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Chapter

IoT-Enabled Health Monitoring and Assistive Systems for in Place Aging Dementia Patient and Elderly

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Abstract

Hospitals and nursing care homes are facing severe challenges such as lack of skilled workforces and cost explosion, among others. Especially, the western healthcare systems are headed over a cliff. German nursing care houses, hospitals, and government are working hard on solutions to overcome the crucial workforce's crises. Therefore, they are planning to hire nursing-workforces from abroad. They would also like to motivate families with monetary incentives, such as tax-reduction, if they can care for their elderly and/or dementia family members at home. However, caring for a sick person at home is challenging for a working family member especially in the case the patient requests around-the-clock nursing care since elderly with cognitive impairments, people with physical disabilities, and people with dementia need (medical) assistance around the clock. The present study reveals an increasing tendency for family members to care for their sick family member at home despite the challenges and issues faced like the lack of time to intensively care for the sick person due to today's family lifestyle, challenging employment market, financial constraints, etc. The study reported in this chapter aims at providing family members willing to care for their sick member at home as long as possible with smart home automation enabled Patient@Home solution to effectively and efficiently care for their sick member despite working full time. People living in nursing care homes can also take benefit of the proposed system. Evidence shows the potential of the proposed system to effectively and efficiently assist in caring for people requesting nursing care around the clock. Though the health-related quality of life is positively impacted, patient's satisfaction is increased (better quality of experience).

Keywords: remote care, dementia, Parkinson, elderly patient, Internet of things, smart, home automation, age-related impairments, cognitive impairments, health-related quality of life, patient's satisfaction and quality of experience

1. Introduction

Nursing care is facing (is going through) an unprecedented crisis in terms of lack of skilled (health) care workforces. Like all high-income countries (HIC), Germany is going through the said crisis, which is continuously accentuating year after year.

The workforce's needs for long-term care in German nursing houses have been estimated in [1] for the period from 2009 to 2030, expecting an increase:

1. from 94.000 to 331.000 professional nursing and

2. from 157.000 to 298.000 care staff.

Elke Peters et al. have estimated in [2] the number of people living in Germany requesting nursing care to 3 million and to 5 million by 2050. The authors present a recent assessment of the nursing care services at nursing homes and at patient's home and point out the needs for patients to live at home despite the benefit of all care services.

In November 2016, in Mondorf-les-Bains (Germany), a workshop [3] on nursing care had taken place. The topic of the workshop was: Nursing Care at the (German) border Regions? (Ger. Pflege an der Grenze?). The workshop's main objectives were to strengthen the social aspect of nursing care and to more consider the nursing care to be taken place at the place of residence of the patient because of the demographic change and economic as well as employment market policy change. The said workshop pointed out that the share of family nursing care (also called care at home) is very small in comparison with ambulant nursing care. This means, family members do not care for their member requesting for nursing care. One of the main reasons leading to this situation is that the person requesting nursing care at home is living alone. Furthermore, direct family members are requested to participate in care costs. In order to participate, they must work to gain the necessary financial means to face the costs. This situation drives sometimes the family members to employ care staff without or with beginner's care skills to care their parents at home or they send their parents aboard to East-European countries since the nursing care costs are cheaper there though caring at home for a person is not as easy as one can think. Prof. Dr. Eckart Hammer points out in [4] that many dementia patients are subjected to violence by family members who are caring for them at home. By analyzing this book section, one can understand why the German government put effort to solve the care workforce issues faced in order to admit enough nursing care requesting people to the care or nursing homes. Thus, family members who are not able to care for their patients can send them to a nursing/care home. They obviously also want to help the family to decently and lovingly care for their patients and protect the patient against as well as prevent violence. Violence can result from stress faced by the caring person. And the causes of stress are multiple. Violence also occurs in nursing care houses.

People with advanced dementia have complex needs [5]. Schmidt et al. have investigated the needs in a recent study. The study shows the evidence that people with advanced dementia are requesting monitoring round the clock even for a simple activity like "food intake." At nursing care house, monitoring is guaranteed. But what happens if those people are living at their regular residence? This research question is justified by the results carried out by [6], which point out the causes of nursing care workforce shortage and provide recommendations to overcome the issues faced. In [7], the author recommends a series of solutions to fix the workforce shortage. One of these solutions is to use telemedicine to overcome the shortage of issues faced. He writes

Other solutions proposed to reduce the effects of shortages include the use of telemedicine to reach far-away neurologists (though this is unlikely to reduce workloads), the development of artificial intelligence to help in making diagnoses, and expanding neurological care to include non-neurologist physicians and advanced practitioners (specially trained nurses and physicians' assistants)…

The recommended solutions are intended for neurology, though some of them can suite other medical fields.

Using telemedicine to overcome workforce shortage implies to keep a patient at his residence or at the care unit with only primary care services. A further research question rising here is what is the quality of life (QoL) of patients treated at home? Is it worth treating dementia patients at home instead of a nursing care home? Rebecca Palm et al. investigated in [8] the environment as a factor impacting the health-related QoL regarding nursing care for dementia patients. The study reveals that the structural and organizational characteristics of care units may impact the QoL though the study does clearly prove through empirical evidence that the care unit's structure and organization influence the QoL. However, to our best knowledge, no study has investigated the impact of homecare on the health-related QoL based on the QoL measurement metrics pointed out in [8] such as *temperature, noise, lightning, familiarity, adequate space, and opportunities to participate in domestic activities*; it could be subsequently deduced that if the patient's residence place also provides the same environmental criteria as temperature, familiarity, sufficient food, and water, etc., the patient treated at home will undergo the same health-related QoL. In [9], the authors investigated the impact small-scaled nursing care homes have on health outcome-related QoL. They found out that moving from large-scaled to a small-scaled nursing house can improve the aspect of the QoL by reducing the anxiety. This study allows us to conclude that a patient treated at home in his family circle and habituated residence place has less anxiety and better QoL.

It is obvious that patients requesting nursing care can receive nursing care at their residence places with a better health-related QoL. The factors impacting the QoL are well known though caring for dementia, Parkinson's disease, and elderly patients suffering from possible cognitive impairments is a challenging task. The research question raised here is how to assess the factors impacting the QoL for better health outcome?

The literature review on technologies in nursing care or commonly in healthcare reveals that nursing care at home for dementia and elderly patients can take benefit of the technology (cf. section methodology/literature review).

1.1 Study objectives

Homecare is increasingly getting attention among the population for multiple reasons such as the nursing care crisis. This research mainly aims at proposing smart home automation enabled personalized homecare solution for a better quality of life (QoL) for the patient and for assisting the patient's family members to cost-effectively and efficiently care for their patients at home without any impairment of QoL. Furthermore, this study pursues the objectives to assess the impacts of being assisted by home automation system on the QoL of all involving family members.

1.2 Study contribution

This study contributes to the *multidimensionality of the concept of the smart* home where many dimensions of home automation have been considered. The study focuses on many aspects of home automation such as energy saving [10, 11], temperature management, and regulation, security, and safety by managing the entrance, control doors, and windows.

Additionally, the study creates an environment for well-being for people limited in the movement.

1.3 Structure of the chapter

The remainder of the chapter presents in Section 2 some backgrounds and definitions. The research methodology, consisting of a literature review, research data, and system design, is presented in Section 3. Research findings and discussion are presented in Section 4. Section 5 handles a daily personal assistance system, which is designed and implemented to assist patients receiving nursing care at home and who is most of the time alone, and Section 6 concludes the study.

2. Backgrounds and definitions

2.1 Nursing houses and nursing care

According to NIH-UK (National Institute of Health United Kingdom), a nursing home provides hospital-like care services to people (outpatients, elderly, palliative, etc.) that cannot stay in the hospital for any aftercare or for elderly care.

A nursing home is a place for people who don't need to be in a hospital but can't be cared for at home. Most nursing homes have nursing aides and skilled nurses on hand 24 hours a day. (NIH-UK)

It is worth noting the main risk factors of being admitted to nursing and/or care homes (both are similar but are different regarding the qualification of the care-staff—*see care homes vs nursing homes*).

- *Age*: elderly people have more chance of being admitted to a nursing/care home.
- *Low income*: people with low income are vulnerable and have not enough possibilities to hire private care workforce to care for them at home.

Precisely for these reasons, they have a higher chance of being admitted to a nursing home.

- *Poor family support*: especially in cases where the older adult lacks a spouse or children.
- *Low social activity*: isolated people because of cognitive or age-related impairment.
- *Functional or mental difficulties*.

Regarding the risk factors of being admitted to nursing or care homes, it is obvious that a group of people can be excluded from being admitted since they would not meet the conditions.

2.1.1 Nursing homes versus care homes

According to [12], nursing homes have been recommended to employ higher skilled nurse staffing in their homes, with 24-hour registered nursing care.

As the Balcombe Care Homes defines on its website:[1]

[1] https://balcombecarehomes.co.uk/about-us/

A nursing home will provide all the day-to-day care that you would expect from any care home, but the care is supervised by registered nurses who are on duty all day and all night.

while

Care homes are staffed 24 hours a day and a proportion of the staff will be qualified care assistants with NVQs (National Vocational Qualifications) at Level 2 or 3.

2.1.2 What is nursing care?

Segen's Medical Dictionary defines nursing care as

A nonspecific term in medicine; among medically qualified doctors in the UK, nursing care generally refers to procedures or medications which are solely or primarily aimed at providing comfort to a patient or alleviating that person's pain, symptoms or distress, and includes the offer of oral nutrition and hydration

Based on the Segen's Medical Dictionary definition of nursing care, nursing care can be assimilated to palliative as well as elderly care. Most elderly people are requesting nursing care due to health conditions such as cognitive impairments that include dementia, Parkinson, blindness, etc. [13, 14]. Though their chance of being admitted to a nursing home is low, modern technology, as well as methodology such as remote care, can assist to provide them with the needed nursing care at their residence place. The question raised is how will this work?

2.2 Elderly and age-related impairments

The demographic structure of the developed countries (DC) or high-income countries (HIC) contains a large number of older (from 85+ years) and elderly (from 60+ years) people than young people (up to 59 years) and a very small number of teenagers (up to 15 years) in their population. The population of older adults is fastly growing in HIC [15], whereas the population in developing or low- and middle-income countries (LMIC) is remaining younger, although the number of young people is decreasing (see the example of Uganda—**Figure 1**). The median age in LMIC is around 15 years (see **Figure 1**), while the median age in the European Union (EU) is predicted to pass from 36.5 years in 1995 to 47.6 years in 2060 with an increasing tendency [16]. Thus, EU countries are facing an increasingly elderly population with all related needs like nursing and care homes, accommodated elderly healthcare services, etc.

The term "Elderly people" is defined as adults aged 60+ years, while people aged 65+ years are considered as an elder. Orimo, Hajime et al. had reviewed the definition of the term "elderly" in [17] and found out a correlation between elderly and the request or need of medium to severe nursing care.

According to the conventional definition presented by the authors in contrary to the definition above, the elderly is from 65+ years.

Conventionally, "elderly" has been defined as a chronological age of 65 years old or older, while those from 65 through 74 years old are referred to as "early elderly" and those over 75 years old as "late elderly." [17].

Though the World Health Organization (WHO) considers people aged 60+ years as elderly.

At the moment, there is no United Nations standard numerical criterion, but the UN agreed cutoff is 60+ years to refer to the older population [18].

And arguments follow such as why no one can exactly determine the age at which one has to be considered as elderly.

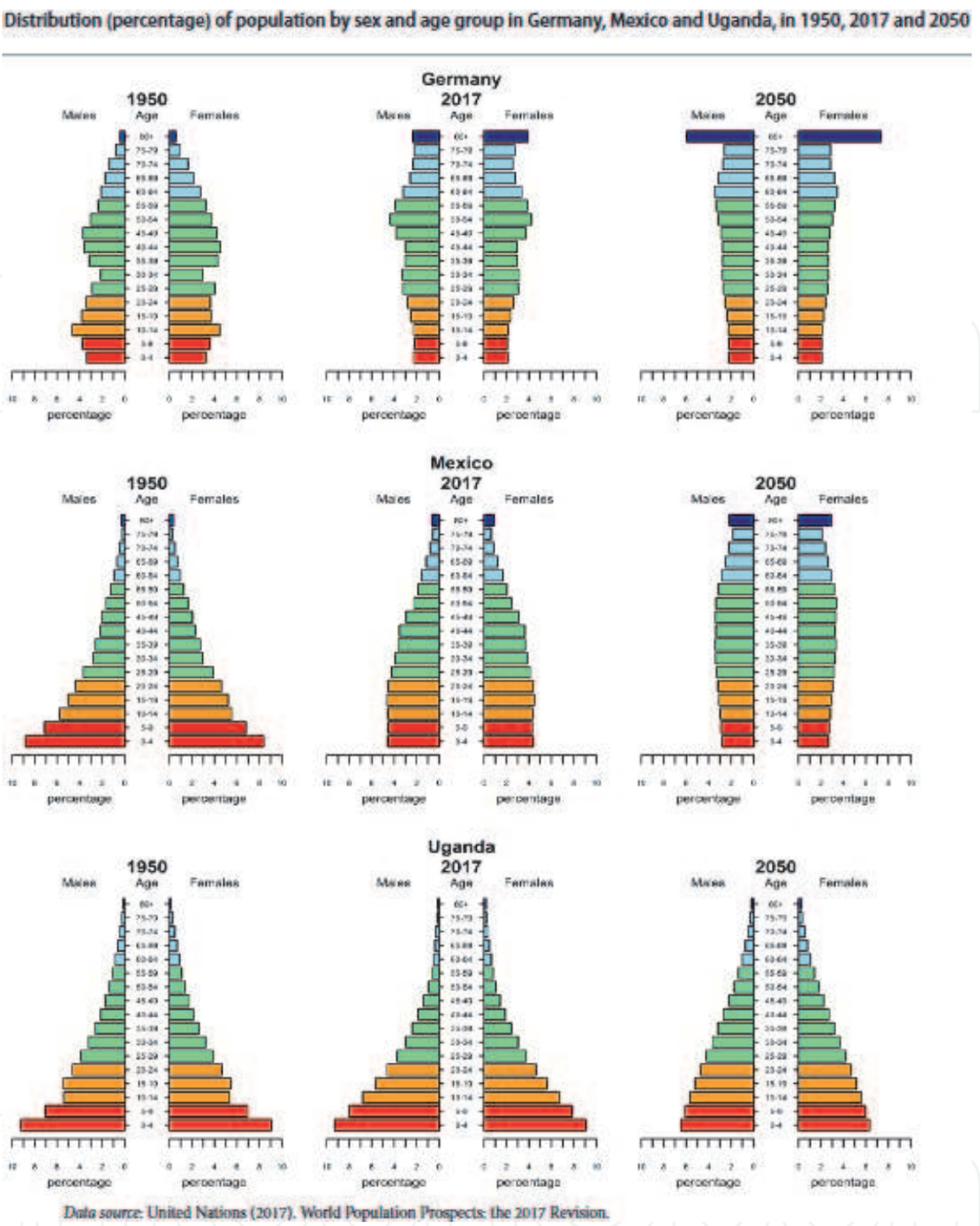

Figure 1.
Projection on demographic change LMIC versus HIC (from 1950 to 2050) [source [19]].

In addition, chronological or "official" definitions of aging can differ widely from traditional or community definitions of when a person is older. We will follow the lead of the developed worlds, for better or worse, and use the pensionable age limit often used by governments to set a standard for the definition [18].

According to the United Nations projection, about 79% of the world elder population aged 60 years or over will live in LMIC by 2050 [19]. Therefore, 20% of them will live in HIC.

Analyzing the population distribution (Figure 6 in [19]) reveals that in countries like Germany, population will count more aging people while an LMIC's population like Uganda's population will remain young.

As a conclusion, it is worth noting that the needs of nursing and care homes are higher in HIC than in LMIC. Therefore, the chapter will more focus on the nursing situation in HIC.

2.2.1 What is age-related impairment

Age-related impairment mostly known as cognitive impairment is a group of diseases, which occurs with advancing age. Cognitive impairment can also occur in young people. Mostly age-related cognitive impairments are dementia, Alzheimer's, Parkinson's, loss of vision, hearing loss, depression, incontinence, etc.

Obviously, cognitive impairment progresses with advancing age. In [17], the authors found out that elderly need from 75+ years severe nursing care. Though nursing care shows the potential to improve the individual's quality of life (QoL), most cognitive impairments cannot be cured. The patient, therefore, needs more attention, for example, reminding him to take food and drink enough water, and bringing him to get socialized again.

In order to better understand why these patients need more nursing care than others, it is worth understanding the symptoms of some cognitive diseases as follows.

2.2.1.1 Dementia

Dementia is a progressive health condition mostly in elderly people. Dementia is a consequence of health conditions like Alzheimer and is characterized by cognitive impairment (loss of cognitive capabilities or abilities).

The Journal of the American Medical Association defines Dementia as

Dementia is diagnosed only when both memory and another cognitive function are each affected severely enough to interfere with a person's ability to carry out routine daily activities.

The free dictionary gives a similar definition as

Loss of cognitive abilities, including memory, concentration, communication, planning, and abstract thinking, resulting from brain injury or from a disease such as Alzheimer's disease or Parkinson's disease. It is sometimes accompanied by emotional disturbance and personality changes.

Regarding the characteristics of dementia, it is highly requested to assist round the clock people suffering from such health condition in order to protect them against any accident that can result from forgetfulness. On one hand, they need assistance, and on the other hand, they can be refused to being admitted to nursing or care home. Furthermore, keeping these people at home remains challenging. Family members caring for these people are mostly by day time at their own job. In this case, the only solution is to employ care/nursing personnel to care for them during the absence of all family members. It is reportedly known that most "care/nursing personnel" hired for homecare are poorly skilled and mostly come from a different cultural background as the patient. The question is can all these factors impact the patient's QoL? Especially, can the cultural differences contribute to QoL loss? Answering this question is out of the scope of the present study.

2.2.1.2 Parkinson's

Parkinson's disease is one of the best-known and most common diseases of the nervous system. It is a cognitive disease and mostly related to advancing age. James Parkinson, the British physician, described the typical symptoms of the disease for

the first time in 1817 and gave his name to the disease. Like a most cognitive disease, is a slowly progressive neurological disease that affects certain areas of the brain. The main symptom of Parkinson's disease is the movement disorder.

People suffering from Parkinson's disease are, therefore, dependent on other people since they are limited in their movement. Furthermore, they can lose the sense of smelling and mostly suffer from Dementia, depression, and anxiety.

2.3 Technologies enabling home automation

The main role of home automation is to control and manage devices at the local network(s) in the house. It can enable remote interactions with the network in order to access some information or to set command. For example, one can remotely ask his fridge or the fridge can send him a grocery list. Many technologies are included in home automation. Technologies like wireless sensor networks, videos, and connected devices support smart home automation paradigm. In [20], Toschi et al. reviewed the technologies that enabled a machine-to-machine (M2M)-based house automation. According to the authors, home automation is tending beyond connecting autonomous toward smart process and devices.

In this section, two technologies are briefly presented. In prior, the term automation is defined.

2.3.1 What is smart home automation?

In [21], Vasseur and Dunkels defined home automation as follows:

Home automation is an area of multiple and diverse applications that include lighting control, security and access control, comfort and convenience, energy management, remote home management, and aging independently and assisted living.

In the context of nursing care, home automation (HA) is a network system and application that includes at the first place bio-signal monitoring, well-being control, and other medical means like medication intake, physical exercises, etc. Further, HA includes temperature management, patient-safety, and security by preventing dangerous actions like leaving furnace or gas on, going out without adequate wearing.

Figure 2 (Source Figure 23.1 in [21]) presents a sample of home control devices.

In [22], Pham et al. defined smart home automation as an environment context-related data for precise health monitoring. They write:

A smart home environment provides ample contextual data related to a resident's health, which allows more accurate health monitoring than only using physiological signals.

They further presented cloud-based home automation that collects bio-signals and location information in order to accurately monitor nursing home residents.

2.3.2 Internet of things and the common architecture

The Internet of things is a paradigm for autonomous data gathering and processing. In [23], Luigi Atzori et al. had defined the Internet of things as follows:

"The Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects, such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc., which, through

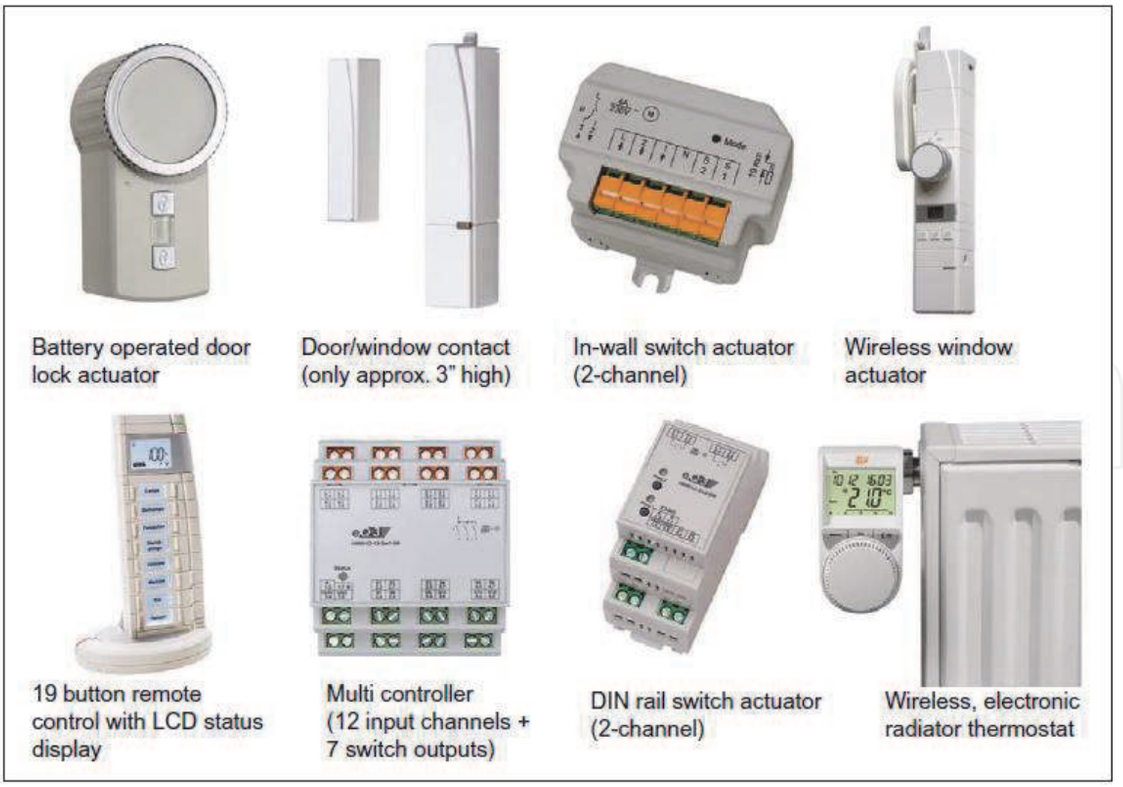

Figure 2.
Sample of home control devices (source: [21]/Figure 23.1).

unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals."

Internet of health things (IoHT) is designed for medical data gathering and processing. IoHT connects unconnected health means with network connectivity ability. Digital and physical medical objects can thus network with each other in collaborating for data collection, processing, and storage. IoHT is a special case of the Internet of things (IoT) that combines health technologies and IoT and takes full advantage of IoT technology like the ability to initiate actions based on collected and analyzed data [24].

IoT finds its application already in the medical world as Istepanian et al. discussed in [25]. Williams et al. have defined the healthcare Internet of things (also called IoHT—Internet of health things) as

"...the new embedded sensing capabilities of devices together with the availability of always being connected, to improve patient care whilst reducing costs [26]."

The common architecture of IoT consists of sensors and actuators called things. Things are located at the data perception level. Behind the things are placed the IoT-gateways and data acquisition systems, followed by the edge IT and the data center (commonly on a remote server) and cloud. There are three (03) layers: (i) perception layer, (ii) gateway layer, and (iii) IoT platform layer.

IoT has the potential to enable home automation in collecting and processing data as well as to autonomously request actuators to execute some tasks for example temperature control by regulating the heater according to the set (for patient comfortable) room temperature.

IoT presents various domain-specific architectures that use various technologies and areas such as RFID, service-oriented architecture, wireless sensor network, supply chain management, industry, healthcare, smart city, logistics, connected living, big data, cloud computing, social computing, and security. **Figure 3** shows an IoT-enabled healthcare data perception system.

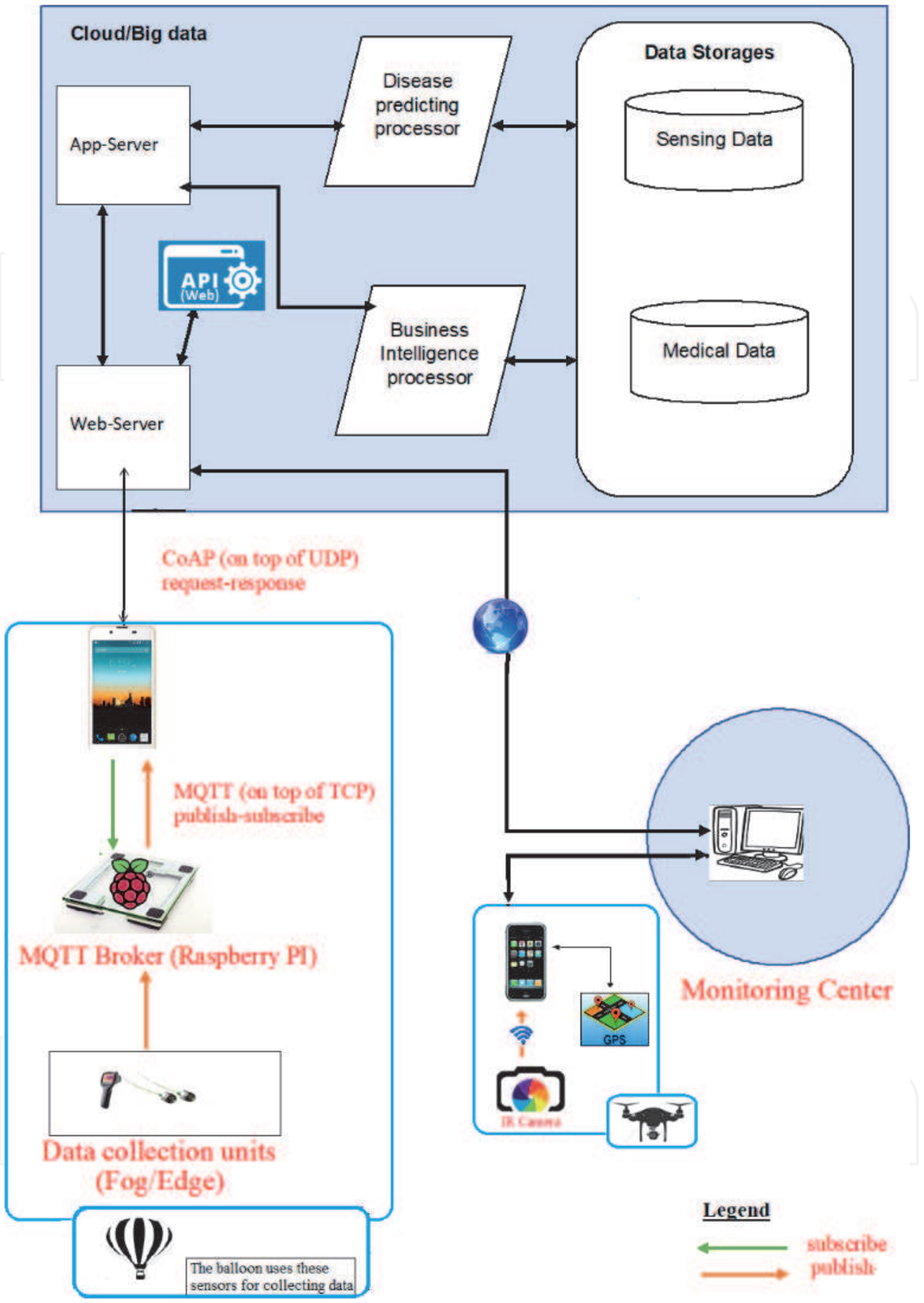

Figure 3.
Healthcare domain specific IoT architecture (source: [27]).

2.3.3 Wireless sensor networks (WSNs) and body area networks (BANs)

Wireless sensor networks (WSNs) find their use in smart home automation application since a while. They are used for medical application and devices to measure the patient's vital parameter. Bio-signals like body temperature, blood pressure, pulse oximetry, ECG, and breathing activity can autonomously and event-based automatically and seamless be measured.

Clinics, hospitals, and care/nursing homes can remotely use end-point devices like video and audio devices to assist family members to care for their sick member at home. Thus, home automation systems can be connected to medical emergency stations at clinics and hospitals close to the patient's residence place and regularly forward the patient's critical data gathered by WSMs and BANs. How this works is presented by Moghadam et al. in [28] where they have designed and implemented a communication system single and multi-antenna in a BAN. They wrote:

"an energy efficient data transmission technique for communication between a single-antenna medical sensor/microrobot inside the body to a multi-antenna receiver on the body surface through non-homogeneous propagation environment."

Transmitting over multiple spatial and temporal scales is challenging in advanced health informatics [29] though advancement achieved in the Internet of things (IoT) protocols like LoRaWAN with platforms like the things network (TTN) [https://www.thethingsnetwork.org/] eases transferring data today.

Wireless body area network (WBAN) is part of wireless sensor networks (WSNs) that can enable monitoring and collecting the patient bio-signal. This has been shown in a previous study [30] where a wireless sensor network system has been used at a cardiologic intensive care unit (CICU) for collecting and monitoring, round the clock, cardiologic activities in-patients. WSNs were connected to the patients and thus bio-signals have been collected in real time. This study has shown the feasibility of using WSNs and WBNs in home automation.

3. Research questions, hypotheses, and scopes

The main objectives behind the research questions are on one hand to investigate the tendency toward homecare regarding the nursing care homes and care work-force shortage and on the other hand to additionally investigate challenges and issues people are facing in homecare. Homecare is when family members care for their sick member at home. The needs in terms of appropriate solutions to over-come challenges and issues faced by caring for patients in homecare are assessed.

3.1 Questions

Q1: What is the tendency for homecare regarding the current nursing care crisis facing HIC?

Three nursing care options are noticed in Germany: (i) nursing care residences with 24 h registered care services and (ii) homecare with the assistance of ambulant nursing staff for a couple of hours per day. Many families hire care personnel from abroad (e.g., Yugoslavia, Budapest, and Ukraine), mostly with beginner's skills or no skills at all to care for their sick parents. Family members also care for the patient following medical instructions, (iii) regarding nursing care homes practiced fees, many families send their sick parents abroad in East European countries.

Q2: What challenges and issues are facing homecare?

Caring for a patient in homecare can be challenging for family members since many patients request round the clock nursing care. This is a full-time job. This study aims at investigating the challenges and issues that can be faced in such a situation.

Q3: Is it worth caring for dementia patients in homecare instead of at nursing care home?

Dementia patients are forgetful. They can forget to take food and drink water. They could forget to turn off a furnace or turn on a heater. Regarding these issues, it is worth assessing how to handle dementia patients.

Q4: What is the quality of life (QoL) of patients treated in homecare?

Many studies investigated the patient's QoL in nursing homes. Measuring or assessing the QoL level of patients in homecare is not achieved. This study aims at assessing it.

Q5: How to assess the factors impacting the health-related QoL for homecare?

There are well-established metrics for assessing the level of QoL in the nursing context though patient in homecare is exposed to additional environmental means. Therefore, it matters to investigate the impact of the QoL of other members on the QoL of the patient. Furthermore, can noise negatively impact the QoL in homecare? A grand-mutter (an elderly) will not be disturbed by a crying grand-child. It is, therefore, important to analyze which criteria are contributing to measuring the QoL in the case of homecare.

Q6: Can the technology assist to overcome homecare-related challenges and issues?

Round the clock care cannot be achieved by one person. It is a challenge. Previous studies have shown evidence for using the technology in healthcare to deliver care at remote, to monitor 24 h a day intensive care patients, etc. Many works have been achieved regarding mental health sensing and assessment, etc. In the present context, this study aims at investigating how home automation supported solution can assist in homecare and overcome challenges and issues faced.

3.2 Hypotheses

H1: The tendency to care for patients in homecare is on increase since the nursing crisis.

The study would like to verify if the nursing crisis has impacted the family member behavior.

H2: Smart automation home technology assists in homecare and impacts the QoL of both family members and the patient.

H3: Smart home automation enables to combine occupation (job) and caring adequately (efficiently and effectively) for a patient at home.

3.3 Scopes

Measuring the quality of services of nursing/care homes is out of the scope of this study, whereas only assessment of the patient's QoL in homecare before and after using the proposed solution constitutes the scope of the present work.

4. Methodology and data

This section presents the conducted literature review on the smart home automation for healthcare purposes. Additionally, data have been collected using semi-structured interview methodology with the objectives to answer the research question and verify the hypotheses.

4.1 Literature review

4.1.1 Paper sampling

In order to conduct a quantitative and qualitative literature review, papers have been sampled using snowball technology. Each found paper provides with

numerous other papers through its references. Appropriate papers were thus found and used for the purpose of this study.

Papers were sought on three major bases: (i) home automation for medical applications, energy, security in the smart home, and trends in the smart home at cities. Beyond the technical part, papers dealing with the nursing care home, homecare, quality of life in nursing residences, and user satisfaction toward the nursing care are the main expressions used to find papers in the better academic literature database.

Table 1 summarizes the important papers reviewed.

Pos.	Title	Abstract	Year of publication	Reference
1	Design of an IoT smart home system	This paper basically deals with the design of an IoT smart home system (IoTSHS) which can provide the remote control to smart home through mobile, infrared (IR) remote control as well as with PC/laptop.	2018	[31]
2	A systematic review of the smart home literature: A user perspective	To facilitate the implementation and adoption of smart home technology, it is important to examine the user's perspective and the current state of smart homes. Given the fast pace with which the literature has been developing in this area, there is a strong need to revisit the literature. The aim of this paper is to systematically review the smart home literature and survey the current state of play from the users' perspective.	2019	[11]
3	Implementation of Smart home automation system on FPGA board using IoT	There has been a rapid introduction of network-enabled digital technologies in home automation. These technologies provide a lot of opportunities to improvise the connectivity of devices within the home. Internet helps to bring in with an immediate solution for many problems and also able to connect from any of the remote places which contribute to overall cost reduction and energy consumption. Intelligence based on microprocessors is used by home automation to incorporate electronic structures in the household.	2018	[32]
4	Smart home technologies in everyday life: do they address key energy challenges in households?	This paper interrogates their contribution to the ambitious carbon emission reduction efforts required under the 1.5 _C mitigation pathway set by the Paris Agreement and their suitability for energy poverty alleviation goals. In	2018	[32]

Pos.	Title	Abstract	Year of publication	Reference
		contrast to aspirational claims for a 'smart utopia' of greener, less energy-intensive, and more comfortable homes currently present in market and policy discourses, we argue that SHTs may reinforce unsustainable energy consumption patterns in the residential sector, which are not easily accessible by vulnerable consumers, and do little to help the 'energy poor' secure adequate and affordable access to energy at home.		
5	Environmental impacts and benefits of smart home automation: life cycle assessment of home energy management system	This paper discusses the life-cycle environmental impact of home energy management system (HEMS), in terms of its potential benefits and detrimental impacts. It is the expectation that adapting smart home automation (SHA) would lead to reduced electricity usage in the household and overall environmental advantages.	—	[33]
6	A review of smart homes—present state and future challenges	In the era of information technology, the elderly and disabled can be monitored with numerous intelligent devices. Sensors can be implanted into their home for continuous mobility assistance and nonobtrusive disease prevention. Modern sensor-embedded houses, or smart houses, cannot only assist people with reduced physical functions but help resolve the social isolation they face. They are capable of providing assistance without limiting or disturbing the resident's daily routine, giving him or her greater comfort, pleasure, and well-being. This article presents an international selection of leading smart home projects, as well as the associated technologies of wearable/implantable monitoring systems and assistive robotics. The latter are often designed as components of the larger smart home environment. The paper will conclude by discussing the future challenges of the domain.	2008	[10]
7	Home automation networks: A survey	Home automation networks provide a promising opportunity in designing smart home systems and applications. In this context, machine-to-machine (M2M) networks are emerging as an	2017	[20]

Pos.	Title	Abstract	Year of publication	Reference
		efficient means to provide automated communication among distributed ubiquitous devices in a standardized manner, but none have been adopted universally. In an effort to present the technologies used in the M2M and home integration environment, this paper presents the home area network elements and definitions and reviews the standards, architectures, and initiatives created to enable M2M communication and integration in several different environments, especially at the smart home domain. This paper points out the differences between them and identifies trends for the future.		

Table 1.
Selected literature among the sampling.

4.2 Data gathering and analysis

A semi-structured interview was conducted. Patients living at home as well as at nursing care home, care and nursing staffs, and people on the street were interviewed. The data collection was carried anonymously in accordance with the operative data privacy regulation in the country.

4.2.1 Data collection approach

4.2.1.1 Quantitative data collection approach

The data collection method has included questionnaires with a mixture of closed-ended (yes or no questions) and open-ended questions. Nursing home residents and patients in homecare were interviewed. Data were thus collected about nursing place tendencies and health-related as well as patient's quality of life with regard to the residence place: nursing home or homecare. No data on the quality of services in any nursing were collected.

4.2.1.2 Qualitative data collection approach

Quality of experience (QoE/QoX) or the satisfaction level is commonly based on a subjective appreciation of the quality of services. Patient's quality of life can be subjective somehow. For example, two distinct persons can differently appreciate noise or the presence of other people. Some elderly can feel uncomfortable when the nurse is a foreigner and ignore some elementary cultural rules. Therefore, nursing home residents were especially interviewed about their feeling, about what makes them feel uncomfortable in order to detect the impacts on their quality of life.

An important point was to determine their subjectivity level toward what makes them feel uncomfortable. Furthermore, test participants were asked

about any discomfort the system has caused to them as well as if they feel observed or patronized.

4.2.2 Cohort sampling

4.2.2.1 Snowball sampling approach

This approach is the more appropriate method to sample the research cohort since sensible data were (anonymously) collected, and for this reason, precisely, it is difficult to find people willing to provide with their medical data. Participants have been selected on the basis of trust in the person who recruits them.

Table 2 summarizes the nursing home resident's cohort. A total of 33 patients were selected and classified per age range and gender. **Table 3** shows the structure of the patients in homecare. A total of 30 patients were selected. The two cohorts were interviewed for investigating the health-related QoL in nursing homes or in homecare as well as their preference in terms of staying at residence or living at home with their family.

Table 4 presents the cohort for investigating challenges and issues faced by homecare.

Table 5 presents an overview of the structure of the testing cohort. According to [17], elderly people aged 75+ years request severe nursing care. Based on this finding, the testing cohort is split into two groups: (i) < 65 year old participants and (ii) 65+ year old participants. All test participants are living at home. Participants living or having poor family support as well as participants with good family support have been selected. The objective was to verify to what extent the proposed solution can assist the patient even if he has no support. Furthermore, the limitations of the proposed system need to be tested in terms of to what extent the third person is needed so that they can fully assist the patient.

Age range	**Total cohort size N = 33**			
	N = 17		**N = 16**	
	Female		**Male**	
	Number	**Health conditions**	**Number**	**Health conditions**
< 50	2	1 Victim of road accident (outpatient)	4	1 Heart attack
		1 Physically disabled		1 Depression
				2 Schizophrenia
50–64	4	2 Dementia (early stage)	5	2 Depression
		1 Blindness + anxiety		2 Physically disabled
		1 Not diagnosed with a mental disorder		1 Anxiety
65–80	5	3 Alzheimer	4	2 Alzheimer
		2 Anxiety		2 Depression
>80	6	3 Parkinson's disease Advanced dementia	3	2 Alzheimer
		3 Alzheimer		1 Advanced dementia

Table 2.
Nursing home residents (cohort structure and diseases they are suffering from).

Age range	Total cohort size N = 30			
	N = 14		N = 16	
	Female		Male	
	Number	Health conditions	Number	Health conditions
< 50	4	3 Heart attack	7	2 Heart attack
		1 Physically disabled		3 Depression
				2 Blindness
50–64	5	2 Mental disorder (early stage)	5	2 Depression
		2 Anxiety		2 Physically Disabled
		1 Physically disabled		1 Anxiety
65–80	3	2 Alzheimer	3	Depression
		1 Anxiety		
> 80	2	1 Parkinson's disease	1	1 Alzheimer
		1 Alzheimer		

Table 3.
Homecare patients (cohort structure and diseases they are suffering from).

Assessment method	Total cohort size N = 515		
	N = 50	N = 68	N = 397
	Care staff*	Nursing staff`*	Other individuals**
Paper-based questionnaires	45	60	385
1:1 semi-structural interview	5	8	12

***Only people that are caring or have cared for a family member were selected to participate.*
**Only staff involved in homecare.*

Table 4.
Nursing staff and people interviewed on the street.

Age range	Gender	Participants	Family support		Dementia		Other cognitive diseases		NCD/CD
			Good	Poor	Yes	No	Yes	No	
<65	Female	6	5	1	1	5	4	1	Diabetes
	Male	9	4	5	0	9	7	2	Heart diseases diabetes
>65	Female	11	8	3	3	8	8	3	
	Male	7	2	5	1	6	6	1	

**NCD, non-communicable diseases; CD, communicable diseases/infectious diseases. No data collected on CDs.*

Table 5.
The testing cohort.

4.2.3 Questionnaires for semi-structured interviews

This section summarizes the different questionnaires (**Tables 6–8**) used for the different surveys. At nursing homes and at participant's home (case of homecare),

the questionnaires were used in 1:1 structured interview followed by a semi-structured interview. Distractor or control questions are inserted into the questionnaire in order to detect discrepancies in the responses and thus filter the biased responses (**Tables 6–8**).

4.2.4 Data analysis

Data analysis was made using IBM SPSS Statistics. Data were cleaned up; biased responses were not included in the analysis. Data dealing with a tendency for care at home as well as at nursing were accordingly classified. An AVG of the scores each category reaches was built. Before building the AVG, the different scores per category (stay at home or living at a nursing residence) obtained were compared with each other. The tendencies were plotted for visual analysis.

4.3 Testing design and methodology

Participants (**Table 5**) were selected using a snowball approach.

The action research methodology was applied for the testing. The system was adjusted according to the results in a phase and re-tested in the next phase. The test lasted one (01) week in the first phase. Data were collected and analyzed. The second phase took one (01) week again and findings from phase 1 were worked into phase 2.

Pos.	Questions	Observations
1	What do you most of all miss here?	Check how many patients prefer staying at home instead of living at the residence
2	Do your relatives visit you?	
3	How often do your parents visit you?	
4	Do you have any close friends here?	Socialization measurement
5	Are you missing your former friends?	Socialization, if he misses his former friends, this means he does not find a one here
6	Do you miss your parents, children, and grandchildren?	If yes, it means he does not receive enough or regular visits
7	Do you like living here?	
8	Do you have enough space for you?	
9	Are you missing your home?	
10	Do you receive enough and regularly food and water?	
11	What did you eat today?	Check if he is forgetful in order to consider or not the responses above
12	How do you feel today?	Assess the quality-of-life related to the patient's health state and care services he is provided with
13	Are the nurses nice to you?	
14	Which nurse is your best friend?	

Table 6.
Questionnaire for patients.

Pos.	Questions	Observations
1	Do you face any challenge during the admission process?	Assess how hard is it to get admitted to a nursing home
2	Would you prefer caring for your parent in homecare? If yes, why? If no, why?	Assess the tendency for homecare And find out why they have a tendency for one or other
3	Are you more confident to let care for your parent in a nursing home? If yes, what gives you that confidence? If no, why? Do you have no trust in nursing?	
4	Do you have a job? If yes, full-time or part-time?	Determine how one can manage both activities
5	If you respond to questions 2 and 4 by yes, then continue here; otherwise, go to the next question. How could you care for your parent in homecare and go to your job or on holidays?	
6	Have you ever experienced caring for a parent at home? If yes, how challenging was this?	Find out the real challenges people who experienced homecare are facing
7	Do you have any idea about which challenges and issues can be faced in homecare? If yes, which ones?	Challenges and issues in homecare. Home automation system should help to overcome these issues
8	Can modern information technology assist in homecare? If yes, how?	Determine the most needed functionality

Table 7.
Questionnaire for no-care staff to check their tendency for homecare or nursing care homes.

Pos.	Questions	Observations
1	Which challenges and issues are you facing daily?	
2	Do you have any technical assistance?	
3	How do you monitor the residents around the clock?	
4	Do you often assess the health-related quality of life of each patient?	
5	How many admissions do you register every year?	Assess the admission tendency
6	What is the admission tendency?	
7	How can you explain the tendency?	

Table 8.
Questionnaire for care-staff to investigate the trend toward the admission application.

At the end of each phase, a quantitative and qualitative analysis was performed. Patient's quality of life (QoL) and satisfaction level were measured in the light of the defined metrics (**Table 9**).

An important point was to involve participants living alone or having poor family support as well as those who have good family support. The objective to do so was to test if the system is well designed to assist people living alone too and how they are comfortable toward using the system (usability).

Quality of life measurement metrics	Description
Food and water intake	This metric verifies how many times the participant failed to take food and water.
Medication intake	Does the participant follow the medical instructions and take the medicine as prescribed?
Physical activities	Does the participant go out for physical activities or perform some at home?
Socialization	How many social contacts the patient has? Does he connect to other people or is he isolated?
Room temperature management	Does the system correctly learn from the participant preferences and set the temperature accordingly?
Noise and lighting control	Noise and light can make the individual feel uncomfortable
Familiarity	How familiar is the place to the individual
Accident rate	Does the system assist and prevent the participant from accident such as injury with a knife, fall down, etc.?
Emergency management	Does the system correctly detect emergency cases and thus manage the emergency?
Bio-signal gathering and data quality	

Table 9.
Quality of life measurement metrics.

4.3.1 Health-related quality of life (QoL) and user satisfaction (quality of experience) measurement metrics

In order to measure and asses the impacts of the proposed solution on the quality of life, a set of quality of life metrics were defined. The results of the experiment were analyzed in light of these metrics.

4.4 Ethical approval

Authorization and written informed participant consents were received from all major participants and their parents. An ad-hoc ethics committee at the involved clinics examined the request to conduct such an interview involving home's residents and approved it. Resident's parents also approved the study.

5. Findings and discussion

This section presents the study findings and discusses the results in light of data analytics.

5.1 Literature review on smart home automation for homecare

The literature review has pointed out that only a few previous types of research consider the *multidimensionality of the concept of the smart home.* Mostly the studies are focused on one aspect of smart home such as energy management [11].

A total of 656 abstracts and 239 full papers (journal and conference papers) were reviewed. Only 41 papers were retained having met the requirement of the present study. Unfortunately, only two papers have discussed many dimensions of smart homes. The rest mostly handle the topic of energy management at home. Smart home for elderly people is well considered in many papers, but the papers have failed to consider the multidimensionality of the concept of "aging at home".

Regarding the results, a novel solution considering the multidimensionality is therefore highly needed.

5.2 Interview findings

5.2.1 Patient's preferences

The interview with nursing home residents has revealed that elderly people prefer staying at home in their familiar and usual social environment (familiarity) and take care of their health by themselves as long as they are able to though only participants with good family support and those who have children, grandchildren, and good social contacts have the wish to stay at home as long as possible. However, alone living people, poor people, and people having no family support feel comfortable at the nursing residence.

Table 10 summarizes the results of the interview. Up to 91% of people living alone prefer residing in nursing homes, while more than 91% of people with good family support prefer staying at home with their family members.

5.2.2 Tendency toward homecare and nursing homes

Beyond the research questions, three (03) hypotheses were set. One hypothesis concerns the tendency for homecare as well as for nursing care home.

***H1**: The tendency to care for patients in homecare is on increase since the nursing crisis.*

The study verifies on the light of interview results the hypothesis H1. The survey was carried out to investigate the impact of the nursing crisis on the family member behavior toward the nursing care option for their patients.

The surveys point out the following results:

Category	Social status	Number	Preferences	
			Living at nursing care home	Staying at home
Nursing home residents (33 participants)	Poor family support Poor (financial) Have lived alone	21	17 (85%)	4 (15%)
	Rich Good family support Good social contact	12	01 (8.3%)	11 (91.7%)
Homecare participants (30 participants)	Living alone	23	21 (91.30%)	2 (8.70%)
	Living with family	7	0	7 (100%)

Table 10.
Participant's preferences toward living in nursing homes or staying at home.

There exist two categories of care: (i) stationary and (ii) ambulant nursing care [34].

People traditionally choose nursing residences for many reasons: (i) many people are living alone or have poor family support, (ii) the patient is at the end of life and needs severe intensive and palliative care, (iii) the care level (Ger. Pflegestufe).

A total of 118 healthcare staffs were interviewed. A total of 397 individuals on the street were also interviewed. A total of 56.78% of the interviewed care personnel admitted that the number of applicants for being admitted to a nursing home is

Assessment method	**N = 118**		
	Application for being admitted in nursing care residence		
	Decreasing	**Increasing**	**Stable**
Care personnel	67 (56.78%)	23 (19.50)	28 (23.72)

Table 11.
Tendency viewed by healthcare staff.

Assessment method	**N = 397**			
	Care experience	**Care for sick family members in homecare**		
		Prefer	**Do not prefer**	**Prefer going abroad**
People on the street	200 experienced with nursing homes	233 (58.69%)	97 (24.43%)	67 (16.87%)
	197 not experienced with nursing homes			

Table 12.
Preference of caring for a patient at home.

Pos.	**N = 397**		
	Challenges and issues	**Number (%)**	**Comments**
1	Nocturnal rest	397 (100%)	The family members have no rest. They can sleep well since assisted by the machine
2	Emergency issues	375 (99.5%)	Patient-centric data are collected.
3	Limited round the clock nursing	397 (100%)	x
4	Inaccurate collected data	40 (10.07%)	x
5	Combining job and care for a family member		The system shows potential to assist people in caring for their in parents aging in place
	Only part-time	317 (80.01%)	
	Stress	397 (100%)	
	Financial issue	298 (74.81%)	
6	Loss of quality of life	397 (100%)	
7	Limited social activities	290 (73.04%)	
8	Depression	15 (3.8%)	

Table 13.
Challenges and issues faced in homecare.

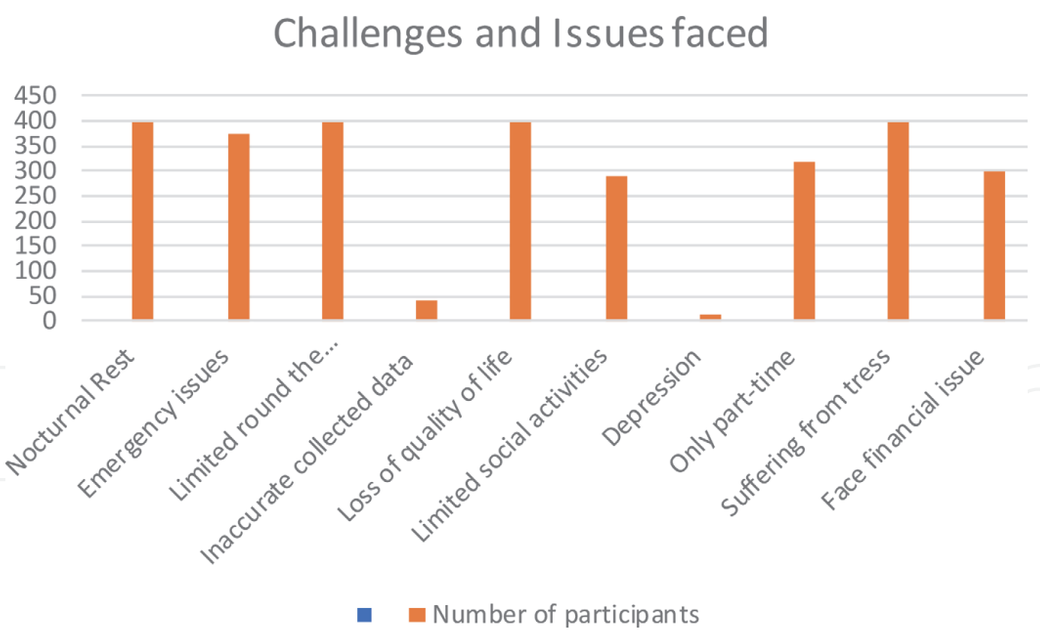

Diagram 1.
Number of participants facing challenges and issues in homecare.

Pos.	Metrics		N= 30 (Test last 2 weeks)			
			Number (%)			
			Before the test (AVG of 5 days observation)		After the test (Data provided by the system)	
			Have met the metrics			
			YES	NO	YES	NO
L1	Food and Water Intake		12 (40%)	18 (60%)	22 (73,33%)	8 (2,66%)
L2	Medication Intake		17 (56,6%)	13 (43,4%)	23 (76,6%)	7 (22,4%)
L3	Physical Activities		4 (13,3%)	26 (86,7%)	11 (36,6%)	19 (62,4%)
L4	Socialization		3 (10%)	27 (90%)	13 (43,33%)	17 (56,6%)
L5	Room Temperature management		3 (10%)	27 (90%)	26 (86,7%)	4 (13,3%)
L6	Noise and Lighting control		2 (6,6%)	28 (97%)	7 (22,4%)	23 (76,6%)
L7	Accident rate		1 (3,3%)	29 (26.7%)	1 (3,3%)	29 (26.7%)
L8	Good Emergency management		5 (16,6%)	25 (23,4%)	15	15
L9	Bio-signal gathering and data quality		1 (3,3%)	29 (26,7%)	18 (60%)	12 (40%)
L10	**Results**	Quality of life	Mediocre		Good++	
L11		Health outcome	Good-		Good+	

Legend (Comparing before and after test data)

Good++	
Bad	
Unchanged	

AVG	

Table 14.
Comparison of patient's quality of life before and after applying the proposed solution.

being slowly decreasing, while 58.69% of people interviewed on the street prefer to care for relatives in homecare.

Tables 11 and **12** show the tendencies of nursing care. The results obtained have confirmed the hypothesis H1.

5.2.3 Challenges and issues faced

The quantitative results regarding challenges and the number of people that reported these challenges and issues by caring for a family member are summarized in **Table 13** (**Diagram 1**). The quantitative data analysis reveals that very few people in home care are faced with data collection issues. This means data are rarely

collected in home care. Thus, patients laying at home do not produce patient-centric data. The few data there produce is patient-centered. It is though known that patient-centered data are subjective, incomplete, and sometimes biased [27, 35].

5.3 Testing findings

H2: Smart automation home technology assists in homecare and impact the QoL of both family members and the patient.

The testing has confirmed the hypothesis (H2) regarding the user satisfaction's level and the quality of life (QoL) at both patient side and family side. **Table 14** (**Diagram 2**), **Table 15** (**Diagram 3**), and **Table 16** show detailed results.

H3: Smart home automation enables to combine job outside and adequately (efficiently and effectively) care for the patient in homecare.

The hypothesis is verified. Working family members can partially, full-time, work at home (home office), or go to the job and also care for a member.

5.3.1 Patients

Overall, broad satisfaction is noticed among the participants and their relations.

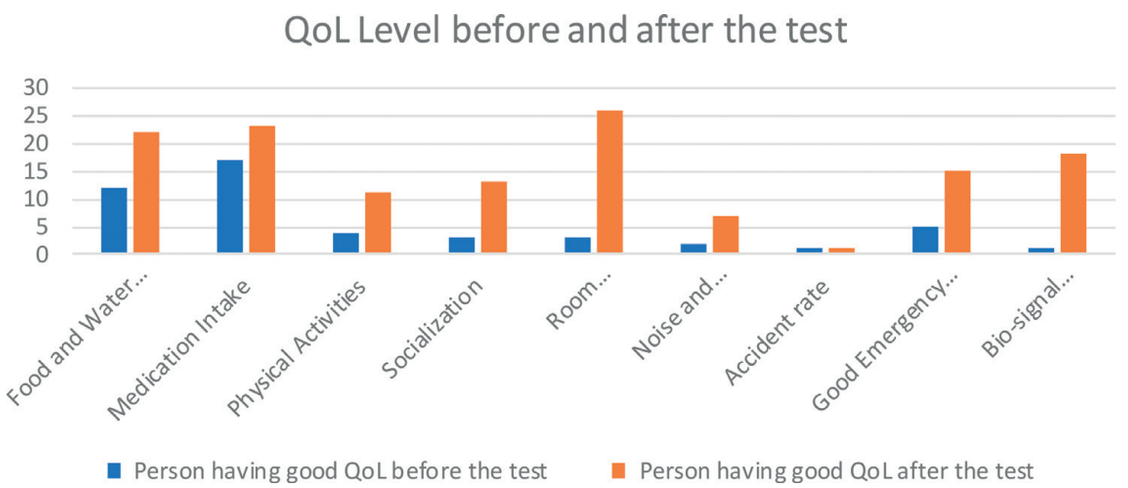

Diagram 2.
QoL level.

Metric [Link to Table 14 (column YES in after test)]	**Cohort sampled after the test. It contains people having good metrics.**		
	Total participants	**Participants with good QoL and the family support level they received during the test**	
		Poor	**Good**
Food and water intake [L1]	N = 22	7	15
Medication intake [L2]	N = 23	5	**18**
Physical activities [L3]	N = 11	2	9
Socialization [L4]	N = 13	3	10
Results	*About **7** have good QoL among 30 Patients after the test* *About **18** have good QoL among 30 Patients after the test*		

Table 15.
Impact of family support level on the patient's QoL.

The solution shows positive impacts on the quality of life (Good++, 36.6% started physical activities and 43.33% re-socialize). Due to the solution, 36.6% reconnect to physical activities, which means an increment of 23.3%. Nevertheless, about 62% remains without physical activities.

5.3.2 Family members

The solution has the pottential to assist people in combining full-time or parttime job with caring for a family member in home care. Since many people

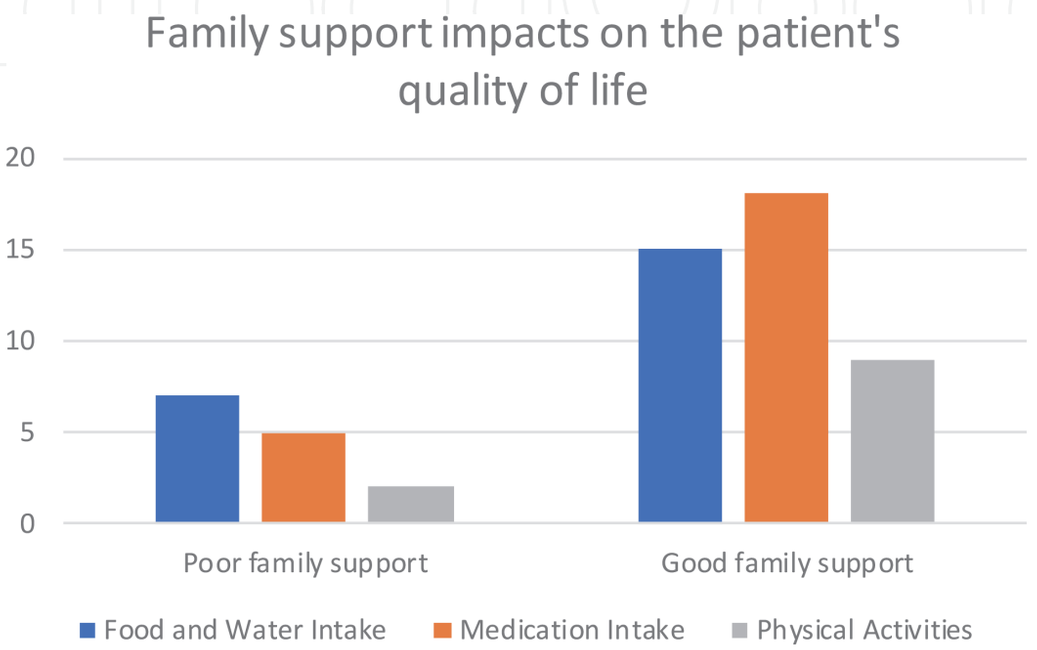

Diagram 3.
Impact of family support on the QoL.

N = 45 (patient's relatives)		
Metrics	**Before the test (Survey + 5 days observation)**	**After the test (Data provided by the system + observation)**
Quality of life	Average	Very good
Socialization	Few	Good
Nocturnal rest	Bad	Very good
Emergency management (quick medical assistance)	Bad	Good
Quality of communication with doctors	Bad	Improved
Bio-signal gathering and data quality	Worst	Improved (good)
Job situation	Worst (no job, part-time job)	Good (mostly full time)
Financial issues	Bad	Improved
Depression	Highly depressive	Less depressive

Table 16.
Comparison of family member's quality of life before and after applying the proposed solution.

aging in place still have the ability and capability to walk and can go out and back home alone, the system assists them and monitor their health condition in order to timely alerte parents and medical doctors in the case of emergency. The results had also shown evidence of improving the quality of life. An upcoming paper will report work conducted on this topic.

6. Health monitoring and daily personal assistance as approach

This section presents the concept of a *multidimensional smart home automation Internet of health things* for assisting dementia patients and elderly to "aging well at home". Additionally, the solution should assist the patient's family members to care for them and go to their occupation as usual.

The section presents the system requirements, features, concept, and architectural view.

6.1 System design

6.1.1 Requirements

The need analysis including the analysis of collected data leads to define the following system requirements and features, which the smart home solution for elderly and dementia patients will provide. As shown above, the health-related quality of life (QoL) is measurable by means of:

1. *The nutrition level (intake of food and water):* elderly and/or dementia patient is the most forgetful and could forget to take food and regularly drink water. This can cause severe health issues.

2. *Medication adherence:* medication adherence level influences patient health outcomes. Dementia patient who adheres to the prescribed medication could have comfortable days.

3. *Physical activities and socialization level:* both influence the patient's QoL.

4. *Family support:* Makes the patient feel more confident, secure, and safe. This is a factor impacting the patient's QoL.

5. *Space and comfort*: More space is a comfort that prevents anxiety in an individual since small space limits activities and movements.

Regarding the QoL measurement metrics, the following system requirements have been defined:

1. Qualitatively and quantitatively assess a patient's QoL level

2. Provide daily living assistance

3. Support patient empowerment and autonomy

4. Positively impact patient's health outcomes

5. Collect patient-centric data and information for accommodated and personalized health care services

6. Further, assist family members to efficiently and effectively care for their sick member at home

The main system-relevant requirement is to provide patients with a cheaper, simple, and better usability by considering their cognitive impairment like eye, hearing, and feeling impairment, restricted movement, etc. Additionally, the proposed solution should work online and offline.

6.1.2 System features

According to the system concept, the following features are provided to meet the requirements above.

6.1.2.1 Food and water intake monitoring

A designed water and food dispenser monitors the patient and can provide him with the food he needs. The system ensures that the patient drinks enough water so as to prevent him from feeling thirsty.

6.1.2.1.1 Food order process

1. Day menu presented.

2. The patient chooses a menu or the system selects 3 favorites based on historical data collected.

3. Food is ordered at the close restaurant and registered for the program.

4. Food is delivered.

6.1.2.1.2 Food dispenser

1. Food is stored in the special fridge (WaFoD).

2. At an appropriate time, the food is warmed.

3. The patient is served.

6.1.2.1.3 Reminder for family member

In case a family member is at home and wants to care for the patient, WaFoD sends an alert to the member.

In the case of ordering food, then food order process will run otherwise the food dispenser will run.

6.1.2.2 Medication intake monitoring

Similar to food intake, a drug dispenser is equipped with a high-resolution camera which logs the drug intake. A future extension will automatically perform anomaly detection on recorded films.

The medication intake is then logged. The logs are sent to the family member and the doctor.

6.1.2.3 Physical activities (in- and outdoor activities)

Special TV programs are displayed at certain times of the day to help the patient to train himself. The patient wears a body-area-networking (BAN) equipped with bio-sensors and accelerometer, which continually controls the position of the patient in order to detect if the patient is falling down or lying on the bed.

For dementia patients, no outdoor program is set.

6.1.2.4 Room temperature monitoring

Temperature control is a well-achieved domain application in smart home automation. Existing devices and systems are added to the network.

6.1.2.5 Noise and lighting control

This feature prevents any noise and controls the lighting.

6.1.2.6 Window and door monitoring

Doors and windows are controlled and closed when too noisy.

6.1.2.7 Reminder and assistance for indoor and outdoor

A smartphone-based application plays the role of a reminder and assistant. It follows the patient everywhere. Based on the patient calendar, this application can autonomously and automatically plan the whole day for the patient.

It can look for an appointment with the treating doctor for the next medical visit. The application is parametrizable.

6.1.3 Concept and architectural view

This section presents the concept of the proposed systems and gives an overview of its architecture.

The system features (i) a data perception unit, (ii) water, food, and medication management unit, and (iii) outside and inside activities.

6.1.3.1 Concept

6.1.3.1.1 Data gathering

IoT-enabled patient-monitoring systems present many advantages for the patient and for treating care personnel. Patient-centric data are collected. Personalized care can be based on these data. Actually, healthcare professionals base their treatment on patient-centered data, which can be biased since they are subjective. Further diagnoses are therefore needed or performed to verify the patient-centered

data. Patient-centered data are data provided by the patient through narratives, while patient-centric data are data collected using modern information technologies like (wireless) body area network (W-BAN) or (wireless) sensor networks (WSNs).

Aging persons are often forgetful and thus provide mostly biased information when they are requested to report on their health conditions. Though in a smart home automation enabled healthcare solution for "aging well," collecting patient-centric data in an autonomous way is mandatory. In a previous study [35], various advantages of collecting patient-centric data were discussed. The healthcare personal gets a complete picture of the patient's health condition and can thus pose the right diagnosis.

Based on the requirement above, the proposed concept provides a patient-centric data collector in terms of sensors connected with the patient that fully collects any bio-signal as well as positions data and sends the data to a record system at the remote. A duplicated copy of the data is saved on the local server and serves as training data for a machine learning (ML) routing. Additionally, a set of networking capable video recorders are used to collect the patient's body expressions, behaviors, mimic, and any physical activities. These data are also used by the ML algorithm to predict patient's behaviors, expectations, and physiological needs (like thirst, hunger, going to the toilet, etc.).

Sensors (in a body area network) connect the patient to an IoT-gateway that transfers the collected data, using the MQTT protocol, to the local server. We talk of edge-computing that happens at the edge. Collected data are processed and stored on the local server. Using the CoApp protocol, data are sent to the cloud. Treating care/nursing homes or medical doctor as well as patient's family members can access the data and can send data to the local server, which would use received data to regulate some connected devices.

6.1.3.1.2 Food and water intake and control

For "food and water intake", a smart device is designed. This device combines microwaves and the fridge. The device called water and food dispenser (WaFoD) with networking ability is connected to the patient's smartphone and the local server, which in turn is connected to a remote server at the cloud that connects the home to the outside and can dispatch information and data in the whole network. WaFoD can learn from the individual's behaviors and preferences.

WaFoD is connected to the IoT gateway and can collect data, transfer data, and receive data from a remote unit (system or individual). Registered behaviors build the training data for a machine learning processor (ML) located on the local server, the master in the entire network. The ML processor predicts patient menus, proposes menus to the patient, and can order at the registered restaurant the selected menu. All proposed services to the patient are based on his behaviors and preferences.

WaFoD is designed to remind the patient to regularly drink water. It dispenses water or soft drinks. It can warm food and serve the food to the patient. The system logs each nutrition behavior and sends at the end of the day an activity journal, or in the case of emergency (that means the patient does not drink for a while or refuse to take food), it alerts the nursing home close to the patient's residence.

The patient is provided with a touchscreen that displays TV programs and can display the pictures of menus proposed by WaFoD.

The entire system is designed following the Internet of things (IoT) paradigm: (i) data collection unit(s) and (ii) IoT-gateway place between the local server. The local server is a light copy of the remote server at the cloud, which can perform complex and memory consuming computing activities; (iii) the IoT platform at the cloud.

A copy of data like room temperature, updated patient's preferences, etc. that are needed for any computing action are stored at the local server.

The patient is provided with a set of accelerometers (sensors to determine his position- fall down, laying , staying, seating, etc.). with the objective to detect, predict if the patient is falling down or will. Furthermore, other sensors like "Feuer alrm" have been used to monitor fire harzard.

6.1.3.1.3 Medication intake

A drug dispenser is provided. The dispenser is connected to the IoT-gateway via Bluetooth. It features an alarm and can remind the patient to take his medicine. The medication intake is logged and a protocol is stored on the network. Family members can be informed if the patient does not take the medicine on time, thus, action can be taken to help the patient to take the medicine. Care/nursing homes are also connected to the dispenser via the le cloud and can get alerted when the patient refuses to take the medicine.

6.1.3.1.4 Indoor activities

The local server is connected to a touchscreen TV. It can display physical activity programs, which can let the patient to also do so, for example, activities like a walk in the room, some light movements, etc.

6.1.3.1.5 Outdoor activities

Elderly people need real socialization. They need therefore to go out and meet other people. The solution proposed feature a smartphone-based application that manages and looks for senior-meeting close to residence place. This application integrates Google Maps that drives the patient to the meeting and takes him back home.

Similar is done with medical visit.

6.1.3.2 Architectural view

The architectural view presents 4 layers (**Figure 4**).

6.1.3.2.1 Network things

Bio-signals, behavior, preferences, room temperature, physical activities, food, water, and medication intake data are collected at this stage through sensors.

The data collected data are forwarded to the aggregation stage.

6.1.3.2.2 Data aggregation stage

At this stage, collected data are aggregated, filtered, cleaned up, processed, and pre-stored.

6.1.3.2.3 IT edge stage

Processed data from the prior stage are used here, but also forwarded the cloud.

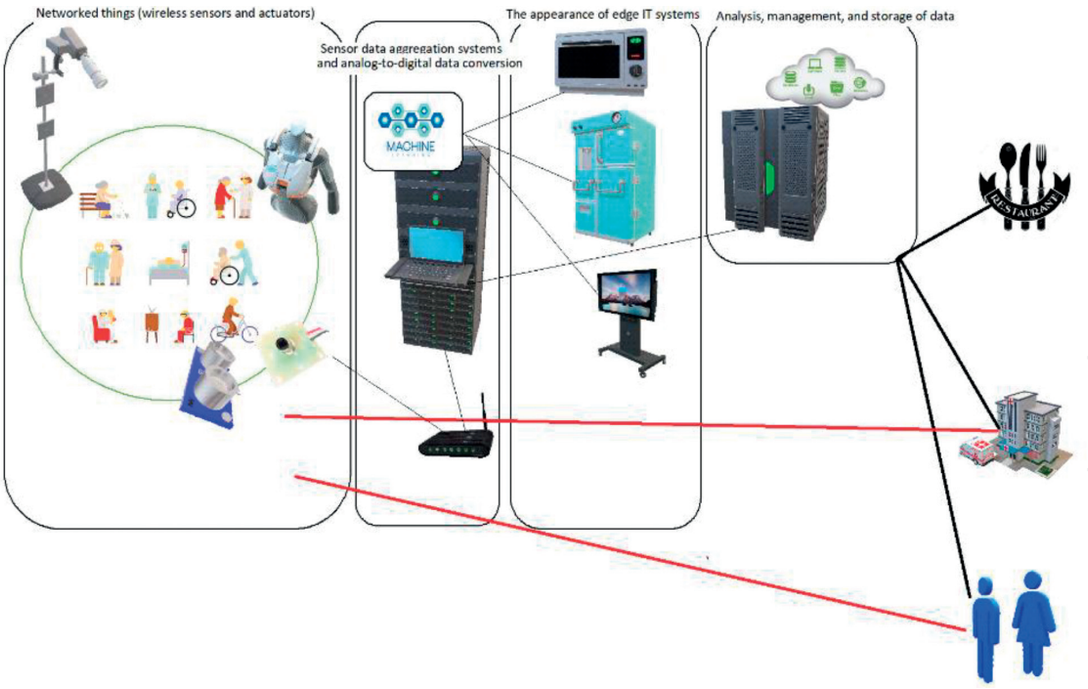

Figure 4.
Architectural view of the proposed system.

6.1.3.2.4 Analysis and other processes at the cloud

Stages A, B, and C happen in the local area (patient residence). In order to enable communication with the remote side, data are forwarded to the cloud. A communication line is, therefore, open between C and D.

Family members, restaurants, nursing homes, and all people authorized to deal with the stored data can access the data through the cloud.

6.1.3.3 Data security

This topic will be discussed in the upcoming paper.

7. Conclusion

This study has investigated the state-of-the-art of "ageing well at home." Many previous studies had archived interesting works on making the "home" comfortable and smarter for elderly and dementia patients. Though most of the previous works have failed in providing a complete solution of smart home automation (*multidimensionality of the concept of the smart home)* for people requesting homecare, this study covers this limitation and shows that smart home automation can impact the patient's and his family member's QoL in a positive way. People staying alone at home as well as those living in nursing care homes would take benefits from such a solution.

8. Upcoming works

The future works aim at launching a human hologram in the program to assist the patient. The patient would though see a family member and can receive from him any instructions or discuss with him. As **Table 15** shows, the presence of a

family member has a great impact on the patient's health-related quality of life and thus on his health outcomes.

Setting and remotely regulating the room temperature is well achieved though patient temperature feeling also depends on the treatment he is under. Certain drug or after-physical activities make the patient feel warm or hot. There exists no system that can automatically and autonomously recognize that the patient's room temperature is not more appropriate. Therefore, we plan to design a wearable that can verify if the patient is feeling cold or hot and thus regulate the heater.

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