web application.	The proposed system can be deployed and used in indoor environments and has full end-to-end implementation including web application for monitoring and setup.	Not yet ready for specific cases such as hospitals, workplaces, schools etc.	Hyundai Livart solution [91] is focusing on Living room, kitchen where it clean the air by UV LED – Violeds solution
Diabetes mellitus	Jara et al., 2011 [38]	Description of personal-care devices	Design of prototype equipped with sensors and devices, connectivity, web services and applications, wearable sensors, RFID, and IoT 6LoWPAN. Evaluation with patients, sisters and physicians.	Personal-care devices; nurses/physicians desktop application to manage personal health cards (glycaemic index IS) via patient's web portal	No details about evaluation, no numbers of respondents	Smarty Pans solution [94] for household with temperature, weight monitoring and diet monitoring.
	Costa et al., 2009 [54]	Present the VirtualECare project.	Design of technical solution - multiple component system with mobile devices and web services – its presentation.	Intelligent multi-agent system able to monitor, interact and serve its customers, which need care services.		
	Henkemans et al., 2008 [55]	Adaptive computer assistant development for the supervision of diabetics' self-care, to support limiting illness and need for acute treatment.	28 older adults evaluated usability of assistant in the Georgia Tech Aware Home using sensors and mobile devices, electronic diabetes diary, and an interaction frame and a traffic light.	Older adults were able to use the adaptive computer assistant. In addition, it had a positive effect on the development of health literacy.	Targeted to elderly	Smarty Pans solution [94] for household with temperature, weight monitoring and diet monitoring.
	Charon-Prochownik et al., 2007 [56]	Present the results of the process evaluation and patient experience in completing the Diabetes Self-management Assessment Report Tool (D-SMART)	Approximately 290 patients' data collected by sensors in mobile devices was used because they had diabetes. D-SMART was linked to the telephone and computer systems to five sites.	Of the sample, approximately 76% people thought that D-SMART had been helpful in ensuring they thought of diabetes. Of this, 67% said that good information was provided about the disease and themselves. A staggering 94% were happy with it. The satisfaction level was linked to the system and how it was used.	The examination was not created based on the experiment and therefore the collected data couldn't be controlled rigorously inn terms of the population – at least high degree = limit.	
	Bond, 2006 [57]	Development and implementation of a Web-based intervention to enhance diabetes self-management for older adults.	Implementation and testing. Researcher's experience with the development using web services and applications.	The benefits associated with usability testing include reduced training time, support calls, and maintenance, and increased user satisfaction	For elderly – many technological issues which negatively influenced testing of application	Smarty Pans solution [94] for household with temperature, weight monitoring and diet monitoring.
	Earle, K..A., et al., 2010 [95]	To create an end to end system for glucose monitoring using Opto-physiological Glucose sensor	Hardware and software implementation using IoT concepts. Web servers with sensors connected to gateway that communicates with hospital software.	The concept of Internet of m-health Things can be used and applied to tele monitoring of patients.	Not yet implemented and tested	
	Salvo et al 2017 [96]	To create materials for monitoring ulcers on feet of diabetic patients	Sensor hardware implementation	The proposed hardware can be used to monitor the pH and temperature and thus monitor the state of ulcers by introducing it to smart wearables	Only in prototype phase, not yet clinically tested	

the publications do not report technology acceptance or user satisfaction. This is a considerable shortcoming considering that these aspects are essential for any solution that is to be used by older adults. The reason is the scepticism towards using novel technologies in everyday life which has been reported in many publications.

B. ANALYSIS OF PATENTS

Based on the summary provided in Table 3, the most-filed patent application is in the field of Smart Homes, especially in the monitoring of biomedical information of home residents. SoberCam Engine [100] as the most-cited patent application is in this case also the most sophisticated solution, and it also has a variety of computer analyses methods and technologies meant to protect elderly in homes or private care, elderly homes, or caregiver environments. SoberCam Engine [100] contains a fuzzy logic intelligent camera system which covers recognition of body actions, facial patterns, stress, voice stress analysis, voice recognition, lip-reading, facial and emotional stress analysis and many other methods. The proposed system is suitable for elderly persons living alone and suffering from some kind of disease such as a heart attack or stroke or timely falling. When movement by the user is detected, the system records and monitors said movement so that it can later be identified or examined. Moreover, it can moreover identify or detect health issues such as heart attacks or seizures, should they present themselves, alongside health and drug or alcohol information. The system also

TABLE 2. Overview of used ICT solutions.

	Consideration of sensing technologies in study			Consideration of Smart capabilities		User interface				User			Technological maturity			Reported technology acceptance and/or satisfaction			
Publication	*Invasive*	*Non-Invasive*	*Not reported or not used*	*Yes*	*No*	*Speech*	*Mobile*	*Desktop, web, screen*	*Not reported or not used*	*Caregiver*	*Doctor*	*Older adult*	*R&D*	*Prototype*	*Product*	*Low*	*Medium*	*High*	*Not reported*
(Muuraiskangas et al. 2012) [47]			X		X		X					X		X		X			
(Lavoie et al. 2015) [49]			X		X		X				X	X	X						X
(Hayward et al. 2015) [50]	X				X			X				X			X		X		
(Ocepeket et al. 2013) [51]		X		X			X	X				X		X			X		
(Arcelus et al. 2009) [39]		X		X					X			X	X						X
(Alberdiaramendi et al. 2018) [40]	X	X		X					X	X	X	X	X						X
(Tartarini et al. 2017) [41]		X			X				X	X	X	X	X						X
(Hattink et al. 2016) [42]		X		X			X			X	X	X		X				X	
(Rudzicz et al. 2015) [37]		X		X		X						X	X			X			
(Lyons et al. 2015) [43]		X		X				X				X	X						X
(Cavallo et al. 2015) [44]	X	X		X				X		X		X		X		X		X	
(Hwang et al. 2015) [45]	X	X			X			X		X		X	X						X
(Lotfi et al. 2012) [46]		X		X					X	X		X	X						X
(Sacco et al. 2012)[36]]	X			X					X	X	X		X						X
(Wai et al. 2008) [48]		X		X					X	X	X	X	X						X
(Johnson et al. 2014) [60]	X	X		X		X						X		X				X	
(Sun et al. 2014) [52]		X		X			X			X	X	X		X					X
(Demongeot et al. 2002) [53]	X	X		X				X		X	X	X	X						X
(Jara et al. 2011) [38]	X				X			X			X	X		X				X	
(Costa et al. 2009) [54]	X	X		X			X			X	X	X	X						X
(Henkemans et al. 2008) [55]			X		X			X				X	X				X		
(Charron-Prochownik et al. 2007) [56]			X		X	X	X	X				X			X			X	
(Bond et al. 2006) [57]			X		X			X				X		X			X		
(Hervás et al. 2013) [75]	X	X		X			X			X	X	X		X			X		
(Kańtoch 2018) [76]		X		X					X	X	X	X		X					X
(Marques et al. 2018) [93]		X		X				X				X		X					X
(Istepanian et al. 2011) [99]		X			X			X			X		X						X
(Salvo et al. 2017) [96]		X			X				X			X		X					X
(Mahoney et al. 2015) [86]		X		X			X			X			X					X	
(Lazarou et al. 2016) [88]		X		X				X			X		X						X
(López-de-Ipiña et al. 2013) [89]		X		X					X		X		X						X
(Pastorino et al. 2014) [81]		X		X			X	X			X	X		X				X	
(Oliver et al. 2018) [82]		X		X				X			X	X		X				X	
(Griol et al. 2016) [90]		X		X		X				X		X		X				X	

incorporates the use of medical alerts, breach of places and property, fire, etc.

The European patent application from the Chinese inventor Yibing Wu [101] contains 142 uses for the elderly population in the patent description. This application, named ''Life maintenance mode, brain inhibition method and personal health information platform'', also represents a very complex ICT solution. The system comprises of several parts, where resident activity monitoring measures the urine volume, amount of relative limb exercise, body weight, amount of exercise sweat, food intake, water intake and defecation amount. The proposed system is connected via a wireless network to a mobile terminal responsible for vital sign data acquisition and transmission, and this terminal is used by each user in the living and working environment. The mobile terminal measures (1) vital signs and physiological data (e.g., EEG, blood wave, ECG, pulse oximetry, EMG, etc.), (2) acquired living condition data and (3) acquired subjective feeling data. The system also utilizes pressure, temperature, and near-infrared laser sensor data. All data mentioned above are processed, and if the system detects an abnormal activity, an automatic no-response alarm service is activated.

''Recovery system for old people suffering from Alzheimer's disease'' by Wang *et al.* from University of North Eastern [102] is the next example of a patent application focusing on monitoring the elderly users to prevent them from being lost due to Alzheimer's disease. Monitoring is provided via remote video monitoring and GPS positioning while an anti-lost function for the elderly users is

TABLE 3. Summary of patents.

Publication number	Title	Proposition	Summary/Main findings	Type of usage by the elderly population
WO0124700A1	"Spoof detection for biometric sensing systems" [105]	biometric sensing system and techniques for detection of non-living body using finger	Methods including average intensity, pixel density, rate of warming, ridge uniformity, ridge signal strength, water droplet differential, fingerprint vitality, and inverted spoof techniques.	biometric sensing device producing a fingerprint by capturing images is worn to report a living finger = living user
CN1662204A	"Reciprocating movement platform for the external addition of pulses to the fluid channels of a subject" [106]	apparatus for providing medical treatments	Design of apparatus (which enables non-invasive monitoring) containing a mattress, cast shoes, a footboard support, a drive for causing reciprocating movement	platform for user health treatment by providing various exercises to support user health treatment
US2006190419A1	"Video surveillance data analysis algorithms, with local and network-shared communications for facial, physical condition, and intoxication recognition, fuzzy logic intelligent camera system" [100]	Voice, Lip-reading, Face and Emotion Stress Analysis, Fuzzy Logic Intelligent Camera System	SoberCam Engine includes a plurality of computer analysis techniques and technologies (video pattern recognition, Facial recognition, body action recognition, stress analysis, voice stress analysis, voice recognition) to protect senior citizens in private care, senior homes, or caregiver environments	Seniors living alone and suffering from heart attack, stroke, falls, detecting stumbling or falling. When movement by a person is detected, the system starts to monitor and record this movement for later analyses or identification. A sensor is used to alert medical personnel.
CN1900886A	Method for single click and multiple key combining click mixing input Chinese and English and keyboard [107]	Method of single clicking and multiple keys applicable to various types of keyboards/keypads, etc.	Input method can be more convenient and quicker on dual-purpose keyboard/mobile phone/other digital keyboards for the input of Chinese characters or English text. 6 to 12 keys can be pressed simultaneously.	Using this input method can bring better convenience to seniors in the typing speed of the new method
CN1908870A	Method and keyboard for mixed inputting English with a single button and multiple buttons [108]	Invention adds new technology to simultaneously allow 4 keys for one hand or 8 keys for two hands.	This invention can improve input speed greatly and fit both Chinese and English.	Using this input method can bring better convenience to seniors in the typing speed of the new method
CN101075316A	Method for managing electronic ticket trade certification, including its carrier structure, system and terminal [109]	A certification-managing method of electronic ticket transaction including setting up a certification-management centre of electronic ticket transaction	Exchanging tickets through a transaction-certification network station of ticket for achieving integrated certification in order to ensure truth of the ticket.	Old-age insurance version generated as one of the steps for an electronic safety strategy
CN101089795A	Keyboard method for single and multiple input Chinese and English [110]	A method for inputting Chinese and English by single-stroke and twin-stroke	Input method applies spelling and stroke for single-stroke, double spelling and double-stroke input, which means twin input, pressing down 4 keys maximally in one-hand twin stroke and 8 keys maximally in two-hands twin stroke, enabling a single stroke and twin stroke to be applied on the digital keyboard of a mobile phone.	Using this input method can bring better convenience to seniors in the typing speed of the new method
US2008280276A1	"Virtual reality tools and techniques for measuring cognitive ability and cognitive impairment" [111]	Tools and techniques that can be implemented to study the impact of treatment and/or quantify the decline of cognitive abilities over a given period.	For senior men, testosterone could add to the degradation of cognitive function. Tools and methods to test or outline the likelihood of such impairment in older people (i.e., those linked to diseases such as Alzheimer's).	Seniors, both men and women, underwent a virtual reality test and spatial navigation testing. Performance was measured over time to quantify and examine changes in cognitive function of those being tested.
US20103324044A1	Method and mechanism for protection, sharing, storage, access, authentication, certification, attachment and tracking anything in an electronic network [112]	A method for tracking any mechanism for creations, content, thoughts, ideas, intellectual property, discoveries and inventions.	Method enables protecting their intellectual property utilized via networked computers, electronic devices (online and offline) and mobile (wireless) devices.	Elderly person is one type of user.
CN101934111A	"Music chromatic light physical factor: physical and mental health system based on computer" [113]	Remote monitoring by biological information detection/environmental monitoring module, Internet and a multi-path camera/microphone of the system.	By positioning technology, a medical health network system is convenient to establish and instantly detects the therapeutic effects by utilizing a biological information sensor, creating an activity environment of system users into a scientific environment.	Seniors and patients are monitored by video and images which can be sent to a mobile phone user assigned by the operator to address the condition or to the medical centre - Equivalent to hospital wards at home.

TABLE 3. *(Continued.)* **Summary of patents.**

CN101972508A	"Cell-phone-based physical and psychological adjustment device through physical factors of music and colour shade" [114]	Design of the environment with different colour schema, brightness, temperature, and humidity for optimal psychological treatment.	Adjustment device (phone based) with integrated positioning technology which is convenient for establishing a medical care network system to detect a treatment effect instantly. Furthermore, it embodies a new biological-psychological-social medical mode, which is a brand-new nonpharmacological treating mode.	Draw a life curve for elderly - regulated body temperature, pulse, heart rate, blood sugar, blood pressure, brain wave, acupoint potential, myoelectric, respiration, vital capacity, vision and hearing biometric information sensor detecting user.
CN102142076A	Dragon ball alphabetic writing as well as application device and method thereof [115]	New kind of writing suitable as a generation/recognition/input method for alphabetic writing-related improvement/design methods for various product equipment.	Civil intelligent automatic recognition eyes which can be arranged on intelligent automobiles, trains, wheels, airplanes, military equipment, automatic production lines of factories, detection equipment of ports and customs and robots.	No specific benefit or use.
US20150732 81A1	"Generating a flow-volume loop for respiratory function assessment" [103]	System and method for respiratory function assessment of a patient in a non-contact, remote sensing environment.	Monitor respiratory function of patients (elderly), chronically ill patients with respiratory diseases and premature babies in a non-contact, remote sensing environment for lung/respiratory function and by a video acquisition system.	Monitors the respiratory function of patients (elderly) free to move around in environments while being monitored for respiratory function.
US20152549 52A1	"Platform of Smart Security Protection Integrated System" [116]	Smart security protection integration system platform coupled with devices to report and extinguish fires	Smart security protection-integrated system platform that has a device to put out fire, notify or send a security alert through a device, a transmission for communication device, an automatic moving device, and a detecting device.	Equipment can achieve the goal of good senior care. The senior caring device electronically connects to the communication transmission device.
EP2918222A1	"Life maintenance mode, brain inhibition method and personal health information platform" [101]	Mode for life maintenance, inhibition of the method and platform for personal health data	Mobile vital sign information acquisition terminal as a tool, taking automatic extraction of characteristic indicators of the vital sign data as the core	Continuous diagnosis and inspection analysis report and trend; performing active control of the change in life condition data by means of the senior.
CN204995459U	"Long -range health monitoring system of family" [117]	Long-range home remote health monitoring system of the family	Home remote health monitoring system including (1) monitoring module with oxygen humidifier (2), microcontroller (3) temperature control for air conditioning, and (4) blood pressure module via Bluetooth	Real-time adjustment of the environmental oxygen content and cooling environment to reduce the probability of a flare-up of an old illness.
CN106215336A	"Recovery monitoring system for old people suffering from Alzheimer's disease" [102]	Recovery monitoring system for seniors suffering from Alzheimer's disease via rehabilitation	Intelligent system used for mild and severe AD patients including (1) ultrasonic brain stimulation therapy recovery module, (2) intelligent smart home video monitoring module, (3) GPS positioning navigation module, and (4) mobile phone APP client module.	Positioning and navigating function for preventing seniors from becoming lost; rehabilitation for elderly with Alzheimer's disease.
EP3178525A1	"Smart mask for health care service" [104]	Smart mask for health care service	Concept of smart mask with functions of health care and facial skin care - detection of snoring or sleep talking during sleep; GPS positioning used for user location; photo-plethysmography (PPG) and electrocardiogram (ECG), blood oxygen saturation (SP02).	The elderly population and patients with respiratory disease, snoring and rhinitis are being treated.
US2018342329A1	Happie home system [83]	Home automation system is provided to facilitate senior care as well as care for individuals suffering from Alzheimer's disease or other dementias.	A home control unit is provided that is connected to, and interfaces with, a combination of health equipment, smart home appliances, a smart medicine cabinet, a smart pantry, wearable sensors, motion detectors, video cameras, microphones, video monitors, speakers, a smart thermostat, lighting, floor sensors, bed sensors, smoke detectors, glass breakage detectors, door sensors, and other perimeter sensors.	Many applications: Solving the consequences of not following a prescribed medication regimen. Monitoring elderly users, remote communication; designed ICT furniture devices for the elderly population.

implemented for outside navigation. The system uses surveillance cameras, photosensors, smoke detectors and alarms, temperature and humidity sensors and relays to remotely control home appliances (e.g., for gas and lights). The system also implements a fire/gas alarm function when smoke $>$ 0.06%. It also contains an automatic voice prompt to alert the elderly users, an automatic delay voice reminder that is started again after several minutes, and an SOS alarm.

The last two examples of patent applications "Generating a flow-volume loop for respiratory function assessment" filed by Xerox Corp. in 2013 [103] and "Smart mask for health care service" filed by Chong-Sik Choi in 2014 [104] address monitoring the respiratory function of the elderly population in some monitored environment. By the Xerox patent, the elderly individual or person with respiratory diseases is free to move around in the environments while being monitored for respiratory function and by a video acquisition system while an image-based depth-sensing device is used to obtain video images and to provide a time-varying sequence of depth maps. The alert signal is generated to a nurse,

TABLE 4. Overview of used ICT solutions for supporting elderly living.

	Publication number	Publication//Granted date	Applicants	Type of Applicants		Family size	Citations							TOP 14 diseases	Monitoring				Wireless Connectivity	Alert/Reminder Service	Elderly cited (abstract/claims/description)	type of usage by Elderly
							BW	Type of Applicants	To Whom Patent is Cited (name or characteristic)	FW	Inter/National	Type of Applicants	Who Cited (name or characteristic)		Resident Activity	Home Environment	Resident Health	Home Appliance				
1	WO0124700A1	12.04.2001	VERIDICOM INC [US]	C	11-50 employees, Computer SW, USA Virginia	1	3	C	FUJITSU - Fingerprint-detecting device, Biometric, personal authentication system	45	I	C, S	NEC, L'Oreal, Fujitsu, Motorola, TATA, Qualcomm, Konika Philips, Infineon, Toshiba	1	X		X		O	O	-/2/-	X
2	CN1662204A	31.08.2005//02.07.2008	NON-INVASIVE MONITORING SYST [US]	C		5	0			2	I	S	Passive simulated jogging device	11		O	O				-/2/13	X
3	US2006190419A1	24.08.2006	BUNN FRANK E ADAIR RICHARD D	S		-	13	S, C	Microsoft, GE MED Syst.,	130	I	S, C	AT&T, IBM, Schneider Electric, American Express Travel, SONY Ericsson	1	X	X	X		O	X	-/23/2	X
4	CN1900886A	24.01.2007	LI YIXIN [CN]	S		-	0			5	I	S	Chinese inventors - methods and keyboard for Chinese characters		-	-	-	-	-	-	-/-/1	X
5	CN1908870A	07.02.2007//29.06.2011	YIXIN LI	S		-	0			2	N	S	Only self-citations - Method and keyboard for Chinese characters		-	-	-	-	-	-	-/1/2	X
6	CN101075316A	21.11.2007	LU HANGCHENG [CN]	S		-	0			39	I	C, S	VISA INT, China Telecom, China Unicom, Chunghwa Telecom, Sharp		-	X	-	X	X	X	-/-/-	-
7	CN101089795A	19.12.2007//16.11.2011	LI YIXIN [CN]	S		-	0			1	N	S	Only self-citation method and keyboard for inputting English		-	-	-	-	-	-	-/-/3	X
8	US2008280276A1	13.11.2008	UNIV OREGON HEALTH & SCIENCE	U		2	34	S, C, U	Eastman Kodak, University California US, University of Emory, University of Rochester, Einstein College of Medicine	16	I	S, C, U	University of Coruna, medical corporations	1	X		X				1/-/39	O
9	US2010332404A1	30.12.2010	VALIN DAVID	S		3	19	S, C	Amazon, Microsoft, Tektronix	64	I	S, C	IBM, Microsoft, Sony, JBF		O	X	O	O	X	O	0/1/2	O
10	CN101934111A	05.01.2011	LONG LI	S		3	0			12	I	C, I, U	Self-citations 3x, University of Nanjing, Hisense, etc	1	X	X	X		X	X	-/6/15	X
11	CN101972508A	16.02.2011	LONG LI	S		1	0			12	I	S, C	Konika Philips, Huizhou TCL Mobile Comm	1	X	X	X	X	X	X	-/1/1	X
12	CN102142076A	03.08.2011	YIZHI GUO,XIEPING HUANG	S		1	0			0					-	-	O	O	X	-	0/0/0	-
13	US2015073281A1	12.03.2015	XEROX CORP [US]	C	130,000 employees, Stanford, USA	-	5	S, C	KONICA PHILIPS ELECTRONICS NV - Ultrasonic image stabilization system and method	3	I	C	SHARP, XEROX CORP - Measurement apparatus, system, and method, respiratory pattern identification	2	X	X	X	X	X	X	1/-/2	O
14	US2015254952A1	10.09.2015	CHAO KANG [TW] CHAO YUNG TAI [TW]	S		2	8	S, C	Boeing, and sole Applicants	6	I	S, C	Monitoring and early warning instrument, systems and solutions	1	X	O	X	X	X	X	-/2/17	X

TABLE 4. *(Continued.)* **Overview of used ICT solutions for supporting elderly living.**

15	EP2918222A1	16.09.2015	WU YIBING [CN]	S		8	2	S, U	UNIV PENNSYLVANIA - Concurrent electrophysiologic and cerebral blood flow neuroimaging	0				1	X	X	X	X	X	X	2/5/142	X
16	CN204995459U	27.01.2016//27.01.2016	HUACHENYANG (SHENZHEN) TECH CO	C	51-200 employees, Medical Devices, China	-	0			0				1		X	X	X	X		1/3/-	O
17	CN106215336A	14.12.2016//28.08.2018	UNIV NORTHEASTERN	U		-	0			0				1	X	X	X	X	X	X	8/14/39	X
18	EP3178525A1	14.06.2017	CHOI CHONG SIK [KR]	S		7	2		KOREA ELECTRONICS TELECOMM - physiological monitoring during sleep, vital signs measuring apparatus and management	1	I	C	L'Oreal - Tool for measuring property of a body surface	1	X		X		X	X	2/-/18	O
19	US2018342329A1	29.11.2018	HAPPIE HOME INC [US]	C	2-10 employees, Computer SW	-	0			0				1	X	X	X	X	X	X	1/1/22	X

NOTE: X - ACTIVE USAGE OR FULL DETAIL; O - PASSIVE USAGE OR ABSTRACT LEVEL OF DESCRIPTION

doctor or respiratory therapist, and the alert can be a pre-recorded voice, text, or video message. A smart mask patent [104] proposed detection of snoring or sleep talking during sleep. The smart mask uses GPS positioning for the user's location and photo-plethysmography (PPG), electrocardiogram (ECG), and blood oxygen saturation (SP02). An alarm is sent out via a speaker and vibration stimulator to the user when the pre-set bio indexes are not met. Both patent applications are trying to manage existing respiratory diseases in the elderly population.

Most patent applications in the patent pool were filed in China (9), United States (7), Canada (1), Taiwan (1) and Korea (1). The first relevant application was filed in 1999 by the inventors O'gorman *et al.* and published as a world patent application [105]. However, most of the selected patent applications were filed in the last 12 years (16x). The most cited patent is ''Video surveillance data analysis algorithms, with local and network-shared communications for facial, physical condition, and intoxication recognition, fuzzy logic intelligent camera system'' [100] with 130 citing patent applications. The patent application that appears most often as a result in the search is ''Reciprocating movement platform for the external addition of pulses to the fluid channels of a subject'' [106]. Nonetheless, it is not entirely relevant as a clear ICT solution because the solution represents the concept of a hospital bed suitable for a specific exercise that has a positive effect on the elderly population with a specific disease in 11 cases (see Table 4).

Modern ICT solutions can communicate wirelessly in most common cases, and 12 of 19 patents also describe a specific wireless communication standard by which other communication devices (of the user or another system) can connect to the designed system or solution protected by the patent application. In recent years WiFi, Bluetooth, ZigBee or NFC connectivity is often mentioned, whereas in earlier patent applications GSM, Internet or radio frequency communication is mentioned [83], [118], [119]. As shown in Table 4, most of the patent applications focus on monitoring user activity, the home environment and health. Since 2011, they often cover the connection and control of home appliances. This trend is a consequence of the increasing trend of IoT, wireless sensors and Industry 4.0 [120]–[122]. Most cases also perform monitoring; when some anomaly is detected, they issue alarms.

1) PATENTS VALUE ANALYSIS

In total, 19 selected and classified patent applications comprised a set of patents where applicants were 5 companies, 2 universities and 12 individual applicants. Most companies were characterized as mostly small- and medium-sized with 10 to 200 employees while one US patent belongs to a big company, Xerox. The university applicants are from the US and China while individual applicants are mostly from China (9 times) and US (2 times and 1 from Korea).

Five patent applications were already granted. The value of a patent application is closely connected with the number of citations from newer patent applications (forward citation count). Seven applications in the pool had received more than 10 citations already. From this point of view, the most valuable patent is US patent No. US2006190419A1 which has 130 international citations. The structure of the citing patents consist of well-known companies, such as AT&T, IBM, Schneider Electric, American Express Travel, and SONY Ericsson, to name a few. The other selected company names are shown in Table 4.

There also other patents with a high number of citations, namely, 64, 45 and 39. These high citation counts confirm that the selected patent applications are from a very active industry area. The total number of all citations to the selected patents is 185.

As mentioned earlier, the patent pool also contains two university patents, cited 0 and 16 times. While even 16 citations is a relatively high number, there was no big company among the citing patents.

2) PATENT CODE CLASSIFICATION

The 19 patents results summarized in the table (Table 4) represent our patent pool, which can be characterized by several properties. One of the most usable is a patent map using International Patent Classification (IPC) codes (Fig. 5).

Each of these three main IPC code groups can be examined in more detail, where the most frequent ones are shown in Fig. 5.

The IPC code A61B5/00 (measuring for diagnostic purposes) was used by 5 patents, representing 18% of our patent pool result of 19 patents. The next most important IPC code G06F3/00 represents input peripheries such as keyboards to be attached to a computer. Furthermore, the other relevant IPC codes were A61N (a subcode for ELECTROTHERAPY; MAGNETOTHERAPY; RADIATION THERAPY; ULTRASOUND THERAPY) and A61 (MEDICAL OR VETERINARY SCIENCE; HYGIENE) of the A group (HUMAN NECESSITIES) already mentioned in Fig. 6 [123].

To provide a more precise technology analysis, we also analysed the technologies in our patent pool, where the IPC classification codes were mapped to technologies and clustered into groups. The clustering algorithm used similar IPC codes to form technological areas, which are defined according to Schmoch's classification (WIPO, 2010) [123]. The result for our patent pool is shown in Table 5, where the largest group represents electrical engineering with 17 patents and the second cluster consists of 14 patents focused on instruments (Table 5).

TABLE 5. Technological areas mentioned in patent pool.

Electrical engineering - 17x	
Audio-visual technology	2
Telecommunications	3
Digital communication	2
Computer technology	8
IT methods for management	2
Instruments – 14x	
Control	5
Medical technology	9
Chemistry – 1x	
Environmental technology	1
Other fields – 1x	
Other consumer goods	1

TABLE 6. Technological areas mentioned in citations to patent pool.

Electrical engineering - 190x	
Electrical machinery, apparatus, energy	1
Audio-visual technology	26
Telecommunications	6
Digital communication	20
Computer technology	101
IT methods for management	36
Instruments – 55x	
Optics	1
Measurement	4
Control	20
Medical technology	30
Chemistry – 1x	
Environmental technology	1
Mechanical engineering 7x	
Handling	1
Other special machines	2
Transport	4
Other fields – 1x	
Furniture, games	3

3) PATENTS TEXT CLASSIFICATION

Another option for patent analysis and classification is the use of text analysis, where it is possible to extract various types of words such as adjectives using a syntactical interpretation of English sentences. A standard visualization uses a tag cloud, as shown in Fig. 7.

To provide a cross-domain analysis, we marked six adjectives for which we provide a more in-depth combination analysis with result visualization (see Fig. 8). Notably, the 15 patents meeting the criteria are Smart, Digital, Personal or Individual. Every patent from our patent pool of 19 selected patents falls under one adjective from the six selected (Fig. 8).

As a final step in the patent analysis, the future trends in patent applications also need to be discussed as evolutionary potential. This analysis showed the number of patents (up to 19) in which a property was identified (see Fig. 9). Properties with a lower count (Test, Components, and Liquid to spray) have a greater innovation potential instead of the most frequently used ones (Information).

Contrarily, properties with high count (Information, Colour, Integration, etc.) provide information about a high accumulation of interest and innovation in this field based on the patent pool structure (Fig. 9).

4) PATENT CITATION ANALYSIS

The patent value is mostly indicated by the number of citations together with the patent family size. Thus, the analysis of citations provides a vital overview of an analysed technological area. For our selected patent pool of 19 patents, there were 185 citations from other patents. These patents were targeted mainly at Electrical engineering, where some

of the subfields were mentioned 190 times according to the IPC classification code analysis (Table 6). The main subfield is Computer technology, which was covered 101 times.

The structure of companies in the role of patent applicants can be characterized as mostly covered by big and well-known world ''players'' such as the already-mentioned IBM, Microsoft, SONY, Sharp and Xerox (see Table 4).

Another factor of patent value is the status that a patent application is granted. This attribute was assigned for 132 patents among the 185, indicating the very high quality of these patent applications.

The analysis also needs to be performed with the evolutionary potential for all 185 citations (Fig. 10). The shape of the graph is similar. All patents deal with Information properties. The most significant increasing update is in the Market property, where almost 4/5 patents covered this parameter compared with only 3/5 for the original patent pool of 19 patents. The citing patents also did not often fall into Surface, which decreased from 4/5 to 2/5 (Fig. 10).

V. DISCUSSION

A. ANALYSIS OF RESEARCH ARTICLES

The results of the analysis of research articles show that elderly users are the leading target group of the solutions, followed by their caregivers and the doctors. Most solutions are in the ''research and development'' phase; meanwhile, only several prototypes and only one final product was presented. In most cases, they are non-invasive solutions, most of which focus on people with dementia and stroke. The study addresses design issues, development, and preliminary deployment, demonstration of effectivity and acceptability. Fig. 11 shows evaluation from the Smart Solution Validation and Ecosystem (Table 1) point of view and according to the three aspects of QoL and well-being (smart ageing determinants, smart solution context and service users).

The most evident fact shows that long-term care is the most frequently used case of ICT and smart solutions usage. Such technologies aid the elderly population in increasing their QoL and well-being and help care for them in case they are affected by some of the most frequent diseases. The second-most used case of ICT solution, Diet and Nutrition, reveals that monitoring of food frequency and quality is very important for elderly home care services. Both most-frequent cases address elderly or patient monitoring as the main group categories of ''Smart Solution Context'' were Resident Activity Monitoring (12) and Resident Health Monitoring (6). The remaining two were distributed according to Resident Health Managing (9) and Home Environment Monitoring (1). Finally, service users were distributed into two major groups as Older Person (15) and Care members (11) while only two remained as Others (2).

B. ANALYSIS OF PATENTS

Patent applications for ICT are targeted mostly by some technical solutions which can be described as a set of interconnected blocks. A set of 19 applications resulted from our search and analysis, whereas compared with the ISI WOK set of 34 analysed records, the patents were even more focused on monitoring the user (resident). Ninety-two percent of the patents included resident health monitoring while 83% covered resident activity monitoring; 71% of patents also provided some alert or reminder service for users or a superior system. Half of the analysed patents also addressed controlling home appliances, and these examples were all from after 2011. This fact confirms the availability and growth of IoT solutions and services which facilitate designing new Home Care and AAL solutions. While almost all new patent applications contain some kind of superior system, none covers the financial aspect of such a solution; this is the most crucial aspect, when a patent application is going to be licensed and used in real life. From the many analysed patent applications only a very few, and in our set none, propose a low-cost home care system useful for easily helping the elderly population in daily life and that can create an information bridge to the caregiver in a remote location. This could bring benefits to almost every elderly person living alone or without daily care by some service or nursing home.

Based on the reviewed literature one can conclude that articles addressing this matter do not cover disability prediction and health-related QoL or fall prevention. Furthermore, the offered solutions do not provide assistive support for prediction, and neither they are flexible, adaptive, or user-centred [34], [58], [125]. Many of the articles did not report about the technology acceptance and/or satisfaction, which is important for the implementation of the smart environments for the elderly population with certain disease conditions. This finding is in line with a previous review which reports that most solutions have never been properly verified by the elderly population [126].

C. SUMMARY OF SUGGESTED SOLUTIONS

The above literature and patent database search show that there are many emerging solutions in relation to selected diseases. To support older people with chronical conditions in being as independent as possible, the existing ICT smart solutions must address the following issues [127]: (1) ease-of-use because many older adults are not comfortable with technologies; (2) invisibility and disuse to isolate older adults; (3) privacy and security to avoid older adults from becoming vulnerable considering their health conditions; (4) affordability of technology in terms of cost; (5) supporting older people to stay in their homes or move in different environments independently.

This is evidenced not only by the specification of technologies from expert articles but also by information about producers that address the given area and that put the products into practice (Table 1).

Most of the publications report solutions that can be used by the older adults, and caregivers or doctors can also use many of them. The trend shows that the recent publications almost always report usage of some type of artificial intelligence in their implementation, which means that with

TABLE 7. Summary of TOP 10 causes of death by WHO in Europe in the context of Smart Home & AAL AND Elderly in ISI WOK database.

Cause of death	Elderly TOP 10 causes of death by WHO 2016 (Europe)					TOPIC by ISI WOK		Smart Home & AAL area (58 701 by topic, 7 027 by title by ISI WOK 2018)						Smart Home & AAL area AND Elderly (2 803 by topic, 717 by title by ISI WOK 2018.12.10)				
								TOPIC			TITLE			TOPIC				
	Age 60-69		Age 70+		TOTAL	TOTAL	Highly Cited in Field	TOTAL	Article	Conference Proceedings	TOTAL	Article	Conference Proceedings	TOTAL	Highly Cited in Field	Article	full text available	Conference Proceedings
	#	total	#	total														
Ischaemic heart disease OR Coronary artery disease OR cardiovascular diseases	1	306700	1	1821000	2127700	454992	4808	78	48	16	3	1	2	9	0	**6**	**6**	2
Stroke	3	121600	2	784000	905600	308645	2121	192	104	93	39	22	16	31	1	**17**	**16**	14
Alzheimer disease OR dementia			3	465000	465000	236781	1954	380	208	142	134	79	50	200	11	**103**	**97**	71
Trachea OR bronchus OR lung cancer	2	131900	5	200000	331900	319813	3148	64	52	11	10	8	2	1	0	**1**	**1**	0
Chronic obstructive pulmonary disease OR COPD OR Chronic bronchitis OR emphysema	5	46800	4	280000	326800	96427	489	43	19	13	6	4	2	10	1	**3**	**3**	3
Colon OR rectum cancers	4	57600	7	169000	226600	205925	1128	32	28	3	8	8	0					
Lower respiratory infections OR respiratory			6	176000	176000	414673	1838	157	93	44	31	17	9	13	0	**6**	**6**	6
Diabetes mellitus OR diabetes	10	27300	8	134000	161300	260034	1870	39	25	13	1	0	1	21	0	**12**	**12**	8
Hypertensive heart disease OR High Blood Pressure OR Hypertension			9	130000	130000	495305	2508	75	52	26	6	4	1	17	0	**9**	**9**	9
Kidney diseases			10	111000	111000	36336	187	17	10	6	1	1	1					
Cirrhosis of the liver	6	46000			46000	61884	614	22	20	1	1	1	0					
Breast cancer	7	36500			36500	530085	4409	124	80	14	20	18	1	5	0	**4**	**4**	0
Stomach cancer	8	35300			35300	24032	168	3	2	0								
Pancreas cancer	9	31700			31700	16601	138	2	1	0								
Elderly	Eurostat EU-28 65+ 1/2016				**98000000**	**1622243**	**5664**	**2803**	**1216**	**1521**	**717**	**193**	**382**	**307**	**3**	**161**	**154**	**113**
					Search results at ISI WOK for "Elderly" only in given columns									SUM by columns				

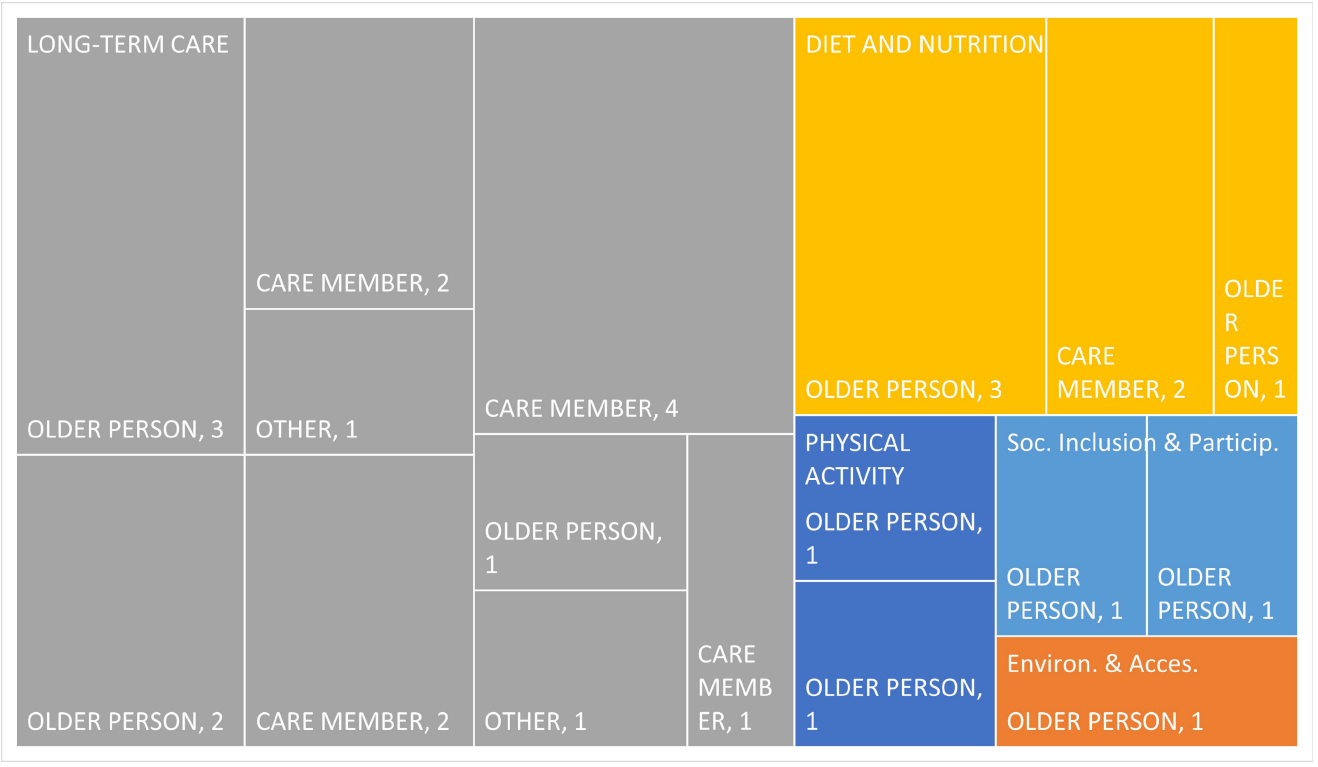

FIGURE 11. Graphical representation of Smart Ageing Determinants, Smart Solution Context and Service Users.

the increased quantity of available data, the solutions will become even better. More than half of the publications use non-intrusive sensing technologies; this is also an improvement because it preserves the privacy of older adults and does not interfere with their daily routine. The negative aspect of the publications is that they rarely address the critical issue of technology acceptance; furthermore, the user interfaces, where available, could be improved with more modern approaches. The smart capabilities, the non-intrusiveness and the ability of the reported solutions to be used by both older adults and caregivers offer promise for the future development of solutions for older adults that would increase their quality of life and maintain health and well-being.

TABLE 8. Summary of TOP 10 causes of death by WHO in Europe in the context of Smart Home & AAL AND Elderly in Patents databases.

Cause of death	Elderly TOP 10 causes of death by WHO 2016 (Europe)					TOTAL Patents		Smart Home & AAL area (70 705 by topic, 58 217 by title and abstract by Patents (14.8.2019))		Smart Home & AAL area AND Elderly (367 by topic, 249 by title and abstract by Patents 2019.8.14)				
	Age 60-69		Age 70+											
	#	total	#	total	TOTAL	TOPIC	TITLE	TOPIC	TITLE	TOPIC (title & abs.& claims)	abstract available	country?	granted?	relevant? (publication No)
Ischaemic heart disease	1	306700	1	1821000	2127700	63738	34040	74	21	4	3	3xCN, 1xCA	2	CN204995459U, CN1662204A
Stroke	3	121600	2	784000	905600	268154	177706	250	117	18	17	13xCN, 2xUS, 2xCA, 1xWO	7	CN101236617A, US2006190419A1, CN1662204A, CN102142076A, US2010332404A1, CN101089795A, CN101075316A, CN101004641A, CN1908870A, CN1900886A
Alzheimer disease OR dementia			3	465000	465000	79230	38985	67	15	14	14	10xCN, 3xUS, 1xCA	6	CN106215336A, US2008280276A1, CN101236617A, CN1662204A, US2018342329A1, CN101089795A, CN101004641A, CN1908870A, CN1900886A
Trachea OR bronchus OR lung cancer	2	131900	5	200000	331900	94399	40163	97	39	5	3	4xCN, 1xCA	2	CN101236617A, CN1662204A
Chronic obstructive pulmonary disease OR COPD	5	46800	4	280000	326800	33421	12995	30	6	3	2	2xCN, 1xUS	1	US2015073281A1, CN1662204A
Colon OR rectum cancers	4	57600	7	169000	226600	39248	8344	34	2	2	0	1xCA, 1xWO	0	0
Lower respiratory infections			6	176000	176000	93020	57562	168	79	7	6	4xCN, 2xEP, 1xUS	2	EP3178525A1, EP2918222A1, US2015073281A1, CN1662204A
Diabetes mellitus	10	27300	8	134000	161300	157881	93436	123	52	5	4	3xCN, 1xUS, 1xCA	1	CN1662204A
Hypertensive heart disease			9	130000	130000	77236	42287	138	30	16	14	12xCN, 2xCA, 1xUS, 1xWO	3	US2015254952A1, CN101972508A, CN101934111A, CN1662204A, WO0124700A1
Kidney diseases			10	111000	111000	35991	12481	43	4	8	7	7xCN, 1xCA	4	CN101236617A, CN1662204A
Cirrhosis of the liver	6	46000			46000	8680	2937	8	1	1	1	1xCN	1	CN1662204A
Breast cancer	7	36500			36500	66620	20732	53	3	3	2	2xCN, 1xCA	1	CN101236617A
Stomach cancer	8	35300			35300	18062	4036	28	3	5	3	3xCN, 2xCA	1	CN101236617A
Pancreas cancer	9	31700			31700	10107	1200	14	0	1	1	1xCN	1	CN1662204A
Elderly	**Eurostat EU-28 65+ (1.1.2016)**				**98000000**	**34879**	**30965**	**367**	**249**	**92**	**77**		**32**	

The patents review identified many solutions that provide caregivers with the means to monitor the state of older adults considering their condition. Some are products that enable impaired adults to interact with the environment, and others are solutions that help them to be more or less independent of caregivers for some activities. Although there are many patents, there are still limitations to the provided solutions, and there is still much research and development that need to be done in order to overcome these limitations. The scientific publications that were considered provide many different solutions to critical problems that the older population faces. These solutions, however, are mostly in the research and development state or in an early prototype state with a small number of exceptions.

The currently available products reflect the specifics of the disease rather than the wider context. They are devices monitoring the state of the individual's health or the surroundings. They are also devices intended to facilitate mobility. Often, they can be used across diseases, but there is no direct link and

benefit towards managing the disease. Thus, the fundamental space and challenge for the applied research workplace is evident as well as the directions of the further research of companies.

D. LIMITATIONS

Despite the valuable insights provided in this study, it suffers from several limitations as well. First, some relevant articles could have been unintentionally left out of this review due to the specificity of the search strings. Second, the examined articles were categorized by variability in the objectives, populations, and results. However, what is generally missing in this area is a quantification of the relationships among QoL, its dimensions, smart determinants, and the factors affecting them, which can be considered a challenge for further research.

E. IMPLICATIONS OF REVIEW

From the review above it is evident that there is a need for standards, safety and interoperability of health-related ICT solutions for the elderly population, as their application requires new infrastructure that is unavailable, expensive or unadjusted to the needs of older adults. In addition, there is a requirement for validation and verification methods to prove the reliability and sustainability of health-related ICT solutions. Furthermore, the awareness of the potential of health-related ICT solutions for the elderly population with different stakeholders should be increased. Finally, there is a need to reflect the various aspects of one's well-being and QoL in the research activities in order to have more accurate results. An initial solution would be to consider each QoL dimension, associate it with key determinants of healthy ageing (e.g., long-term care, diet and nutrition, social inclusion and participation, physical activity, and environment and accessibility), and discuss ICT solutions as building blocks that all sync into the concept of personalized ageing.

Thus, this paper results in several managerial, theoretical, and policy implications, which should be discussed on the micro, mezzo, and macro levels, as done in smart city research [128].

At the micro-level, the essential requirements include communication and connectivity, a unified approach towards data management, and the training and awareness of people in old age, their family members, and caregivers. At the mezzo level, there is a demand for different business intelligence and analytics to be investigated together with the approaches to increase the establishment and management of smart environments for the elderly population. At the macro level, the crucial need is associated with data management and advanced analytics used for monitoring and prediction of indicators related to innovations and sustainability. Finally, all three levels must incorporate the unique needs of people with chronic disease in old age in the design of ICT solutions, which should follow a comprehensive and multidimensional approach in order to improve the QoL and well-being of older people. Furthermore, strategies and policies related to smart environments for the elderly population should cover research into sustainable innovations and related case studies, promoting academic and industrial partnership.

VI. CONCLUSION

A significant current demographic trend is the ageing of the population, which is because of both augmented expectancy of life and a lower rate of births. Therefore, the motivation of this research was to answer the following research questions: What are the described ICT solutions for chosen diseases? Are the current state of knowledge and deployment of technology in practice consistent?

The results from the literature review show that ICT solutions are focused on invisibility, privacy and security to avoid older adults becoming vulnerable and generally support them in staying in their homes or moving in different environments independently.

Regarding the results of the patent analysis, the solutions can often be used across diseases, but there is no direct link and benefit towards managing the disease. Thus, the fundamental space and challenge for the applied research workplace is evident.

An ageing population cannot be seen as a negative phenomenon if society can adapt to this new situation. Information and communication technologies and assisted living services for the elderly population have been shown to significantly reduce the negative consequences of an ageing population.

When considering the current interconnection of research problems in theory, research publications and practice, and actually existing products, it is clear that there is a large gap between the current state of knowledge and the marketing of R&D results.

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CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise, concerning the material or methods used or the findings specified in this study.

REFERENCES

[1] M. Chan, E. Campo, D. Estève, and J.-Y. Fourniols, "Smart homes—Current features and future perspectives," *Maturitas*, vol. 64, no. 2, pp. 90–97, Oct. 2009, doi: 10.1016/j.maturitas.2009.07.014.

[2] M. J. Deen, "Information and communications technologies for elderly ubiquitous healthcare in a smart home," *Pers. Ubiquitous Comput.*, vol. 19, nos. 3–4, pp. 573–599, Jul. 2015, doi: 10.1007/s00779-015-0856-x.

[3] J. Alcalá, J. Ureña, Á. Hernández, and D. Gualda, "Assessing human activity in elderly people using non-intrusive load monitoring," *Sensors*, vol. 17, no. 2, p. 351, Feb. 2017, doi: 10.3390/s17020351.

[4] D. De La Iglesia, J. De Paz, G. Villarrubia González, A. Barriuso, and J. Bajo, "A context-aware indoor air quality system for sudden infant death syndrome prevention," *Sensors*, vol. 18, no. 3, p. 757, Mar. 2018, doi: 10.3390/s18030757.

[5] M. Alirezaie, J. Renoux, U. Köckemann, A. Kristoffersson, L. Karlsson, E. Blomqvist, N. Tsiftes, T. Voigt, and A. Loutfi, "An ontology-based context-aware system for smart homes: E-care@home," *Sensors*, vol. 17, no. 7, p. 1586, Jul. 2017, doi: 10.3390/s17071586.

[6] M. Ghamari, B. Janko, R. Sherratt, W. Harwin, R. Piechockic, and C. Soltanpur, "A survey on wireless body area networks for eHealthcare systems in residential environments," *Sensors*, vol. 16, no. 6, p. 831, Jun. 2016, doi: 10.3390/s16060831.

[7] C. M. el Achkar, C. Lenoble-Hoskovec, A. Paraschiv-Ionescu, K. Major, C. Büla, and K. Aminian, "Physical behavior in older persons during daily life: Insights from instrumented shoes," *Sensors*, vol. 16, no. 8, p. 1225, Aug. 2016, doi: 10.3390/s16081225.

[8] A. Zoha, A. Gluhak, M. Imran, and S. Rajasegarar, "Non-intrusive load monitoring approaches for disaggregated energy sensing: A survey," *Sensors*, vol. 12, no. 12, pp. 16838–16866, Dec. 2012, doi: 10.3390/s121216838.

[9] H. Tokuda, "Smart furniture: A platform for creating context-aware ubiquitous applications everywhere," in *Embedded and Ubiquitous Computing*, vol. 3207, L. T. Yang, M. Guo, G. R. Gao, and N. K. Jha, Eds. Berlin, Germany: Springer-Verlag, 2004, p. 1112.

[10] A. L. Bleda, A. J. Jara, R. Maestre, G. Santa, and A. F. G. Skarmeta, "Evaluation of the impact of furniture on communications performance for ubiquitous deployment of wireless sensor networks in smart homes," *Sensors*, vol. 12, no. 5, pp. 6463–6496, May 2012, doi: 10.3390/s120506463.

[11] A. L. Bleda, F. J. Fernandez-Luque, A. Rosa, J. Zapata, and R. Maestre, "Smart sensory furniture based on WSN for ambient assisted living," *IEEE Sensors J.*, vol. 17, no. 17, pp. 5626–5636, Sep. 2017, doi: 10.1109/JSEN.2017.2721434.

[12] L. Smolentzov, "Older and Younger Adults Perceptions of 'Smart' Furniture," *Gerontologist*, vol. 49, p. 266, Oct. 2009.

[13] R. Maskeliunas and V. Raudonis, "ROBOSOFA-Low cost multimodal I/O fusion for smart furniture," *Int. Arab J. Inf. Technol.*, vol. 10, no. 4, pp. 317–328, Jul. 2013.

[14] P. Marešová, B. Klímová, O. Krejcar, and K. Kuča, "Legislative aspects of the development of medical devices," *Ceská a Slovenská farmacie?: Casopis Ceské farmaceutické Spolecnosti a Slovenské Farmaceutické spolecnosti*, vol. 64, no. 4, pp. 133–138, 2015.

[15] P. Marešová, M. Penhaker, A. Selamat, and K. Kuča, "The potential of medical device industry in technological and economical context," *Therapeutics Clin. Risk Manage.*, vol. 11, pp. 1505–1514, Oct. 2015, doi: 10.2147/TCRM.S88574.

[16] P. Marešová, B. Klímová, and K. Kuča, "Alzheimer's disease: Cost cuts call for novel drugs development and national strategy," *Ceska a Slovenska Farmacie*, vol. 64, pp. 25–30, Jan. 2015.

[17] *Social Services of General Interest—Employment, Social Affairs & Inclusion—European Commission*. Accessed: Jun. 2, 2019. [Online]. Available: https://ec.europa.eu/social/main.jsp?catId=794

[18] *Access to High-Quality Social Services—Employment, Social Affairs & Inclusion—European Commission*. Accessed: Jun. 2, 2019. [Online]. Available: https://ec.europa.eu/social/main.jsp?catId=1169&langId=en

[19] *European Social Policy Network (ESPN)—Employment, Social Affairs & Inclusion—European Commission*. Accessed: Jun. 2, 2019. [Online]. Available: https://ec.europa.eu/social/main.jsp?langId=en&catId=1135

[20] F. van Poppel, G. Bijwaard, M. van Lieburg, F. van Lieburg, R. Hoekstra, and F. Verkade, "The life expectancy of medical professionals in The Netherlands, sixteenth to twentieth centuries," *Population*, vol. 71, no. 4, pp. 659–682, 2016, doi: 10.3917/popu.1604.0659.

[21] J. Rychtarikova, "Length of life, health and attitudes in the European Union.," *Geografie*, vol. 120, no. 4, pp. 542–563, 2015.

[22] N. Botev, "Population ageing in central and eastern Europe and its demographic and social context," *Eur. J. Ageing*, vol. 9, no. 1, pp. 69–79, Mar. 2012, doi: 10.1007/s10433-012-0217-9.

[23] E. Zagheni and B. Wagner, "The impact of demographic change on intergenerational transfers via bequests," *Demogr. Res.*, vol. 33, pp. 525–534, Sep. 2015, doi: 10.4054/DemRes.2015.33.18.

[24] H. Beltran-Sanchez, S. Soneji, and E. M. Crimmins, "Past, present, and future of healthy life expectancy," *Cold Spring Harb. Perspect. Med.*, vol. 5, no. 11, Nov. 2015, Art. no. a025957, doi: 10.1101/cshperspect.a025957.

[25] *Quality of Life Indicators—Statistics Explained*. Accessed: Apr. 23, 2019. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php/Quality_of_life_indicators

[26] O. Vermesan, P. Friess, P. Guillemin, M. Serrano, M. Bouraoui, L. Freire, T. Kallstenius, K. Lam, M. Eisenhauer, K. Moessner, and M. Spirito, "IoT digital value chain connecting research, innovation and deployment," in *Digitising the Industry-Internet of Things Connecting the Physical, Digital and Virtual Worlds*, vol. 49. 2016, pp. 15–29. [Online]. Available: http://www.internet-of-things-research.eu/pdf/IoT_Digital_Value_Chain_Chapter_03_SRIA_IERC_2016_Cluster_eBook_978-87-93379-82-4_P_Web.pdf

[27] G. M. Siddesh, K. G. Srinivasa, S. Kaushik, S. V. Varun, V. Subramanyam, and V. M. Patil, "Internet of Things (IOT) solution for increasing the quality of life of physically challenged people," *J. Organizational End User Comput.*, vol. 29, no. 4, pp. 72–83, Oct. 2017, doi: 10.4018/JOEUC.2017100104.

[28] E. Jones, J. Pike, T. Marshall, and X. Ye, "Quantifying the relationship between increased disability and health care resource utilization, quality of life, work productivity, health care costs in patients with multiple sclerosis in the US," *BMC Health Services Res.*, vol. 16, no. 1, p. 294, Dec. 2016, doi: 10.1186/s12913-016-1532-1.

[29] J. Mendlewicz, "Accuracy of the family history method in affective illness: Comparison with direct interviews in family studies," *Arch. Gen. Psychiatry*, vol. 32, no. 3, pp. 309–314, Mar. 1975.

[30] *Steps to Healthy Ageing | Healthy Ageing*. Accessed: Apr. 23, 2019. [Online]. Available: http://www.healthyageing.eu/steps-healthy-ageing

[31] N. Scherz, I. Bachmann-Mettler, C. Chmiel, O. Senn, N. Boss, K. Bardheci, and T. Rosemann, "Case management to increase quality of life after cancer treatment: A randomized controlled trial," *BMC Cancer*, vol. 17, no. 1, p. 223, Dec. 2017, doi: 10.1186/s12885-017-3213-9.

[32] V. Fernandez-Cervantes, N. Neubauer, B. Hunter, E. Stroulia, and L. Liu, "*VirtualGym*: A kinect-based system for seniors exercising at home," *Entertainment Comput.*, vol. 27, pp. 60–72, Aug. 2018, doi: 10.1016/j.entcom.2018.04.001.

[33] B. Wallace, "Detecting cognitive ability changes in patients with moderate dementia using a modified 'Whack-a-Mole' game," *IEEE Trans. Instrum. Meas.*, vol. 67, no. 7, pp. 1521–1534, Jul. 2018, doi: 10.1109/TIM.2017.2761638.

[34] L. Liu, E. Stroulia, I. Nikolaidis, A. Miguel-Cruz, and A. R. Rincon, "Smart homes and home health monitoring technologies for older adults: A systematic review," *Int. J. Med. Informat.*, vol. 91, pp. 44–59, Jul. 2016, doi: 10.1016/j.ijmedinf.2016.04.007.

[35] D. Pal, S. Funilkul, N. Charoenkitkarn, and P. Kanthamanon, "Internet-of-Things and smart homes for elderly healthcare: An end user perspective," *IEEE Access*, vol. 6, pp. 10483–10496, 2018, doi: 10.1109/ACCESS.2018.2808472.

[36] G. Sacco, "Detection of activities of daily living impairment in Alzheimer's disease and mild cognitive impairment using information and communication technology," *Clin. Interv. Aging*, vol. 7, pp. 539–549, Dec. 2012, doi: 10.2147/CIA.S36297.

[37] F. Rudzicz, R. Wang, M. Begum, and A. Mihailidis, "Speech interaction with personal assistive robots supporting aging at home for individuals with Alzheimer's disease," *ACM Trans. Access. Comput.*, vol. 7, no. 2, pp. 1–22, Jul. 2015, doi: 10.1145/2744206.

[38] A. J. Jara, M. A. Zamora, and A. F. G. Skarmeta, "An Internet of Things–based personal device for diabetes therapy management in ambient assisted living (AAL)," *Pers. Ubiquitous Comput.*, vol. 15, no. 4, pp. 431–440, Apr. 2011, doi: 10.1007/s00779-010-0353-1.

[39] A. Arcelus, C. L. Herry, R. A. Goubran, F. Knoefel, H. Sveistrup, and M. Bilodeau, "Determination of Sit-to-Stand transfer duration using bed and floor pressure sequences," *IEEE Trans. Biomed. Eng.*, vol. 56, no. 10, pp. 2485–2492, Oct. 2009, doi: 10.1109/TBME.2009.2026733.

[40] A. Alberdi, "Smart home-based prediction of multidomain symptoms related to Alzheimer's disease," *IEEE J. Biomed. Health Inform.*, vol. 22, no. 6, pp. 1720–1731, Nov. 2018, doi: 10.1109/JBHI.2018.2798062.

[41] F. Tartarini, P. Cooper, R. Fleming, and M. Batterham, "Indoor air temperature and agitation of nursing home residents with dementia," *Amer. J. Alzheimer's Disease Other Dementiasr*, vol. 32, no. 5, pp. 272–281, Aug. 2017, doi: 10.1177/1533317517704898.

[42] B. J. J. Hattink, F. J. M. Meiland, T. Overmars-Marx, M. de Boer, P. W. G. Ebben, M. van Blanken, S. Verhaeghe, I. Stalpers-Croeze, A. Jedlitschka, S. E. Flick, J. v/d Leeuw, I. Karkowski, and R. M. Dröes, "The electronic, personalizable Rosetta system for dementia care: Exploring the user-friendliness, usefulness and impact," *Disab. Rehabil., Assistive Technol.*, vol. 11, no. 1, pp. 61–71, Jan. 2016, doi: 10.3109/17483107.2014.932022.

[43] B. E. Lyons, "Pervasive computing technologies to continuously assess Alzheimer's disease progression and intervention efficacy," *Frontiers Aging Neurosci.*, vol. 7, p. 102, Jun. 2015, doi: 10.3389/fnagi.2015.00102.

[44] F. Cavallo, M. Aquilano, and M. Arvati, "An ambient assisted living approach in designing domiciliary services combined with innovative technologies for patients with Alzheimer's disease: A case study," *Amer. J. Alzheimer's Disease Other Dementiasr*, vol. 30, no. 1, pp. 69–77, Feb. 2015, doi: 10.1177/1533317514539724.

[45] A. S. Hwang, K. N. Truong, J. I. Cameron, E. Lindqvist, L. Nygard, and A. Mihailidis, "Co-designing ambient assisted living (AAL) environments: Unravelling the situated context of informal dementia care," *BioMed Res. Int.*, vol. 2015, pp. 1–12, Jun. 2015, doi: 10.1155/2015/720483.

[46] A. Lotfi, C. Langensiepen, S. M. Mahmoud, and M. J. Akhlaghinia, "Smart homes for the elderly dementia sufferers: Identification and prediction of abnormal behaviour," *J. Ambient Intell. Humanized Comput.*, vol. 3, no. 3, pp. 205–218, Sep. 2012, doi: 10.1007/s12652-010-0043-x.

[47] S. Muuraiskangas, A. K. Leist, A. Braun, K. Klauß, P. H. M. P. Roelofsma, R. Wichert, P. Klein, and D. Ferring, "V2me: Evaluating the first steps in mobile friendship coaching," *J. Ambient Intell. Smart Environments*, vol. 4, no. 6, pp. 517–534, 2012, doi: 10.3233/AIS-2012-0177.

[48] A. A. P. Wai, V. F. S. Fook, M. Jayachandran, J. Biswas, C. Nugent, M. Mulvenna, J.-E. Lee, and P. Y. L. Kiat, "Smart wireless continence management system for persons with dementia," *Telemedicine e-Health*, vol. 14, no. 8, pp. 825–832, Oct. 2008, doi: 10.1089/tmj.2008.0084.

[49] M. Lavoie, S. Routhier, A. Légaré, and J. Macoir, "Treatment of verb anomia in aphasia: Efficacy of self-administered therapy using a smart tablet," *Neurocase*, vol. 22, no. 1, pp. 109–118, Jan. 2016, doi: 10.1080/13554794.2015.1051055.

[50] K. S. Hayward, B. A. Neibling, and R. N. Barker, "Self-administered, home-based SMART (Sensorimotor active rehabilitation training) arm training: A single-case report," *Amer. J. Occupational Therapy*, vol. 69, no. 4, Jun. 2015, Art. no. 6904210020p1, doi: 10.5014/ajot.2015.016055.

[51] J. Ocepek, A. E. K. Roberts, and G. Vidmar, "Evaluation of treatment in the smart home IRIS in terms of functional independence and occupational performance and satisfaction," *Comput. Math. Methods Med.*, vol. 2013, 2013, Art. no. 926858, doi: 10.1155/2013/926858.

[52] G. Sun, S. Gotoh, Z. Zhao, S. Kim, S. Suzuki, N. Imamoglu, W. Yu, and T. Matsui, "Vital-CUBE: A non-contact vital sign monitoring system using medical radar for ubiquitous home healthcare," *J. Med. Imag. Health Informat.*, vol. 4, no. 6, pp. 863–867, Dec. 2014, doi: 10.1166/jmihi.2014.1334.

[53] J. Demongeot, "Multi-sensors acquisition, data fusion, knowledge mining and alarm triggering in health smart homes for elderly people," *Comp. Rendus Biologies*, vol. 325, no. 6, pp. 673–682, Jun. 2002, doi: 10.1016/S16310691(02)01480-4.

[54] R. Costa, P. Novais, L. Lima, J. B. Cruz, and J. Neves, "VirtualECare: Group support in collaborative networks organizations for digital homecare," in *Handbook of Digital Homecare*, K. Yogesan, L. Bos, P. Brett, and M. C. C. Gibbons, Eds. New York, NY, USA: Springer, 2009, pp. 151–178.

[55] W. A. Rogers, A. D. Fisk, M. A. Neerincx, J. Lindenberg, C. A. P. G. V. D. Mast, and O. A. B. Henkemans, "Usability of an adaptive computer assistant that improves self-care and health literacy of older adults," *Methods Inf. Med.*, vol. 47, no. 01, pp. 82–88, 2008, doi: 10.3414/ME9105.

[56] D. Charron-Prochownik, "The diabetes self-management assessment report tool (D-SMART)," *Diabetes Educ.*, vol. 33, no. 5, pp. 833–838, Oct. 2007, doi: 10.1177/0145721707307613.

[57] G. E. Bond, "Lessons learned from the implementation of a Web-based nursing intervention," *CIN, Comput., Informat., Nursing*, vol. 24, no. 2, pp. 66–74, Mar. 2006, doi: 10.1097/00024665-200603000-00004.

[58] J. van Hoof, L. Schellen, V. Soebarto, J. K. W. Wong, and J. K. Kazak, "Ten questions concerning thermal comfort and ageing," *Building Environ.*, vol. 120, pp. 123–133, Aug. 2017, doi: 10.1016/j.buildenv.2017.05.008.

[59] N. Archer, K. Keshavjee, C. Demers, and R. Lee, "Online self-management interventions for chronically ill patients: Cognitive impairment and technology issues," *Int. J. Med. Informat.*, vol. 83, no. 4, pp. 264–272, Apr. 2014, doi: 10.1016/j.ijmedinf.2014.01.005.

[60] D. O. Johnson, R. H. Cuijpers, J. F. Juola, E. Torta, M. Simonov, A. Frisiello, M. Bazzani, W. Yan, C. Weber, S. Wermter, N. Meins, J. Oberzaucher, P. Panek, G. Edelmayer, P. Mayer, and C. Beck, "Socially assistive robots: A comprehensive approach to extending independent living," *Int. J. Social Robot.*, vol. 6, no. 2, pp. 195–211, Apr. 2014, doi: 10.1007/s12369-013-0217-8.

[61] E. Borelli *et al.*, "HABITAT: An IoT solution for independent elderly," *Sensors*, vol. 19, no. 5, p. 1258, Mar. 2019, doi: 10.3390/s19051258.

[62] A. Algarni, "A survey and classification of security and privacy research in smart healthcare systems," *IEEE Access*, vol. 7, pp. 101879–101894, 2019, doi: 10.1109/ACCESS.2019.2930962.

[63] S. Majumder, T. Mondal, and M. Deen, "Wearable sensors for remote health monitoring," *Sensors*, vol. 17, no. 12, p. 130, Jan. 2017, doi: 10.3390/s17010130.

[64] B. Klimova and P. Maresova, "Wearable and portable monitoring devices for older people," in *Advanced Multimedia and Ubiquitous Engineering* (Lecture Notes in Electrical Engineering), vol. 448. 2017, pp. 446–451, doi: 10.1007/978-981-10-5041-1_72.

[65] S. Lollivier and I. Steinbuka, "Sponsorship group on measuring progress, well-being and sustainable development report of the task force multi-dimensional measurement of the quality of life," EUROSTAT, Brussels, Belgium, Nov-2011.

[66] A. Dasios, D. Gavalas, G. Pantziou, and C. Konstantopoulos, "Hands-on experiences in deploying cost-effective ambient-assisted living systems," *Sensors*, vol. 15, no. 6, pp. 14487–14512, Jun. 2015, doi: 10.3390/s150614487.

[67] D. Giuli, "Ecosystemic evolution fed by smart systems," *Future Internet*, vol. 10, no. 3, p. 28, Mar. 2018, doi: 10.3390/fi10030028.

[68] S. Majumder, E. Aghayi, M. Noferesti, H. Memarzadeh-Tehran, T. Mondal, Z. Pang, and M. Deen, "Smart homes for elderly healthcare—Recent advances and research challenges," *Sensors*, vol. 17, no. 11, p. 2496, Oct. 2017, doi: 10.3390/s17112496.

[69] S. Pearson, "Measuring innovation: Tracking the growth of smart city ideas," in *Smart Cities Application*, S. McClellan, Ed. Cham, Switzerland: Springer, 2020, pp. 153–166.

[70] Y. Liu, L. Zhang, Y. Yang, L. Zhou, L. Ren, F. Wang, R. Liu, Z. Pang, and M. J. Deen, "A novel cloud-based framework for the elderly healthcare services using digital twin," *IEEE Access*, vol. 7, pp. 49088–49101, 2019, doi: 10.1109/ACCESS.2019.2909828.

[71] L. Lei, J. Qi, and K. Zheng, "Patent analytics based on feature vector space model: A case of IoT," *IEEE Access*, vol. 7, pp. 45705–45715, 2019, doi: 10.1109/ACCESS.2019.2909123.

[72] O. Krejcar, "Smart furniture as a component of a smart city—Definition based on key technologies specification," *IEEE Access*, vol. 7, pp. 94822–94839, 2019, doi: 10.1109/ACCESS.2019.2927778.

[73] Z. Liu, Z. Jia, C.-M. Vong, J. Han, C. Yan, and M. Pecht, "A patent analysis of prognostics and health management (PHM) innovations for electrical systems," *IEEE Access*, vol. 6, pp. 18088–18107, 2018, doi: 10.1109/ACCESS.2018.2818114.

[74] E. Zdravevski, P. Lameski, V. Trajkovik, I. Chorbev, R. Goleva, N. Pombo, and N. M. Garcia, "Automation in systematic, scoping and rapid reviews by an NLP toolkit: A case study in enhanced living environments," in *Enhanced Living Environments: Algorithms, Architectures, Platforms, System*, I. Ganchev, N. M. Garcia, C. Dobre, C. X. Mavromoustakis, and R. Goleva, Eds. Cham, Switzerland: Springer, 2019, pp. 1–18.

[75] R. Hervás, J. Fontecha, D. Ausín, F. Castanedo, J. Bravo, and D. López-de-Ipiña, "Mobile monitoring and reasoning methods to prevent cardiovascular diseases," *Sensors*, vol. 13, no. 5, pp. 6524–6541, May 2013, doi: 10.3390/s130506524.
[76] E. Kańtoch, "Recognition of sedentary behavior by machine learning analysis of wearable sensors during activities of daily living for telemedical assessment of cardiovascular risk," *Sensors*, vol. 18, no. 10, p. 3219, Sep. 2018, doi: 10.3390/s18103219.
[77] Y. Xu, "Smart sofa having heating and alarming functions," CN Patent 10 715 717 5A, Sep. 15, 2017.
[78] E. Torres, "Smart Bed," U.S. Patent 053 751 A1, Feb. 21, 2019.
[79] H. Peng, "Smart bed," CN Patent 10 883 659 7A, Nov. 20, 2018.
[80] *Nest × Yale Lock—Key-Free Smart Deadbolt—Google Store*. Accessed: Feb. 13, 2020. [Online]. Available: https://store.google.com/us/product/nest_x_yale_lock?hl=en-US&GoogleNest
[81] M. Pastorino, A. Fioravanti, M. Arredondo, J. Cogollor, J. Rojo, M. Ferre, M. Bienkiewicz, J. Hermsdörfer, E. Fringi, and A. Wing, "Preliminary evaluation of a personal healthcare system prototype for cognitive eRehabilitation in a living assistance domain," *Sensors*, vol. 14, no. 6, pp. 10213–10233, Jun. 2014, doi: 10.3390/s140610213.
[82] M. Oliver, M. Teruel, J. Molina, D. Romero-Ayuso, and P. González, "Ambient intelligence environment for home cognitive telerehabilitation," *Sensors*, vol. 18, no. 11, p. 3671, Oct. 2018, doi: 10.3390/s18113671.
[83] A. P. Rufo, P. K. Rufo, W. J. Mcmaster, J. P. Kosta, and D. S. Petty, "Happie home system," U.S. Patent 342 329 A1, Nov. 29, 2018.
[84] *HAPPIE Home*. Accessed: Nov. 11, 2019. [Online]. Available: http://happiehome.com/
[85] *Smart Home—IKEA*. Accessed: Feb. 13, 2020. [Online]. Available: https://www.ikea.com/us/en/cat/smart-home-he002/
[86] D. F. Mahoney, W. Burleson, C. Lozano, V. Ravishankar, and E. L. Mahoney, "Prototype development of a responsive emotive sensing system (DRESS) to aid older persons with dementia to dress independently," *Gerontechnology*, vol. 13, no. 3, pp. 345–358, Dec. 2014, doi: 10.4017/gt.2015.13.3.005.00.
[87] (Mar. 28, 2019). *Coming Soon: A Revolutionary Smart Mirror by Panasonic*. Medium. Accessed: Feb. 13, 2020. [Online]. Available: https://medium.com/beautytech-jp/coming-soon-a-revolutionary-smart-mirror-by-panasonic-8bcd0d77152e
[88] I. Lazarou, A. Karakostas, T. G. Stavropoulos, T. Tsompanidis, G. Meditskos, I. Kompatsiaris, and M. Tsolaki, "A novel and intelligent home monitoring system for care support of elders with cognitive impairment," *J. Alzheimer's Disease*, vol. 54, no. 4, pp. 1561–1591, Oct. 2016, doi: 10.3233/JAD-160348.
[89] K. López-de-Ipiña, J.-B. Alonso, C. Travieso, J. Solé-Casals, H. Egiraun, M. Faundez-Zanuy, A. Ezeiza, N. Barroso, M. Ecay-Torres, P. Martinez-Lage, and U. Lizardui, "On the selection of non-invasive methods based on speech analysis oriented to automatic alzheimer disease diagnosis," *Sensors*, vol. 13, no. 5, pp. 6730–6745, May 2013, doi: 10.3390/s130506730.
[90] D. Griol and Z. Callejas, "Mobile conversational agents for context-aware care applications," *Cognit. Comput.*, vol. 8, no. 2, pp. 336–356, Apr. 2016, doi: 10.1007/s12559-015-9352-x.
[91] *[LIVART KITCHEN: Brand: Hyundai LIVART]*. Accessed: Feb. 13, 2020. [Online]. Available: https://www.hyundailivart.co.kr/en/brand/kitchen.lvt
[92] A. berbegal y formas SA. *How to Choose Your Office Chair*. Accessed: Feb. 13, 2020. [Online]. Available: https://www.actiu.com/en/articles/news/how-to-choose-your-office-chair
[93] G. Marques, C. R. Ferreira, and R. Pitarma, "A system based on the Internet of Things for real-time particle monitoring in buildings," *Int. J. Environ. Res. Public Health*, vol. 15, no. 4, p. 821, Apr. 2018, doi: 10.3390/ijerph15040821.
[94] *SmartyPans: World's First Smart Cooking Pan*. Indiegogo. Accessed: Feb. 13, 2020. [Online]. Available: https://www.indiegogo.com/projects/1603219
[95] K. A. Earle, R. S. H. Istepanian, K. Zitouni, A. Sungoor, and B. Tang, "Mobile telemonitoring for achieving tighter targets of blood pressure control in patients with complicated diabetes: A pilot study," *Diabetes Technol. Therapeutics*, vol. 12, no. 7, pp. 575–579, Jul. 2010, doi: 10.1089/dia.2009.0090.
[96] P. Salvo, N. Calisi, B. Melai, V. Dini, C. Paoletti, T. Lomonaco, A. Pucci, F. Di Francesco, A. Piaggesi, and M. Romanelli, "Temperature-and pH-sensitive wearable materials for monitoring foot ulcers," *Int. J. Nanomed.*, vol. 12, pp. 949–954, Jan. 2017, doi: 10.2147/IJN.S121726.
[97] E. Zdravevski, P. Lameski, V. Trajkovik, A. Kulakov, I. Chorbev, R. Goleva, N. Pombo, and N. Garcia, "Improving activity recognition accuracy in ambient-assisted living systems by automated feature engineering," *IEEE Access*, vol. 5, pp. 5262–5280, 2017, doi: 10.1109/ACCESS.2017.2684913.
[98] P. Lameski, E. Zdravevski, S. Koceski, A. Kulakov, and V. Trajkovik, "Suppression of intensive care unit false alarms based on the arterial blood pressure signal," *IEEE Access*, to be published, doi: 10.1109/ACCESS.2017.2690380.
[99] R. S. H. Istepanian, S. Hu, N. Philip, and A. Sungoor, "The potential of Internet of m-health Things 'm-IoT' for non-invasive glucose level sensing," in *Proc. IEEE Annu. Int. Conf., IEEE Eng. Med. Biol. Soc., IEEE Eng. Med. Biol. Soc. Conf.*, Aug. 2011, pp. 6–5264, doi: 10.1109/IEMBS.2011.6091302.
[100] F. E. Bunn and R. D. Adair, "Video surveillance data analysis algorithms, with local and network-shared communications for facial, physical condition, and intoxication recognition, fuzzy logic intelligent camera system," U.S. Patent 190 419 A1, Aug. 24, 2006.
[101] Y. Wu, "Life maintenance mode, brain inhibition method and personal health information platform," EP Patent 2 918 222 A1, Sep. 16, 2015.
[102] A. Wang, H. Sun, Q. Ai, and Y. Wang, "Recovery monitoring system for old people suffering from Alzheimer's disease," CN Patent 1 06 215 336 A, Dec. 14, 2016.
[103] L. K. Mestha, E. Shilla, E. A. Bernal, and H. J. Madhu, "Generating a Flow-Volume Loop for Respiratory Function Assessment," U.S. Patent 073 281 A1, 12-Mar-2015.
[104] C.-S. Choi, "Smart Mask for Health Care Service," EP Patent 3 178 525 A1, Jun. 14, 2017.
[105] L. O'Gorman, S. Schuckers, R. Derakhshani, L. Hornak, and X. Xia, "Spoof detection for biometric sensing systems," WO Patent 0 124 700 A1, Apr. 12, 2001.
[106] I. D. Michael and M. A. Sackner, "Reciprocating movement platform for the external addition of pulses to the fluid channels of a subject," CN Patent 1 662 204 A, Aug. 31, 2005.
[107] Y. Li, "Method for single click and multiple key combining click mixing input Chinese and English and keyboard," CN Patent 1 900 886 A, Jan. 24, 2007.
[108] Y. Li, "Method and keyboard for mixed inputting English with single button and multiple buttons," CN Patent 1 908 870 A, Feb. 7, 2007.
[109] H. L. Lu, "Method for managing electronic ticket trade certification its carrier structure, system and terminal," CN Patent 1 01 075 316 A, Nov. 21, 2007.
[110] L. Yixin, "Method and keyboard for single and multiple input Chinese and English," CN Patent 1 01 089 795 A, Dec. 19, 2007.
[111] J. Raber and D. Inman, "Virtual reality tools and techniques for measuring cognitive ability and cognitive impairment," U.S. Patent 2 008 280 276 A1, Nov. 13, 2008.
[112] D. Valin, "Method and mechanism for protection, sharing, storage, accessing, authentication, certification, attachment and tracking anything in an electronic network," U.S. Patent 332 404 A1, Dec. 30, 2010.
[113] L. Long, "Music chromatic light physical factor physical and mental health system based on computer," CN Patent 1 01 934 111 A, Jan. 5, 2011.
[114] L. Long, "Cell phone based physical and psychological adjustment device through physical factors of music and color shade," CN Patent 1 01 972 508 A, Feb. 16, 2011.
[115] G. Yizhi and H. Xieping, "Dragon ball alphabetic writing as well as application device and method thereof," CN Patent 1 02 142 076 A, Aug. 3, 2011.
[116] K. Chao and Y. T. Chao, "Platform of smart security protection integrated system," U.S. Patent 254 952 A1, Sep. 10, 2015.
[117] Z. Gong, Z. Gong, and Z. Gong, "Long-range health monitoring system of family," CN Patent 2 04 995 459 U, Jan. 27, 2016.
[118] A. Nikoukar, S. Raza, A. Poole, M. Gunes, and B. Dezfouli, "Low-power wireless for the Internet of Things: Standards and applications," *IEEE Access*, vol. 6, pp. 67893–67926, 2018, doi: 10.1109/ACCESS.2018.2879189.
[119] M. Zhan, J. Wu, H. Wen, and P. Zhang, "A novel error correction mechanism for energy-efficient cyber-physical systems in smart building," *IEEE Access*, vol. 6, pp. 39037–39045, 2018, doi: 10.1109/ACCESS.2018.2854794.

[120] A. B. L. de S. Jabbour, C. J. C. Jabbour, C. Foropon, and M. G. Filho, "When titans meet—Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors," *Technol. Forecasting Social Change*, vol. 132, pp. 18–25, Jul. 2018, doi: 10.1016/j.techfore.2018.01.017.

[121] B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee, and B. Yin, "Smart factory of industry 4.0: Key technologies, application case, and challenges," *IEEE Access*, vol. 6, pp. 6505–6519, 2018, doi: 10.1109/ACCESS.2017.2783682.

[122] P. Maresova, I. Soukal, L. Svobodova, M. Hedvicakova, E. Javanmardi, A. Selamat, and O. Krejcar, "Consequences of industry 4.0 in business and economics," *Economies*, vol. 6, no. 3, p. 46, Aug. 2018, doi: 10.3390/economies6030046.

[123] U. Schmoch, "Concept of a technology classification for country comparisons," World Intellectual Property Organization, Geneva, Switzerland, Tech. Rep., 2008, pp. 1–15. [Online]. Available: https://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf

[124] *Evolutionary Potential Analysis, PatentInspiration Support*. Accessed: Sep. 7, 2019. [Online]. Available: http://support.patentinspiration.com/hc/en-gb/articles/207202933-Evolutionary-Potential-analysis

[125] A. Vegesna, M. Tran, M. Angelaccio, and S. Arcona, "Remote patient monitoring via non-invasive digital technologies: A systematic review," *Telemedicine e-Health*, vol. 23, no. 1, pp. 3–17, Jan. 2017, doi: 10.1089/tmj.2016.0051.

[126] J. B. Husić, S. Baraković, and E. C. Dinarević, "Smart ageing: Are we succeeding?" in *Proc. IFMBE*, vol. 73, 2020, pp. 387–393, doi: 10.1007/978-3-030-17971-7_58.

[127] O. Vermesan, *Internet of Things Cognitive Transformation Technology Research Trends and Applications*. 2017. [Online]. Available: http://www. internet-of-things-research.eu/pdf/IoT_Cognitive_Transformation_Technology_Research_Trends_IERC_2017_Cluster_eBook_978-87-93609-10-5_P_Web.pdf

[128] A. Visvizi and M. D. Lytras, "Rescaling and refocusing smart cities research: From mega cities to smart villages," *J. Sci. Technol. Policy Manage.*, vol. 9, no. 2, pp. 134–145, Jul. 2018, doi: 10.1108/JSTPM-02-2018-0020.

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