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Connecting Smart Homes to Healthcare Services for People With Neurodegenerative Disorders

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ABSTRACT

The objective of this research is to provide an approach for the design of what we have called 'connected homes' with a study case for elderly people with dementia living alone. These homes would be connected to a center of surveillance for direct and automatic view of multiple status of the day such as patient security and general health indicators (body temperature, heart rate, blood pressure etc.), detect the intake of meals, eating motivation, humor detection prevention of falls, Alcohol consumption detection, safe use of medicines and emergency situations and other Human Activity Recognition (HAR). The model may also predict situations by using past data accumulation. The model could even send alerts in case of emergency. This service would mean that there would minimum intervention from caregivers thanks to the Artificial Intelligence. As a case study, we proposed a new approach for the conception of connected homes for people with dementia to a central office for automatic human activity detection and help and support accordingly. Such conception includes home design concepts according to standard recommendations and the implementation of new added assistive technology tools to permit the automatic surveillance without violating the ethic requirements. Two installation models will be proposed to consider the financial situation of the patient: a unit or appliance at the patient's home or a home that is connected to a central office.

Keywords. Connected homes, Automatic detection, human activity, eating detection, neurodegenerative disorders, assistive technology, Prevention of falls.

INTRODUCTION

Alzheimer's disease or related diseases hit society very hard [1-6]. We are facing four challenges in the design of the connected homes for people with mental disabilities:

- ✓ whether the patient is performing their activity of daily living (ADL) safely, especially if the patient lives alone.
- ✓ when using assistance techniques to help us performing the latest objective, we have to take into account ethical aspect such respect of the patient privacy
- ✓ what is the optimal home design to maximize the patient comfort while minimizing the connected home building cost?
- ✓ automatically managing the immediate intervention of the Health Service Providers (such as Healthcare assistant, Nurse and/or doctor, Neighbors and/or Friends, Relationship, family, and Care staff.)

Based on SWOT method, [7] proposed an analysis of strengths and weakness of current homes to reflect on future homes. 4.0. The weaknesses of the present situation are the resident is alone with less monitoring and no way to alert in case of emergencies. Table 1 provides solutions to the weaknesses. The threats are the patient alone with no help in case of natural disasters. Table 2 provides solutions to the threats.

Table 1 Solutions to the Weaknesses

Weaknesses of the present situation:	✓ The resident is alone with an evolving pathology and security risks ✓ Less monitoring - Monitoring is not continuous - Isolation of the resident, anonymity ✓ Non-regularity of needs - no alerts in case of emergencies (fall, slips, or movements ...)
Solutions with the new design:	✓ Even if the resident is alone, the connected home will provide higher security. ✓ There will be no isolation of the resident because they are connected 24x7. ✓ There will alerts in case of problems (fall, slips, or movements ...) help and support will be provided when needed.

Table 2 Solutions to the Threats

Threat: Retirements homes are growing ...	✓ The resident is ALONE at home ✓ there is no more help, in case of natural disaster or technical problem in the building
Solutions to the Threat with the new design:	✓ The resident is physically ALONE at home but completely virtually connected. ✓ In case of natural disaster or technical problem in the building, there will be immediate help.

The objective of the design of smart homes and their connectivity to the healthcare provider are:

- ✓ To reach an optimal design for the smart homes in terms of the physical design and automatic connectivity (using latest Assistive Technologies tools) with very minimal intervention of the Resident.

Under the following constraints:

- ✓ That the smart home's conception respects the Standards requirements.
- ✓ That the resident's activities of daily living (ADL) should be safe,
- ✓ That the expertise of the Service Provider (healthcare) is shared through the Network of Smart homes. The healthcare accompanies the resident daily.
- ✓ Those smart homes are connected to a Network with availability 24x7.
- ✓ CIA triad: Confidentiality, integrity, and availability. Data, objects, and resources are protected from unauthorized access. Data is protected from unauthorized changes to ensure that it is reliable and correct. Authorized users have access to the systems and the resources they need.
- ✓ To uphold the respect of the privacy of the resident and the ethical policies.
- ✓ To use the Assistive technology to assist the prevention of falls, the safe use of medicine, Emergency Situations and more.
- ✓ To get the most from the iCloud (figure 1.) which will be connected to
  - Healthcare enterprise wireless LAN or Branch offices Wan Network to assist and monitor the health of the resident and provide immediate help when needed.
  - Smart Homes WLAN vis DSL/Cable for Resides (using Assistive technologies) and their relatives for better communication and interaction between both parties.
  - Cloud computing (Artificial Intelligence Application, Platform, and Infrastructure) to develop and create intelligent applications that prevent events and alert for support while continually monitoring the resident.
  - iCloud Storage to store and access in real-time data.

Research problematics are:

- ✓ The use of the Assistive technologies (AT) must comply to the ethical requirements and constraints. This problematic will leave us with only few ATs that can be used.

Current difficulty, and solution limitations:

- ✓ The resident's profile and their financial situation will limit the applied solution.
- ✓ The approach will be implemented as a small prototype including few functionalities, and will grow depending on the resident, parent, and healthcare's requirements.
- ✓ For our approach to be realistic, we are looking for collaboration with Research Centers for Studies in Aging. The objective of this collaboration is to have a real interaction with resident and health care professional and test the solution.
- ✓ The allocated budget and resources are also a limitation.
- ✓ All parties should be included in the process of the requirement study, development, and testing. Otherwise, there will be always some parts of the project will not be specified/developed.

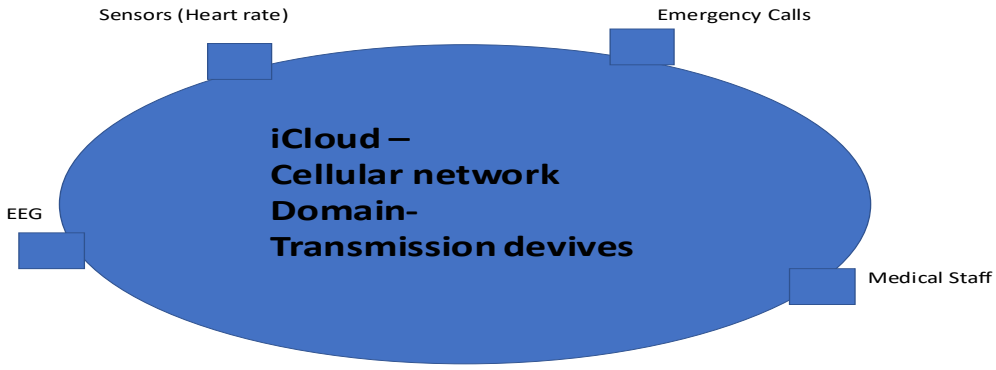


Figure 1. Connecting Assistive technologies via the iCloud.

GOOD PRACTICES IN THE DESIGN OF SMART HOMES AND LIVING SPACES FOR PEOPLE WITH NEURODEGENERATIVE DISORDERS

For Seniors' Homes [8-12], the concept will be as follows:

- There will be groups of small buildings with 10 rooms each. The buildings will be organized around outdoor spaces so residents can take steps and enjoy nature. The rooms will all be air-conditioned, with their own shower and adapted toilet, ensuring privacy for the tenants. Residents will be grouped according to their personalities and similar interests.
- Common areas are also provided for residents to entertain their loved ones. This will help break the isolation and encourage human contact.
- In addition, there will be no long corridors filled with medical instruments that look like hospitals. Nursing positions will be concealed to minimize the appearance of a care facility.

Best practices [8-12], for the design of homes for people with dementia provide recommendations about:

- Colored doors. Bathroom doors in different color will help residents identify the bathrooms.
- Contrast key feature. Using a color that contrasts with background to attract the attention.
- Lighting can be very helpful for people who suffer with sight loss or dementia. A well-lit room can help compensate for poor vision and assist people with maneuvering through either new or familiar spaces. It can also help them accomplish tasks. Maximizing natural light is key. It is also important to consider the effects of artificial light, the position of the lights, the intensity of the lights, as well as how the lighting is controlled.
- Fixtures and fitting. Handrails and grab rails are very helpful.
- Assistive technology. We should use appropriate signage around the home.
- Kitchens. Lighting, color and contrast, as well as worktops set at an appropriate level.
- Bathrooms with traditional fittings.
- Entrances and exits signals must be clear.
- Outdoor spaces.

APPROACH FOR CONNECTED HOMES OF PEOPLE WITH DEMENTIA

The following paragraphs will describe the AI central, the connectivity and the provided services.

The resident could make use of Smart home technology which can use multiple devices (linking sensors, appliances connected to the internet) that can be monitored and controlled remotely to help the resident with their needs.

Central office for on-line monitoring

An Artificial Intelligence based center office connecting through Internet the residents, their parents, healthcare providers, police stations while automatically and continually collecting resident data (no video registered) using Assistive technology tool, analyzing these data, and making automatic decisions to contact healthcare professional for help, police station for emergency, parents for resident status /information or resident interaction.

Figure 2 shows the AI center and its connectivity through the Internet.

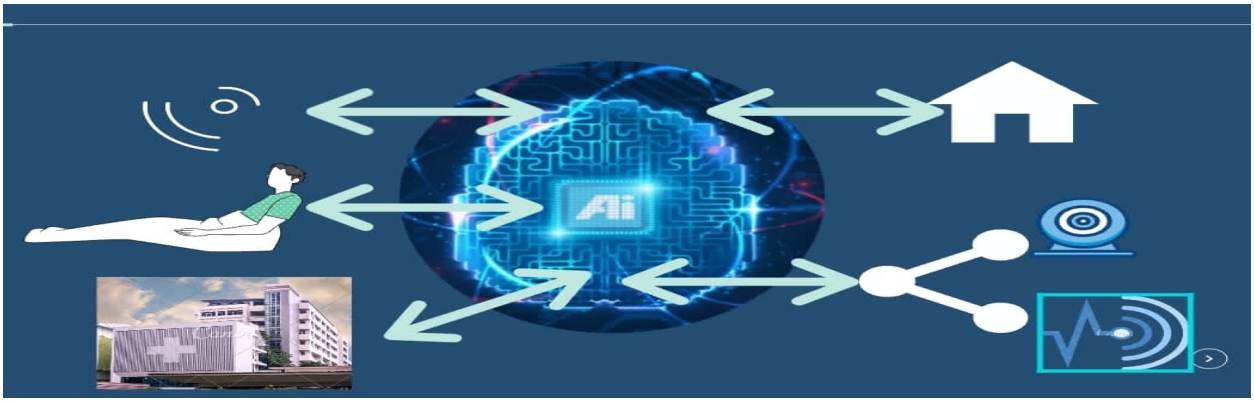


Figure 2. AI central

List of a preliminary services offered by the Central office for on-line monitoring

A home that is connected to the surveillance center will keeps you in touch with the resident whenever you are away. These streaming connected cameras, also known as smart cameras, hook up to your home's Wi-Fi network and offer you a direct view of multiple status of the day such as parent security, eating detection, eating motivation, prevention of falls, safe use of medicines and emergency situations.

The following table describes the preliminary services that are provided by the AI Central, and how can we use AI to design and implement these services.

For each service, there is a description, a list of assistive technologies tools that can be used and our AI approach.

Table 3. Services provided by the AI Central

Service	Description of the Service	Recommendations
Fall Prevention	Falling accounts for 85% of hospitalization and 10% of emergency visits amongst seniors. Hip fractures are the results of 40% of those falls. Bones get weaker and become more fragile with age. Those who suffer with osteoporosis are even more exposed to this. It is important to make fall prevention a priority because a fall can cause long hospitalizations, permanent injuries, disability, or infections. **Assistive Technology:** Webcam can detect the Movement **AI Approach:** Pose estimation approach can detect falls	- Keep safe the two riskiest areas of the house as possible: the bathroom and the stairs. - One can install support bars or bath seats in the washroom. - One can ensure that stairs have secure and accessible ramps to rest on. - One can avoid including objects or furniture that act as unnecessary clutter, which can block passages. - One can avoid using carpets unless they serve a use (a non-slip mat in the bath, for example). - One can make sure there is sufficient lighting in each room. - One can make sure mobility aids are available when needed and that they are adjusted properly. - One can install a bench near the front door to sit when putting on your shoes.
Safe use of medicinal products	When medication is used as prescribed it can maintain the quality of a person's life. Seniors must take several medications at once, and if they are not taken properly, it could pose a threat or cause side effects that can increase the risk of falls and injury. Assistive Technology: Distributor of medicine dose AI Approach: Distribute and Detect if the medicine is not used and alert on screen and send a reminder alert.	- One must never take medication without first talking to a doctor or pharmacist. - One must never take more medication than recommended/prescribed. It is important to understand your recommended dosage. - One must learn the possible side effects as well as the risks involved in drug interactions - One must always carry a complete list of the medications needed. - One must never take medication that is intended for someone else. - One must report any unneeded or expired medication to a pharmacy for safe disposal.
Emergency Situations	When an elderly person lives alone, it is very important that they make themselves prepared in case of emergencies (ie. falls or discomfort). Alert systems that are currently available have wireless backup	- One must make sure to have all emergency numbers in plain sight and in strategic locations, such as the fridge or near a phone. - One must make sure not to wait to contact emergency services. It

	buttons that allow emergency services to be called if there is a problem. Assistive Technology: Webcam and Bracelet (health indicators) AI Approach: Detect anomalies and alert these anomalies for immediate intervention.	is important to not hesitate or act slowly when asking for help. - One must create a list of resources to contact in case of problems. One can focus on people who live nearby and people who are often available to help.
Security of the patient	Real-time monitoring against intrusion, verify if doors/windows are left open, alert if the resident leaves their home during the night. **Assistive Technology:** Webcam (motion detection), proximity switches. Door/windows open/close detector. **AI Approach:** Alert in case on intrusion or health emergency.	- Install enough sensors and webcams. - If possible, connect to surveillance center or permanent connection to a family member.
Real-time General Health monitoring	Collect body temperature, heart rate, blood pressure as well as other indicators and alert if necessary or ask if help is needed. **Assistive Technology:** Smart bracelet **AI Approach:** Detect the following indicators: Heart rate, blood pressure, body temperature, etc. Act automatically depending on health triggers.	- One must make the health of the patient as high priority by insuring good diet, sport, and social activities. - Insuring a recuring medical examination of the patients.
Meal intake detection and motivation [13-15],	Automatically detect the eating activity and report if the resident does not eat for long period. **Assistive Technology:** Webcam **AI Approach:** Pose Estimation Approach. Face Alignment and Facial Landmarks Approaches.	- One must make the health of the patient as high priority by insuring good diet, sport, and social activities. - If possible, connect to surveillance center for meal detection or install automatic meal detection system.
Mood detection	Detect the resident's mood and report if the resident sad for a long period. **Assistive Technology:** Webcam	- Insuring a recuring psychological medical examination of the patients.

	AI Approach: Pose Estimation Approach	
Alcohol consumption	Detect alcohol consumption abuse and send automatic alerts **Assistive Technology:** Webcam, Alcohol sensor. **AI Approach:** Pose Estimation Approach, Face detection	- Limit the number Alcohol bottles to minimum.
Prediction Package	Can we use AI to predict the future based on what has been recorded in the past? For instance, if the resident is always asleep between 9:00 PM and 10:00 AM, what do happen if they are still awake at 1:00AM. **Assistive Technology:** Webcam. **AI Approach:** Behavior modeling and prediction	- Always take actions even if the system fails at the beginning or during testing.

CONCLUSIONS AND FUTURE WORKS

In this paper we have proposed an approach for the design of smart homes and their connectivity to the healthcare services. We will continue using these procedures for human activity detection in general, monitoring the security and the protection of the patient for instance, automatic motivation of the resident.

References

Source Fondation pour la recherche médicale : https://www.frm.org/alzheimer/ampleur-maladie.html

La Société Alzheimer de Québec : http://www.societealzheimerdequebec.com/wp/about/ statistiques /

La maladie au Canada : http://www.alzheimer.ca/fr/Home/About-dementia/What-is-dementia/Dementia-numbers.

Cure Alzheimer's Fund. Targeting breakthrough research: https://curealz.org/alzheimers-disease

Ferchichi S, Giraud M, Smagghe A. La démence à corps de Lewy. La Revue de Gériatrie. 2000 ; 25 : 493-498

Greffard S., Marquis C, Boddaert J, Dieudonné B, Verny M. La démence à corps de Lewy : la

diagnostiquer et la traiter. Repères en Gériatrie. 2004 ; 43 : 31-34

Jean Renaud, Remy Houssin, Negar Armaghan, Mickael Gardoni, Future Home 4.0 for People with Major Neurodegenerative Disorders, Finding the Contradiction, TRIZ Future Conference 2019 (TFC'19) October 9-11, 2019 Marrakech Maroc.

La sécurité des aînés : quelques points à surveiller. https://www.jeancoutu.com/sante/conseils-sante/la-securite-des-aines-quelques-points-a-surveiller/

Corinne Greasley-Adams, Alison Bowes, Alison Dawson and Louise McCabe, Good practice in the design of homes and living spaces for people with dementia and sight loss https://dementia.stir.ac.uk/system/files/filedepot/12/good_practice_in_the_design_of_homes_and_living_spaces_for_people_living_with_dementia_and_sight_loss_final.pdf

Québec dévoile le concept de ses « Maisons des aînés » https://www.lapresse.ca/actualites/politique/2019-11-26/quebec-devoile-le-concept-de-ses-maisons-des-aines

Good practice in the design of homes and living spaces for people with dementia and sight loss, Corinne Greasley-Adams, Alison Bowes, Alison Dawson and Louise McCabe , University of Stirling, https://dementia.stir.ac.uk/system/files/filedepot/12/good_practice_in_the_design_of_homes_and_living_spaces_for_people_living_with_dementia_and_sight_loss_final.pdf -nm—

https://www.jeancoutu.com/sante/conseils-sante/la-securite-des-aines-quelques-points-a-surveiller/

Nour, M., et al. Real-time detection of eating activity in elderly people with dementia using face alignment and facial landmarks. in IFIP International Conference on Product Lifecycle Management. 2020. Springer.

Mhamed Nour, M.G., Jean Renaud, Serge Gauthier, Real-Time Detection and Motivation of Eating Activity in Elderly People with Dementia Using Pose Estimation with Tensorflow and OpenCV. Advances in Social Sciences Research Journal, 2021. 8.

Nour, M., J. Renaud, and M. Gardoni, Place of caregiver who accompanies a person with Alzheimer's disease or related, what should be their role. Advances in Social Sciences Research Journal, 2018. 5(10).