CPCL Vol.3 no.2 | 2020

CPCL
EUROPEAN JOURNAL OF
CREATIVE PRACTICES
IN CITIES AND LANDSCAPES

MAIN SECTION

Intelligent Domestic Ecosystems: Innovative Housing Models for Fragile Elderly

Antonio Magarò — Department of Architecture, University of Florence — Contact: antonio.magaro@unifi.it
Adolfo F. L. Baratta — Department of Architecture, Roma Tre University — Contact: adolfo.baratta@uniroma3.it
Fabrizio Finucci — Department of Architecture, Roma Tre University — Contact: fabrizio.finucci@uniroma3.it

ABSTRACT

Fragile users represent a category in which the elderly population is included (fragile elderly). In 2017, there were 962 million people over 60—half the number expected by 2050—many of them with disabilities. During the recent health emergency, frailty was discriminating for access to therapies creating the risk, not yet evaluated, that the mortality rate of fragile users could be increased.

This is because, even when not infected, fragile elderly people were denied access to the hospital spaces they needed. The contribution would describe the state of the art and the first results of the research conducted at the Roma Tre University which aims to study innovative housing models for fragile elderly people capable of promoting de-hospitalization avoiding the aforementioned risk and improving the quality of life through the technological transfer of the Internet of Things from the ICT sector to the architecture one. First of all, the article defines both the final user of the research—the fragile elderly—through its historical genesis, and the tools of the research—the intelligent domestic ecosystems—as new integrated and interconnected housing models. Secondly, it describes the research core aimed to design a prototype, realized with the use of open source and low-cost technologies.

KEYWORDS

Intelligent Domestic Ecosystems; Fragile Users; Housing for Elderly; Active and Assisted Living; Safe and Inclusive Housing

PEER REVIEWED
https://doi.org/10.6092/issn.2612-0496/10140
ISSN 2612-0496

Introduction

The contribution aims to summarize the progress and the first results of the research conducted in the Department of Architecture of Roma Tre University, which has been investigating the topic of Safe and Inclusive Housing for an ageing society since 2018.[1]

Because of the social criticality determined by the significant increase in the elderly population, the research focuses on new residential models, equipped with characteristics of inclusiveness, sharing, ergonomics, and safety, intended for the fragile elderly or, in a broader sense, for fragile users, i.e., people in conditions of vulnerability, latent or manifest, associated with a growing risk or with an overt permanent or temporary disability.[2]

The research aims to find design solutions capable of supporting the active ageing of the fragile elderly, coming to define innovative residential models that exploit the technology transfer from the ICT sector to the architecture one. The aim is to encourage the active inclusion of this particular category of fragile users and their social interaction at home, in the neighbourhood and city scales, by working on the founding principles of the smart city within the housing.

The research has been articulated in the following phases:

1. definition of the state of the art of the users; analysis of user profiles and drafting of the needs and requirements framework;
2. definition of the state of the art of the tools; identification of the most advanced research, by analysing systems and components to support the active and autonomous life of the fragile elderly;
3. design application, through technological transfer, to a special housing model;
4. realization of the technological prototype of an integrated house-device system, characterized by the use of open source and low-cost technologies;
5. dissemination of results.

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1 The research was divided into two phases: the research group of the first phase, which received departmental funding, is composed of Adolfo F. L. Baratta (scientific director), Laura Calcagnini, Milena Farina, Fabrizio Finucci, Giovanni Formica, Maurizio Gargano, Alfonso Giancotti (Sapienza University of Rome), Antonio Magarò, Sergio Martín Blas (ETSAM Madrid), Luca Montuori and Valerio Palmieri; the research group of the second phase is composed of Adolfo F. L. Baratta (scientific director), Laura Calcagnini, Fabrizio Finucci, Giovanni Formica and Antonio Magarò.

2 Antonio Magarò and Adolfo F. L. Baratta, "Machine Learning e architetture sicure e inclusive per un'utenza fragile," *Agathon. International Journal of Architecture, Art and Design 5* (2019): 109.

The research—which has already produced a series of outputs—[3] has seen the collaboration of six Italian universities (Roma Tre University, University of Udine, IUAV of Venice, University of Florence, Polytechnic of Milan, and Sapienza University of Rome) and a foreign university (ETSAM of Madrid).

For funding the realization of the technological prototype, the topics of the paper have recently been submitted as research project proposal at the Special Integrative Fund for FISR Research.[4]

Fragile elderly, social spending and Active and Assisted Living: a historical perspective

Although the category of fragile users and the elderly has no clear boundaries,[5] in about half a century the sub-category of the fragile elderly has proven to have a consolidated structure. From the historical point of view, the recognition of this condition originates from a series of political-institutional assumptions. Charles Fahey used for the first time the expression "frail elderly" for the first time in 1974 when he was appointed director of a task force on the subject on behalf of the Federal Council on the Ageing.[6] The first definition of "frail elderly" responds to the aim of uniquely identifying a group of subjects for whom there is a conjunction of the condition of seniority, of one or more physical disabilities, of the impairment of affects and of an unfavourable social context.[7] This definition seems too segmented for the scientific community. In fact, the condition of seniority appears to be indefinite, and moreover, the identification of the social needs of the context is uncertain.[8]

At the end of the Seventies, the term "frail elderly patient" is used, referring to some pathologies and only from a sociological point of view. Once again it was not clear whether the use refers to people over 75, or even just over 65, and it generally referred to patients or people already included in an institutional care circuit.[9] The contradictions of the early Eighties on the subject are evident: on the one hand, studies demonstrated that a specific physical characteristic is enough to define frailty in the elderly patient;

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3 These include two International Conferences "Safe and Inclusive Housing for the Elderly", held in Rome in October 2018, and "Inclusive living, the project for an autonomous and independent life", held in Udine in December 2019.

4 Directorial decree n. 562 Covid 2020. The results of MUR evaluation have not yet been published.

5 Antonio Magarò, "Ergonomia cognitiva negli ecosistemi domestici aumentati per un'utenza fragile," in *Abitare inclusivo, il progetto per una vita autonoma e indipendente*, eds. Adolfo F. L. Baratta, Christina Conti, Valeria Tatano (Conegliano, Treviso: Anteferma, 2019), 340-49.

6 George L. Maddox, *The Encyclopedia of the Ageing* (New York: Springer Publishing Company, 1987), 21.

7 Cleonice Tavani, A *Staff Report – Public Policy and the Frail Elderly* (Washington D.C.: US Department of Health, Education and Welfare, 1978), 8.

8 FCA, Federal Council on Ageing "Federal Council on Ageing Focuses on Frail Elderly," *Geriatrics* 33 (1978): 16.

9 O. Stevenson "The Frail Elderly – a Social Worker's Perspective," in *Healthcare of the elderly*, ed. T. Arie (Baltimore: John Hopkins University, 1981), 158-75.

on the other hand, a list of indicators capable of supporting the diagnosis of frailty was drawn up.[10]

The need to redefine the limits of the category does not come from geriatricians, but from sociologists. Until the Eighties, they had focused their studies on independent, active elderly able to express their needs, neglecting the most vulnerable ones. The frail elderly had the characteristics of an over seventy-five-year-old, more often female, usually a widower, not hospitalized, but unable to carry out daily activities independently. In addition, the definition was released from the economic availability of the subject who—even if economically self-sufficient—may not be able to provide for the purchase of the services he/she needs.[11]

At the end of the Eighties, it became clear that the fragile individual is the one who has difficulties in daily activities, regardless of the causes, but the term "elderly" was not well defined. Therefore, it appeared useful to differentiate three types of elderly, according to age:[12]

- *young-old*, to the age between 60 and 69 years;
- *old-old*, in the range between 70 and 79 years;
- *oldest-old*, when the subject is over 80 years old.

Given the increase in the average age, nowadays it is preferred to translate each of these categories by five years forward, in the awareness that they have blurred edges.

The definitions of frail elderly had always been related to a pathological picture that includes or excludes specific disabling diseases. It was becoming increasingly evident that frailty is linked to disability and not to age, a concept close to the more modern and broader idea of "fragile user". This approach expresses how fragility is linked to the lack of autonomy in carrying out daily activities, due to the loss of ability, as the result of a complex pathological picture. This generalization is independent of hospitalization, since daily activities take place within the home, and opens the door to new ways of dealing with the problem, which goes beyond the strictly clinical context.[13]

In the Nineties, the frailty of the elderly was recognized as an epidemiological condition. It started with the first alarming data of the American

10 In the early 1980s, the geriatric literature published a study by the Manchester Department of Geriatric Medicine which intends to demonstrate that the condition of frailty is exclusively physical and linked to skin thinning [Brocklehurst, J. C.; Robertson, D.; James-Groom, P., 1982]. At the same time, the Geriatric Division of the University of Saskatchewan, Canada, proposes the standardization of the definition of frail elderly, through the creation of a series of indicators used to assess the impairment of daily activities, cognitive faculties and health conditions [Stolee, P. and Rockwood, K., 1981].

11 G. F. Streib "The Frail Elderly: Research Dilemmas and Research Opportunities" *Gerontologist* 27 (1983): 618.

12 A. J. Garfein and A. R. Herzog "Robust Aging Among the Young-Old, Old-Old and Oldest-Old" *Journal of Gerontology: Social Sciences* 50B, no.2 (1995): 78.

13 Magarò and Baratta, "Machine Learning e architetture sicure e inclusive per un'utenza fragile", *Agathon. International Journal of Architecture, Art and Design 5* (2019): 110.

Medical Association, which in 1990 counted 25% of over 65 and 45% of over 85 as frails. In 1997 the National Center for Health data identified approximately 1.6 million guests in retirement homes as frails. The turning point for understanding the pathophysiological mechanisms of frailty is its correlation with the reduction of "physiological reserves"[14] as well its dependency on the "susceptibility to disability", a typical condition of old age. And for the first time it was imagined that fragility could be countered.[15]

Therefore, frailty and disability were distinguished: advanced age, disability and comorbidities are not enough to identify a frail person. Even if many disabled people are frail or at risk of frailty, the opposite is not always true.[16] The frail person is the one who suffers an increase in the risk of disability (or death) as a consequence of a stressful event,[17] even a minor one.[18] At the end of the last century, the definition of frailty as a condition of vulnerability associated with age was consolidated, while the following years witnessed an approach aimed at understanding the biological basis of frailty and the possibility of identifying a clinical phenotype, yet unidentified.

What has been consistent since the Eighties is the difference between the frail elderly and the frail patient: the former is not hospitalized, therefore a relatively burden on the National Health System. The condition of the fragile elderly has a significant influence on public spending. In Italy, the most expensive services for welfare are precisely those age-dependent monetary benefits, such as the provision of accompanying allowances and residential and home care. Italian expenditure for all social policies corresponds to 29.1% of GDP just above the European average which settles at 27.9%. If the expenses deriving from the pension and health systems are excluded, Italy ranks among the European countries with the lowest levels of expenditure. The Italian municipalities per capita expenditure has an annual increase in spending on services by 2.5%, while spending on services to the elderly increases by 4.5%. The spending on social services for the elderly is equal to 17.9% of total expenditure, with peaks of 23% in North-Eastern Italy.[19]

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14 The definition is the result of research by the Department of Health Services of the University of Washington in Seattle and the Center for Health Studies also in Seattle.

15 J. C. Brocklehurst and E. H. Wagner "Preventing Frail Health" *Clinics in Geriatric Medicine* 8 (1992):4.

16 L. P. Fried, *Conference on the Physiologic Basis of Frailty* (Baltimore, Maryland, 1992), 251-52.

17 One of the biggest differences that occurred in the 1990s, in the treatment of frailty, concerns the scientific need to identify a broad physio-pathological framework, within which to carry out an experiment. In addition, geriatrics has appropriated the authority on studies in this regard, since the multidimensional approach that it requires is the identification of this medical branch and distinguishes it from traditional medicine. The multidimensional approach to frailty makes it possible to expand the pathophysiological picture by inserting elements relating to musculoskeletal functions, aerobic capacity, cognitive functions, but also nutrition, and quality of life.

18 A. J. Campbell and D. M. Buchner "Unstable Disability and the Fluctuations of Frailty" *Age Ageing* 26 (1997): 315.

To better understand the amount of this expenditure, it is worth noting that for every euro per capita spent on poverty mitigation and adult hardship, 6.78 euro are spent on welfare to the elderly.[19]

These numbers describe a social dimension that stresses the necessity to work on inclusion, to ensure the fundamental rights of assistance to the fragile elderly within domestic, urban and special spaces. That means to enable the so-called Active and Assisted Living (AAL). In 2007, the European research program Ambient Assisted Living Joint Program (AALJP) was born, involving research organizations and companies in sectors ranging from telemedicine to information technology, from home automation to social housing. The aim is to avoid hospitalizations and admissions to assisted residences, thus improving the quality of life of the elderly, and reducing social costs. This seven-year program was followed by another similar one, expiring in 2020, called "Active and Assisted Living" (AAL2), which maintains the objectives of the previous one, focusing on active aging. The overall funding was 1.4 billion euros. The projects presented are different in their field of application, but those that exploit the potential of connection of domestic environments to favour de-hospitalization and assistance, are based on the creation of a real domestic ecosystem within which automated technologies and human beings play their own role.[20] The acronym AAL identifies a system of living spaces in which there is a strong technological integration.[21]

The aim is to provide support and assistance in terms of health and quality of life, especially for frail elderly people.

Through the transfer of technology from ITC to architecture, it is possible to counteract dates in daily activities and mitigate the discomfort due to chronic diseases, dementia, and depression. ,[22] Using the technologies on which services dedicated to the frail elderly are based, it is possible to respond to many needs of these users. The services in question are for everyday use, such as localization or support for movement and independence.[23]

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19 ISTAT "La spesa dei comuni per i servizi sociali. Anno 2017" Accessed July 20, 2020. www.istat.it/it/files/2020/02/Report-Spesa-sociale-dei-comuni.pdf

20 Giovanni Formica and Antonio Magarò, "Abitazioni per Anziani: nuove tecnologie per la fruizione dello spazio domestico" in *Abitazioni sicure e inclusive per anziani*, eds. Adolfo F. L. Baratta, Milena Farina, Fabrizio Finucci, Giovanni Formica, Alfonso Giancotti, Luca Montuori, Valerio Palmieri (Conegliano, Treviso: Anteferma Edizioni, 2018), 347-56.

21 Rytis Maskeliunas, et al. "A review of Internet of Things Technologies for Ambient and Assisted Living," *Future Internet* 11, no. 12 (2019):259.

22 Salifu Yusif, et al. "Older People, Assistive Technologies, and the Barriers to Adoption: a Systematic Review," *Int. J. Med. Inf*., 94 (2016):113.

23 R. Mulero, et al., "An AAL System Based on IoT Technologies and Linked Open Data for Elderly Monitoring in Smart Cities" in *Proceedings of the 2nd International Multidisciplinary Conference on Computer and Energy Science* eds. Perković, T. et al. (Split, Croatia, University of Split, Curran Associates, Inc. 2017), 1-6.

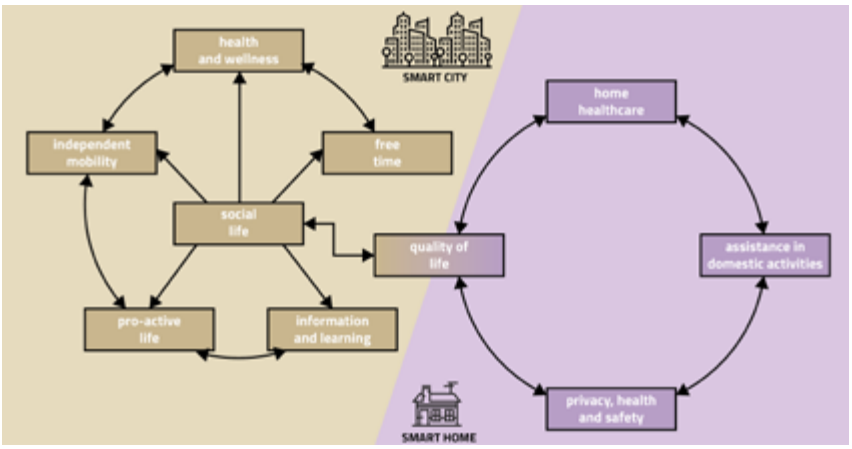

FIG. 1 Relationship between the smart city and the smart home [Source: Authors'].

Domestic ecosystems for fragile elderly: from smart cities to smart homes

The concept of smart city, sometimes abused, is considered the contemporary design approach to the new architectural spaces. The definition of smart city is not univocal, also because its basic assumptions are expressed in different terminologies depending on the country.[24]

The substantial differences split the concept into two categories: which elements a city must contemplate in order to be defined smart, and which resources a city must exploit according to the objectives that make it smart. Each category can generate urban and social policies, often unaware, and therefore unable to determine the transition of modern urbanizations towards smartness.

From our point of view a city can be defined smart when investments in human and social capital, in traditional connection infrastructures and in telecommunications feed a sustainable economic development that provides for a high quality of life and careful management of resources, within participatory decision-making processes.[25] This "citizen-centered"[26] vision reflects the attention to fragile users, subject to the physical and psychological, architectural, and social barriers that the contemporary city implies [Fig. 1].

The city that places the citizen at the centre of its development policies foresees for public and private actors to consider the needs of the different categories of citizens as a priority for any smart city project.[25] Therefore, citizens themselves become agents of change, aware of the role they play within the civic network, characterized by commitment, participation and

24 Hafedh Chourabi et al. "Modelling E-government Business Processes: New Approaches to Transparent and Efficient Performance" *Information Polity Journal* 14, no.1,2 (2009): 93.

25 A. Caragliu, C. Del Bo, P. Nijkamp, "Smart Cities in Europe" *Series Research Memoranda* 48: 6.

26 P. Sanchez Chillon, "The Thirds Rule for the Smart City Plan: Vision & Leadership, Sound Infrastructures and Civic Engagement (let's Count on Digizens)" Accessed July 20, 2020. https://urban360.me/2012/10/13/the-3-thirds-rule-for-the-smart-city-plan/

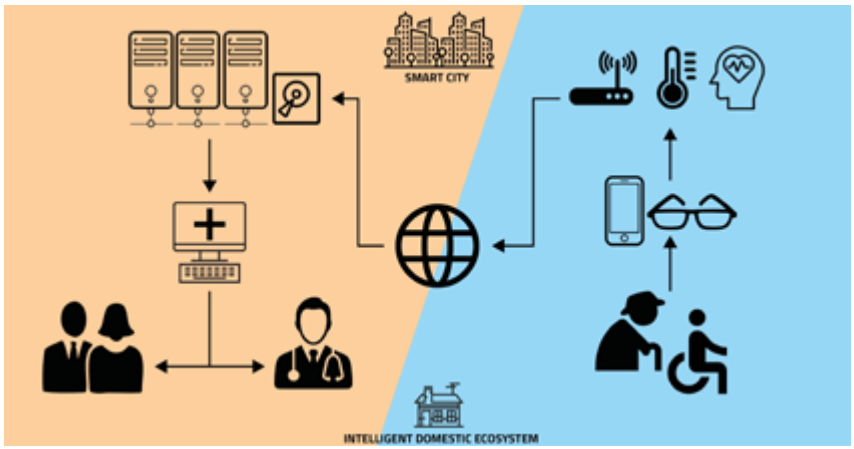

FIG. 2 How an Intelligent Home Ecosystem works [Source: Authors']

sharing. But citizens are not all the same: in the case of fragile elderly, the challenges are linked to overcome the barriers that aging causes, such as the limitation of mobility, of the senses, physical impairments, high susceptibility to diseases, in particular for chronic ones.

With the aim of improving the quality of life of fragile users, the founding principles of smart cities must be able to expand within homes, making them safe and inclusive. The principles underlying the design of so-called smart homes are not recent. Since the 1990s, there has been talking of a physical environment capable of interacting with users thanks to sensors and actuators connected to a local network [Fig. 2].[27]

In the same years research started discussing Ubiquitous Computing to indicate the ability of objects to perform more or less complex computer processing, obtaining information from the environment and/or providing it.[28]

The transition to the so-called Internet of Things (IoT) is very short: it represents the completion of the technology transfer from the automation and ICT sectors to the world of architecture and allows to take advantage of electronic miniaturization and constant and ever-faster connection to improve the quality of life, especially for fragile users. The first definition of IoT comes from Kevin Ashton, of the Massachusetts Institute of Technology. In the late Nineties, he argued that if the internet is a network for exchanging data and information between people, the new generation of computers would work through a network for exchanging data between things.[29] Although the definition of "things" has changed along with the evolution of technology, the goal of computerizing communications between commonly used objects, without the direct intervention of a programmer, remains current. This interoperability constitutes a radical

27 M. Weiser, "The Computer for the 21st Century" *Scientific American, Special Issue on Communications, Computers and Networks* 265, no. 3 (1991): 96.

28 B. Kang, "Ubiquitous Computing Environment Threats and Defensive Measures" *International Journal of Multimedia and Ubiquitous Engineering* 1 (2007): 48.

29 K. Ashton, "That 'Internet of Things' thing" *RFiD Journal* 12 (2009): 122.

evolution of what the internet is today, since it allows the network to collect environmental inputs in order to implement changes in the environment itself, according to the needs of one or more categories of users.

Integrate computerized and automated systems within homes, connected to each other and to the IT systems of health and care facilities, capable of interoperating to improve the conditions of comfort, safety, health, and social inclusion, based on an open platform, would allow to extend the smartness of urban systems, including architectural systems, with evident social, cultural and economic benefits.

The homes, in the broad sense of the living places, can be equipped with miniaturized sensors—even wearable—capable of constantly monitoring the environmental and health conditions of the fragile elderly. Furthermore, by managing these sensors, through a low-cost open-source microcontroller, it is possible to obtain several outputs, ranging from communication with the healthcare system or with caregivers, up to the automatic adjustment of the systems to achieve the best levels of comfort.[30] The homes for the fragile elderly conceived this way, behave like natural ecosystems, providing habitats for living species: for this reason, they can be referred to as domestic ecosystems.

The concept of a domestic ecosystem goes beyond both the concept of home automation and the concept of supply of health care machines within homes. Home automation provides complex systems for managing services within the home, not designed to be automated, customized and to provide support to the specific user.

Furthermore, the prohibitive cost of the closed source systems (to date, the most common systems on the market), devoid of any interoperability, makes them unable to communicate with each other, and not very accessible. On the other hand, the supply of specific machines for health care, in addition to the discomfort they create inside a home, complicate the life of users, already afflicted by conditions of fragility; they constitute a cost that is not always sustainable and in any case the possibility of using them only by fragile users is limited to those who live in the so-called "first world" countries.[31]

A very important part of the cognitive methods and solutions related to smart environments, smart homes and smart services, to transform elderly's houses in domestic ecosystems, are IoT-based. These include home/environment appliances control[32] or the modelling and creation of

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30 Magarò and Baratta, "Machine Learning e architetture sicure e inclusive per un'utenza fragile,"*Agathon. International Journal of Architecture, Art and Design 5* (2019): 111.

31 Magarò, "Ergonomia cognitiva negli ecosistemi domestici aumentati per un'utenza fragile" 347.

32 Dongyu Wang, et al."AnyControl-IoT Based Home Appliances Monitoring and Controlling", in *Proceedings of the 2015 IEEE 39th Annual, Computer Software and Applications Conference* eds. Ahamed, S. I. et al. (Taichung, Taiwan, IEEE Computer Society, 2015), 487-492.

smart buildings,[33] via a cell phone or a smartphone. Another way to use IoT solutions is aimed to detect humans in smart environments, using Bluetooth Wireless Sensor Network (WSN) as a communication platform linked to unobtrusive sensors.[34] Generally, the smart AAL environments monitoring and controlling systems are based on personal mobile terminals (smartphone or tablet) and wearable devices (smartbands or smartwatch).[35] Furthermore, some researchers focus on the emotion recognition by sensors in smart homes.[36]

The IDEAs prototype (Intelligent Domestic Ecosystem for an Ageing Society)

The design and construction of a housing model integrated with a computerized system aimed at monitoring and supporting the daily life activities of the fragile elderly is among the achieved results of this research. The housing model will be interoperable with similar models, within widespread urban areas, revolutionizing the concept of neighbourhood, and promoting social relations. Thanks to the constant internet connection, the integrated housing model will be able to communicate autonomously with the network of the National Health Service and with basic health facilities, in order to facilitate assistance even in the absence of a direct request. It could be defined as an Intelligent Domestic Ecosystem aimed at supporting the daily activities of the fragile elderly.

The housing model is called IDEAs, acronym for Intelligent Domestic Ecosystem for an Aging Society **[Fig. 3]**. It is composed of a housing physical structure, integrated with a system that includes a widespread hardware infrastructure (Structure) and a centralized device, composed of a fixed unit (Core) and a wearable unit (Cell).

The Structure is composed by a series of sensors and a corresponding network of actuators. The sensors are able to acquire a series of input data with the aim of constantly monitoring the environmental comfort conditions. By way of example, the Structure is able to detect, with a pre-ordered, modifiable and/or self-modifiable frequency, the data relating to the internal temperature and humidity of an environment but also the indoor air quality, the presence of harmful gases, the presence of liquids on the floor. The range of actuators, consisting of a huge variety of

33 H. Ghayvat, et al. "WSN- and IoT-Based Smart Homes and Their Extension to Smart Buildings" *Sensors* 15, no. 5 (2015): 10350.

34 Denis Gracanin, et al. "An Approach to Modelling Internet of Things Based Smart Built Environments" in *2015 Winter Simulation Conference* eds. Ylmaz, L. et al. (Huntington Beach, California, IEEE Computer Society, 2015): 3208.

35 Tao Beibei, Lu Yi "Upgraded Application of Intelligent Environment Monitoring System in IOT Smart Home" in *Proceedings of the 2015 Sixth International Conference on Intelligent Systems Design and Engineering Applications* (Guiyang, China, IEEE Computer Society, 2015), 916-919.

36 E. I. Konstantinidis, et al. "Emotion Recognition in the Wild: Results and Limitations from Active and Healthy Ageing Cases in a Living Lab" in *eHealth 360°* eds. Giokas, K. et al. (Cham, Switzerland, Springer, 2017): 181.

FIG. 3 Concept of the IDEAs prototype. In particular, the relationship between the CORE and the CELL that can be mounted on a wearable support is shown [Source: Authors']

electronic components, is designed to create the output based on the acquired data. This function is considerably simple, in the easy visualization of data on the display, or increase its degree of complexity, from the recording of the data on a local or remote server, to the interpretation of any critical conditions, up to autonomous communication with caregivers or with the health system.

In addition, the actuators can independently regulate the movement of the windows to facilitate air changes, ventilation, and natural lighting, with the aim of re-establishing any imbalances in the indoor ecosystem.

The Core is a centralized device, easily identifiable within the home by the fragile elderly, as well as by any rescuers, in case of need. Its function is to host the microcontroller capable of interpreting the input data from the sensors and transmitting the commands to the actuators according to a series of algorithms. Designed as a communication station (reception and transmission), the Core is responsible for hosting some of those actuators, such as for displaying information.

It integrates or replaces the home router to ensure constant connection to the internet and the home network via Wi-Fi, and in the same way it connects with personal devices such as smartphones and tablets close to the user.

These devices integrate or replace the Cell, a wearable bracelet, hosting a slave microcontroller, dependent on the main one but with a certain degree of autonomy, and a series of sensors, with the purpose of monitoring the physical and health conditions of the fragile elderly person. By way of example, if the Structure acquires environmental data, the Cell

can record data on the user's temperature, sleep quality or heartbeat. In addition, because these devices are in solidarity with the user, by equipping them with an accelerometer it is possible to identify any falls, allowing to autonomously activate a communication with the rescuers.

Finally, because the Cell is in constant wireless communication with the Core, the system can acquire data relating to the user's position within the home environment via the Cell or the smartphone GPS, it is possible to trace its position outside or in the ecosystem network.

When the living places of the elderly and the homes they frequent network each other, according to the smart city approach, each Cell can interact with different Cores and related Structures, increasing the levels of health and safety.

The IDEAs system is not just an IoT application, but aims to become an IoT platform, proposing the use and dissemination of an open standard.

In fact, one of the most frequent limits to the spread of IoT applications, for which the technology is already available, is practically zero interoperability between different proprietary systems.

Someone who decides to take advantage of this technology within homes, needs to purchase a range of products from the same brand or resigns to having to manage each device (things) with a different application. In the United States, it is already possible to integrate devices that can be centrally controlled by a general user. In fact, it is sufficient to purchase the special closed-source technology made available by the four large multinationals, the so-called GAFA.[37] In Europe, the market prefers the spread of innovative, agile, and small start-ups focused on developing specific products.

Digital assistants, generally voice-activated, and similar to what the IDEAs Core should be, do not usually communicate with each other. Inevitably, all this leads to the creation of small "information islands"[38] that are impossible to systematize into a real IoT.

The strong originality of the research, which also distinguishes the IDEAs device, provides for close integration within the living spaces of the fragile elderly, bypassing the issue linked to both home automation devices and those dedicated to home care. In addition, the research used open-source hardware and software technologies, making a careful selection

37 J. C. Miguel and M. A. Casado, "GAFAnomy (Google, Amazon, Facebook and Apple): The Big Four and theb-Ecosystem" in *Dynamics of Big Internet Industry Groups and Future Trends* (Berlin: Springer, 2016), 321-29.

38 O. Vermesan and P. Fries, *Digitising the Industry Internet of Things Connecting the Physical, Digital and Virtual Worlds*, (Delft: River Publishers, 2016), 12.

among those international standards, in the process of being drafted and expanded, which are gaining ground globally.[39]

Furthermore, the simultaneous collection of data from the environment and from users could open a new efficient model of Post Occupancy Evaluation about indoor and energy efficiency of a residential building.

Conclusions

Fragile elderlies have proved particularly vulnerable during the recent health emergency: in many cases, they have not been protected in their right to health. Many studies are working on quantifying what the news have narrated: fragility has occupied a leading role in discriminating access to invasive therapies and in increasing the mortality rate. Furthermore, even when not subject to infection, the fragile elderly have been prevented from accessing the hospital spaces they needed for other diseases. This highlighted the need to rethink care models in synergy with life models linked to living spaces, with the aim of reducing hospitalizations for the fragile elderly.

Research on intelligent domestic ecosystems moves in this direction: it aims to redefine the concept of residential care for the fragile elderly, differentiating it from assisted living and hospitalization, with the aim of defining design guidelines that allow for integration of new technologies in architectural spaces.

A device such as the one in the design phase, paves the way for a series of technological transfers with extended perspectives. In fact, the research predicts that the scenario in which intelligent domestic ecosystems must be experimented coincides with the natural one for the fragile elderly, the home space, in addition to the immediately pertinent one and the one dedicated to the socialization that facilitates the social inclusion. Therefore, a complex system is created, determined by the interoperability of these elementary cells which can be considered as a natural ecosystem. However, to behave as such, it must be able to evolve, readjusting to the changing needs of the fragile elderly, whose conditions are variable by definition. This result can be achieved by integrating algorithms related to neuronal networks and machine learning into the system. The latter is defined as

39 E.g.: the *Web of Things* del W3C, an international association that deals with defining and promoting standards in internet programming languages, which aims to create open ecosystems based on standards related to identification and interoperability between devices on different platforms (D. Ragget, "The Web of Things: Challenges and Opportunities" *Computer,* 48 (2015): 26), and the *Alliance for Internet of Things innovation* (AIOTI, *Alliance for Internet of Things Innovation* (Bruxelles: European Commission (2015)), *Open Platform* 3.0 (J. Swetina, G. Lu, P. Jacobs, F. Ennesser, J. Song, J. "Toward a standardized common M2M service layer platform: Introduction to oneM2M", *IEEE Wireless Communications*, 21 (2014): 20), *IEEE Internet of Thing Initiative* (R. Minerva, "Towards a Definition of the Internet of Things", IEEE Internet Initiative, 1 (2015): 3) and *International Technical Working Group on IoT-Enabled Smart City Framework*, developed by NIST, *National Institute of Standards and Technology* (S. Rhee, "Catalyzing the Internet of Things and smart cities: Global City Teams Challenge", in *Proceedings of the 1st International Workshop on Science of Smart City Operations and Platforms Engineering (SCOPE) in Partnership with Global City Teams Challenge*, Vienna (2016), 1–4).

"the field of study that provides the computer with the ability to learn without being programmed".[40] When we talk about machine learning we mean a sort of "training" of the neural network, during which a quantity of data is administered to the computer from which it can derive information, and it is also possible to measure how well it succeeds.[41] In this way, the device that controls the ecosystem cell is able to improve its performance not only by operating in support of the daily activities of the fragile elderly, but by anticipating their behaviour. It will eventually be able to prevent disease states or warn the health system or caregivers before they manifest, further increasing safety.

A further development that the research aims at relates to the integration of augmented reality (AR) technologies with the aim of gradually replacing the assistance activities carried out by the general practitioner. AR consists of the superimposition of information levels, virtual and real, to increase perception and increase the use of reality. Therefore, by exploiting this model of content administration, it is possible to allow the telepresence of medical and assistance staff inside the home.

The possibilities offered by this technology transfer are also linked to the mitigation of the discomfort associated with any periods of forced solitude, both emergency and forced by the conditions of senescence.

However, some issues may arise concerning the difficulty that older people encounter in using complex computerized systems. This problem is strongly felt in the oldest-old, while the number of people over-65 who commonly use personal computing devices is showing a sharp increase. Familiarity with interactivity based on the use of network connections is one of the peculiarities of a generation of elderly people defined as YEEPIEs (Youthful Energetic Elderly Population Involved in Everything).[42] Despite this, Italy shows 25% of the elderly between 65 and 74 using smartphones or computers connected to the internet, against a European average of 45.5%. However, the aptitude for the use of these devices by the elderly in Italy is probably higher than their European peers, since smartphones and tablets are consulted at least once a day by 92% of the sample, against 72% of the European average.[43] Therefore, it will be necessary to refer to that interdisciplinary academic field that aims at looking for sustainable aging through the creation of technologically assisted environments, using the tools of inclusive design aimed at autonomous and independent living. This area is called Gerontechnology.[44]

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40 A. L. Samuel, "Some studies in machine learning using the game of checkers" *IBM Journal of Research and Development* 44, no. 1.2 (2000): 209. https://doi.org/10.1147/rd.441.0206.

41 Magarò and Baratta, "Machine Learning e architetture sicure e inclusive per un'utenza fragile," *Agathon. International Journal of Architecture, Art and Design 5* (2019): 113.

42 Formica and Magarò, "Abitazioni per Anziani: nuove tecnologie per la fruizione dello spazio domestico," 349.

43 S. Carlo *Invecchiare on-line. Sfide e aspettative degli anziani digitali* (Milano, Vita e Pensiero, 2018): 36.

44 T. Harrington *Why and How* (Maastricht, Shaker Publishing, 2000): 45.

At present, the research is strongly oriented towards the development of applications, generally on the software side, that are "one-dimensional", dealing with the mitigation of a specific disability or a narrow spectrum linked to the difference between physical and cognitive disabilities.[45] The prototype proposal focuses on the development of a device capable of governing the integrated house-device system, so as to be able to operate autonomously to support the daily activities of the fragile elderly, exploiting hardware and software, in an interoperable way, i.e. in constant dialogue with commonly used electronic devices, with other cells of the urban domestic ecosystem and with health care facilities.

This way, the augmented intelligent domestic ecosystems are proposed not only as a temporary post-emergency expedient, but as a housing model capable of adapting to the daily activities, transforming the fragile user into a super-able user.

45 Formica and Magarò, "Abitazioni per Anziani: nuove tecnologie per la fruizione dello spazio domestico," 351.

Antonio Magarò Architect, PhD, Research Fellow at the University of Florence. He carries out supplementary teaching activities at the Roma Tre University. He has been visiting researcher at the *Rheinisch-Westfälische Technische Hochschule in Aachen* (DE), at the *Hockschule Technik, Wirtschaft und Gestaltung in Konstanz* (DE) and at the *Universidad de Boyacà* (COL). It deals with the development of marginal urban areas and urban regeneration in areas of the world afflicted by housing deprivation. He is author of numerous publications on technology transfer from ICT to architecture for improving the quality of special housing for fragile users, as well as on innovative materials.

Adolfo F. L. Baratta Architect (1997), PhD in Architecture Technology (2002), since 2014 he is Associate Professor at Roma Tre University. He has been adjunct Professor at University of Florence (2002-2009), at Sapienza University of Rome (2009-2010), Assistant professor at the University of Florence (2005-2011), Visiting Professor at *Universidad de Boyacà* in Sogamoso (COL) (2017) and at *Hochschule Technik, Wirtschaft und Gestaltung* in Konstanz (DE) (2017). His research activity is carried out in a privileged way in three interrelated areas: production and construction, quality and environment, procedure and technological design. He is author of over 200 publications.

Fabrizio Finucci Architect, PhD and contract Professor Sapienza-University of Rome, since 2012 he is Researcher and Adjunct professor in Appraisal and economic evaluation at Roma Tre University. He was visiting professor in 2017 at the *Universidad de Boyacá* (Colombia), *Facultad de Arquitectura, Diseño y Urbanismo*, and in 2019 at the University of Pècs, Faculty of Engineering and Information Technology. In 2018 he obtained the national scientific qualification (ASN) as Associate professor. His main research activity deals with the economic evaluation for plan, project, and program, implemented with inclusive and dialogic approaches. He is author of over 70 publications.

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