The implementation of an optical sensor integrated with artificial intelligence in a nursing home: a study protocol of the experience of ancelia

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***Abstract*—Environmental optical sensors equipped with Artificial Intelligence (AI) can be useful in improving care for residents in long-term care and Nursing Homes (NHs). When strategically placed in the rooms, sensors can signal behaviors related to agitation or mental confusion, allowing healthcare professionals to act promptly and safely to prevent adverse events, such as falls. Although Italy ranks second in the international panorama for studies on AI-enabled devices in care settings, studies have yet to be conducted in real-world settings. The project's general objective is to describe and evaluate the use of an environmental optical AI sensor, enabled with a camera monitoring system, in a NH in Piedmont. This paper aims to describe and assess the implementation of an AI environmental optical sensor, enabled with a camera monitoring system, in a NH, highlighting barriers and facilitators encountered.**

Keywords—Environmental assisting device; machine learning; falls; aged; nursing home

I. INTRODUCTION

Ageing is often associated with chronic conditions and disabilities due to the decline of capacity and increased susceptibility to stressors [1] [2]. The inability to respond efficiently to stressors may lead to the development of geriatric syndromes, which include falls, cognitive syndromes (i.e., dementia, delirium, etc.), depression, polypharmacy, and incontinence [3]. Geriatric syndromes have a remarkable impact on quality of life and disability, increasing the risk of hospitalisations, the demand for primary and long-term health care (e.g., Nursing Homes), and mortality rates [4]. Ageing will require more well-trained workforces and a more age-friendly physical and social environment to better respond to older adults' needs [2].

Among the emerging technologies, Artificial Intelligence (AI) could be a key element in improving care, particularly in settings such as long-term care or Nursing Homes (NHs) [5]. AI refers to a set of multiple technologies able to simulate human intelligence. Given a set of information and a real problem, it can perform numerous tasks to find a solution. AI perceives its surroundings by acquiring and interpreting data according to predefined inputs or processing information derived from these data [6]. Using an algorithm, AI can learn a person's movements, discern between a person's daily activities and potentially dangerous situations, and overcome false alarms [5], [7]. In addition, it can identify changes in the person's habits, gait and psychomotor behaviours that may be potential signs of falling risk or delirium [7], [8], [9], enabling remote monitoring and supporting healthcare workers in the surveillance. AI devices are, therefore, capable of social interactions, support, monitoring, and warning for potential dangers [10]. Adopting these devices could facilitate the response to people's health needs, particularly those of the aged, supporting and promoting the work of healthcare professionals [10].

Literature well describes devices embedded with AI, which greatly impact nursing care. These devices were often developed to prevent falls or allow their rapid detection [5]. Falls still represent an important health problem for aged people, occurring in 28-35% of adults older than 65 years, with an increase in people over 70, reaching 32-42% [4], [11]. Fall prevention strategies are more important, especially in long-term facilities or NH, where residents fall more frequently than community residents [11], [12], [13]. Falls affect 30% to 50% of residents in NHs, with approximately 1.5 falls per NH bed annually [12]. More than half of these falls result in trauma, especially during nighttime [11]. About 40% of people admitted to long-term facilities falls recurrently [2].

Fall reduction is possible by exploiting the AI-device's ability to signal attempts to get out independently from the bed, especially in people with impaired balance, and in case of prolonged absence from the bed or room. [8]. The mentioned situations also allow for defining the most at-risk residents by exploiting a remote notification system that enables prompt interventions [5]. Installing these devices in the residents' room allows continuous monitoring without any restrictions for the person.

Even if these devices are already on the market and used in most countries (i.e., Japan and the United States), more attention is needed in the literature on how AI can facilitate healthcare professionals' work in real-world settings [10]. Exploring these devices' potential benefits and impact on the care provided in NH settings is necessary. Given the impact of falls on the health status of residents in NHs and the associated costs, understanding technology's impact on healthcare professionals would shed light on hindering and facilitating elements for their use and identify room for improvement.

Thus, this paper aims to describe and assess the implementation of an AI environmental optical sensor, enabled with a camera monitoring system, in two units of the NH "G. Agnelli" in Ville Roddolo, highlighting barriers and facilitators encountered. In the first part of the paper the main gaps of knowledge were sintetised. A brief description of the implementation process is presented, including: the aim and main methods (i.e. why and how both qualitive and quantitative will be collected); a description of the setting and participants; of the device and apps used by the NH staff. In conclusions, principal barriers and facilitators of implementation are presented, including those reported by the NH staff during in person interviews. Expected results and limitations of the present paper are presented, also highlighting implication for practice and further research.

II. Current knowledge and gaps

From a literature review conducted by Lee et al. [14], the major areas of AI use are:

- Health prevention (i.e. automatic fall detection, especially in NH).
- Health screening (i.e. illness detection, quick diagnosis, etc.).
- Daily-life health assistance (i.e. devices that help detect older adults' behaviours).

AI could also be useful in areas such as rehabilitation, supervision, and cognitive promotion, especially in older adults affected by cognitive impairment [10].

Available published studies, especially in the nursing field, underline the utility of AI by increasing the efficiency of nurse-patient interaction [15], [16]. As Huang et al. [16] emphasised, AI devices could reduce travel to users' rooms, especially during nighttime, while increasing remote monitoring using a camera and detecting potentially dangerous situations. Moreover, AI devices may be of help, especially in understaffing situations [16]. In addition, devices integrated with AI generated fewer false alarms, decreasing the alarm fatigue experienced by caregivers and healthcare workers [15].

However, studies conducted in real-world settings are needed [9], [15]; the few available were conducted in hospitals and NHs [15], it is not known which device could better respond to specific needs; what are the characteristics of people who could benefit the most from particular types of AI devices (wearable or environmental); in addition, the impact of those devices on the daily-life and person's preferences should be better explored [7], [9]. Available reviews underline the lack of studies on wearable or environmental AI devices, the technical issues during the installation phase, and the fact that most technologies were in the development phase [9], [15].

Future studies should focus on validating AI's role in health and resolving privacy issues declared by users [9], [10]. In addition, it is necessary to integrate the vision of health care, engineering, and computer experts to address the highlighted issues [9].

III. The Ancelia Project

The main aim of the project is to describe and evaluate the use of an AI ambient optical sensor, enabled with a camera monitoring system, in two units of the RSA "G. Agnelli" in Ville Roddolo. Secondary objectives are to verify whether adopting the device has reduced the incidence of falls in the two units considered, as well as the advantages and disadvantages, the perceived usefulness, and the room for improvement.

The first phase of the project will be qualitative, with semi-structured interviews with the main users of the optical sensors: nurses and nurse assistants. An interview guide with open-ended questions will explore the perception of quality of care, the integration of the device into daily practice, advantages and disadvantages, and perceived utility. The experience reported by the interviewed will help researchers to understand better the impact of the device on the everyday activities of healthcare staff and on identifying potentially dangerous situations not detected by the device; difficulties encountered by the staff, and using the device to identify conditions that generate false alarms; to explore the overall advantages and disadvantages of the adoption of the device and the perception of device's utility and how to improve its functioning.

The results of the interviews will be discussed with both users and producers to reach an agreement on the expected requirements that the device should fulfil. In addition, qualitative data could help researchers better understand the perspectives, experiences, perceived utility, and views on AI devices, which still need to be improved in the literature.

During the second phase, sociodemographic data of residents (i.e. sex, age, etc.), health information (i.e. drugs, comorbidities, dependence level, ect.) and all the alerts generated during the monitoring phase (July 2023 – April 2024) will be collected. Quantitative data will involve the number and type of alarms, number of completed alarms by the healthcare staff, mean time of response by the healthcare staff, and mean time of care from the healthcare staff for each participant, which will be extracted from the software. Moreover, data on place, time, and mode of occurrence will be collected in case of fall. These data will shed light on residents who could benefit more from the use of the device and help build different falling-risk profiles.

A. Setting and Participants

The Ville Roddolo NH provides 137 beds, with an Alzheimer's and a residential unit, hosting older people who reside permanently in the NH.

All residents who benefit from the device will be included. The residents will be informed of the study aims, and their caregiver or legal guardian will be asked to sign a consent for data processing, including for research purposes. All the nurses and nurse's assistants who participated in the training sessions for the use of the device and who used it for at least a month during the study period (July 2023-April 2024), and who provided consent will be interviewed.

B. Technology Description

Ancelia is an optical A.I. sensor device provided by Teicare s.p.a., placed above the residents' bed, and can process information in real time. The real time processing is allowed by the Machine Learning computer-based system, allowing the continuous monitoring of the residents. Installing a fixed-optics sensor and a workstation at the healthcare facility enables Ancelia's operation. The optical sensor, implemented above each bed station, frames and films the perimeter of the bed and the area immediately adjacent to it to detect the facility resident's movements. The optical sensor is fixed and is equipped with an infrared and night vision.

Ancelia's training aims to ensure that the A.I. operating system correctly reads the scene and the environmental context framed by the optical sensor (i.e. room). The training phase lasts approximately two weeks. The training takes place according to a supervised machine learning algorithm model: the images taken by Teiacare are subjected, through human intervention, to a special 'labelling' process. Given the scene filmed in the video recording segment, Teiacare's operators precisely indicate who/what is inside the scene (e.g., a person, a shadow, a window, etc.).

The video recording, which lasts approximately 30 minutes, takes place in the clear. The images flow directly into the workstation and remain there for the time strictly necessary for Teiacare to take them and transfer them into its database (DB). This transfer takes place via an encrypted channel. At the same time as the download to the DB is completed, the images are permanently deleted from the workstation, avoiding the duplication of personal data. Once fully incorporated into DB, the video images undergo to a frame extraction process. The extraction is guided by an algorithmic solution that, through automated methods, identifies, selects and isolates the most significant frames. The relevance of frames depends on a variety of factors, including:

- The amount of motion recorded on the scene.
- The pose of the resident.
- The number of subjects present;
- The particular environmental conditions (e.g., light and shadow variation).

The frames selected by the algorithmic solution are stored on Teiacare's Network Attached Storage (NAS) device. Otherwise, the frames discarded by the algorithm are immediately deleted.

Simultaneously with the transfer to the NAS device, the personal data in the selected frames undergo a pseudonymisation process. This process, conducted by an open-source algorithmic solution ('DeepPrivacy'), takes place by applying an 'artificial' face, subject to constant and random change, to each real face detected at the scene. An open-source library on the GitHub portal artificially generates these faces.

Following the pseudonymisation of the personal data in the video footage, Teiacare staff proceeded with the labelling activity. In detail, the Company's operators affix specific identification labels on each element present on the scene and involved in the recording (e.g. people, objects, lights, shadows, etc.). The labelling activity aims to ensure that the application reads and correctly interprets the monitored context, being able to distinguish the elements. The "labelled" images are then used to learn Ancelia's A.I. model, considering the specific configuration parameters and customisation requirements of the Solution defined by the Customer.

Once the application's training phase is completed, the Company proceeds to release the relative A.I. model. The images collected and used for training the application, which have undergone the strictest security measures, are then subject to definitive deletion. Personal data are not processed for purposes other than and in addition to those of training Ancelia (so-called 'secondary use').

The Ancelia device operates through two user-friendly applications, the Operator and the Manager app (Fig.1). The Operator app, designed for healthcare workers in the units, can be easily downloaded on smartphones or tablets. The app functions exclusively via the facility's Internet network, ensuring secure access. This app allows resident monitoring, camera activation, and the display and management of alarms. Healthcare workers can monitor the room by clicking on the resident's chart and checking in real time what is happening in the room. No health information can be obtained, as the device is not linked with the electronic medical chart of the NH, ensuring patient privacy.

Live video cannot be activated if another person is in the room (i.e., a colleague, a caregiver, a resident, etc.) and can function in rooms with two (or more) beds if both guests are in bed. Live video has no sound, lasts up to 15 seconds and can be started anytime.

The alarm is audible and visible from the screen (red background). The sensor does not resume operation until the activity is completed. The device sends notifications until it is muted or if someone enters the room.

The Manager app can be accessed from any device and returns the aggregated data of the units, rooms, or residents. As for the Operator app, accessing the resident's medical information is impossible. The Manager app has two sections: the management, where the nursing coordinator can admit, discharge, or transfer the patient and set the type of alarms. Customising alarms and associating them with multiple residents is also possible, as well as setting night and day alarms. The same alarm can be placed in several time slots; for example, the suspicious immobility alarm can be set off every two hours. The second section, "Statistics", provides the number of alarms generated, the number of completed interventions, the mean response time, and the mean time of care for each level (unit, room, individual user).

IV. Ethics

The protocol was approved by the Ethics Committee of the University of Torino, on 30 January 2024 with protocol number 0081409- [UOR: SI000045 – Classif. III/11].

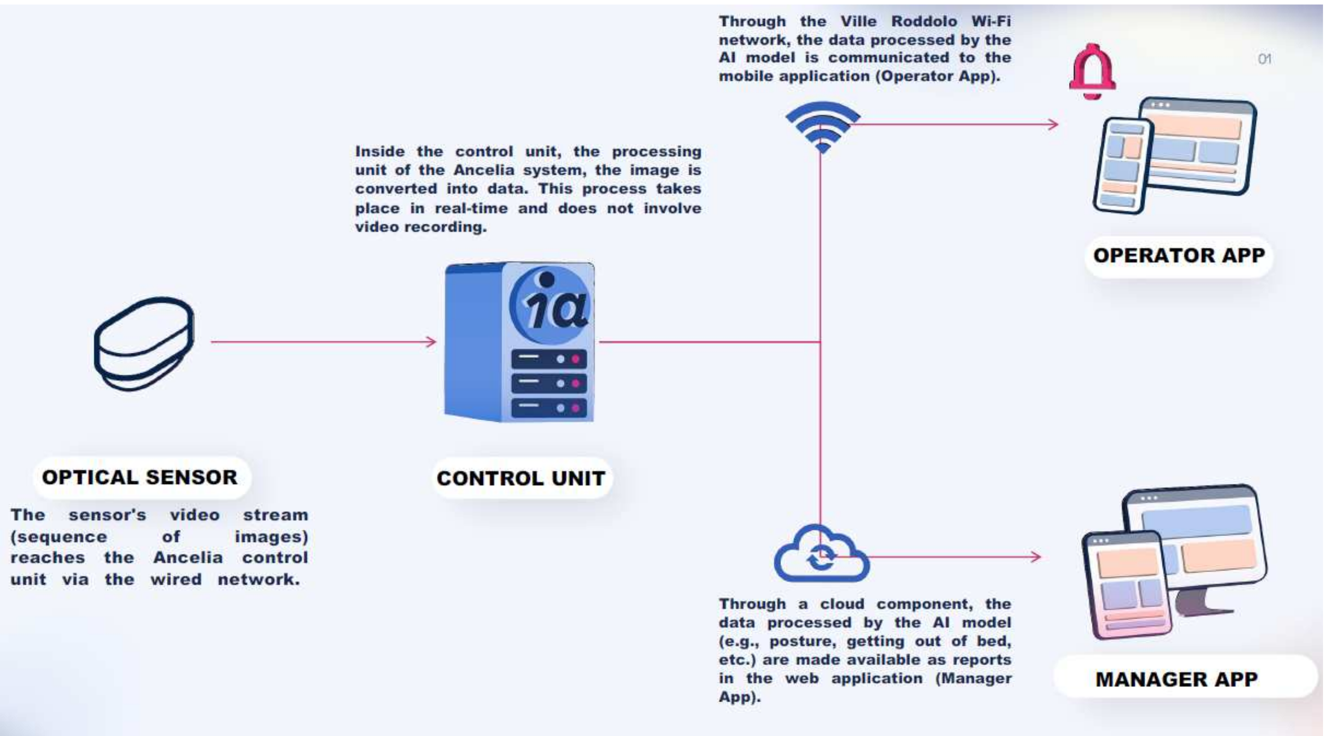

Fig. 1. Device functioning.

V. Preliminary Results

A total of 50 residents were monitored with the device during the observation phase and 11 of them experienced at least one fall. 14 NH staff were interviewed, with a median age of 46 (IQR 43.3;50.8) and a median of 5 years (IQR 3;12.8) of work experience in their role.

A. Barriers and Facilitators

Different barriers and facilitators were encountered from the project start. Firstly, problems emerged during the installation phase, as the Internet network did not cover all the NH. This affected the original choice to install the device in two special units. This limitation did not allow at first to select the guests that could benefit more from the device (i.e. "new entries", guests in rooms far from the nurses' room, etc.). As reported by the NH staff, the lack of a full Internet network coverage divided the residence into two parts. This can lead to a fragmentation of the care provided to the person. Residents without the device require more direct monitoring and, as a consequence, a higher time of response from the NH personnel. Residents more at risk, such as those with advanced Alzheimer's or dementia and who require more monitoring, should be moved to the rooms with the device. Given the absence of studies conducted in real settings, a possible risk profile is not likely to be identified..

As reported by the participants, early delirium symptoms were often identified, and the person was transferred to a room where the device was installed.

Two key factors impacted the device's acceptance in the first phase of our research. The first was the training provided by the device company, which included close mentoring, especially in the first three months after the installation implementation. This training helped users accept the device, fostered a fruitful dialogue between users and manufacturers, and solved some bugs that emerged during use. Initially, the device mistakenly identified some objects, such as a coat rack with many jackets hanging on it, as people. This prevented the activation of the camera and, thus, remote monitoring. The second factor was the easy-to-use interface, which even novice users found easy to understand at first glance. The interviews also confirmed the ease of use.

To facilitate the integration of the device in the NH, only night alarms were set (from 8 p.m. to 7 a.m.) during the first five months (from July to November 2023). Reduced care activities dictated this choice during the night compared to the day, allowing healthcare workers to familiarise themselves with the device. Subsequently, alarms were personalised based on the characteristics and needs of the residents (i.e., level of independence, level of cognitive impairment, etc.), reported by nurses and nurse's assistants. For example, the alarm that signals the user is getting out of bed is set only for residents with preserved mobility who need support during transfers.

The high turnover of nursing personnel, particularly alarming in nursing homes, where staff can leave within a month, is a challenging obstacle. This can strain the NH, requiring the constant training of new staff or the support of existing employees and the guidance and support of recruits, affecting the use of the device, particularly by new hires. This contrasts with what Huang et al. highlighted [16], where AI devices could also be useful in understaffing situations. However, further data are necessary to understand this phenomenon better.

B. The Role of AI in nursing

A preliminary analysis of the interviews reveals the impact of the device on planning activities, particularly during the night. The possibility of activating the camera at any time allowed a monitoring increase, especially for potentially at most risk residents, and to organise activities according to priorities. As reported in the literature, this sensor function may support decision-making and enable staff to identify a resident's deterioration more quickly [15], [16]. In addition, tailoring the alerts to the residents' needs allowed for closer monitoring, avoiding false alarms.

Even if the device was developed for supporting nurses, interviewed nurses often reported no or little use of the device, which nurse assistants mainly used. Our results seems to be in contrast to what reported in the literature [16], [17]. Published studies, such as Huang et al. [16], involved only nurses, while other [18] healthcare staff in general (nurses and nurse assistants). The mix of healthcare personnel may influence the device's use (and perceived usefulness). This may explain our results.

Nurses and nurses' assistants' contribution is an essential element in AI development, as they are the end users of this technology. Their involvement in the design and implementation is pivotal as they can identify pitfalls, suggest solutions, and report bugs (i.e. the coat rack was mistaken for someone). The most desired features were checking the resident's temperature or zooming the camera image.

VI. Expected Results

The main expected results will be to describe how the device works, the number and type of alarms generated and perceived usefulness among professionals. Secondary outcomes include the measurement of a possible increase in the safety of the resident (reduction in the number of falls), given by the device's ability to signal episodes of wandering, bed exit or attempted climbing over the side rails, and by the perception of an improvement in the quality of care reported by the professionals. Continuous monitoring allows nurses and, more generally, NH staff to obtain useful data for care planning (i.e. rethinking the residents' waking-up schedule based on night alarms, evaluating strategies to reduce wandering episodes based on what is reported by the device, etc.). Such data would make it possible to anticipate care needs, foreseeing the timely activation of targeted and customised interventions. Finally, the final expected result is a reduction in the number of nurses and/or nurse assistants rounds due to the possibility of monitoring the person via the camera integrated into the device. In the event of an alarm, the staff may verify the person's real condition without going to the room.

VII. The Main Limitation of the Paper

This paper presents some limitations. Firstly, being a study protocol, a full data presentation is not possible. A more comprehensive and deeper understanding of barriers and facilitators to the implementation of the device will be possible after the full analysis of the interviews performed with the NH staff.

VIII. Conclusion

The preliminary results reveal a marked level of acceptance and use of the device, as reported by the residence staff. It's worth noting that the device is mostly used by nursing assistants, particularly at night, rather than by nurses. Collecting quantitative and qualitative data will provide a comprehensive understanding of the benefits and advantages of using AI compared to alternative solutions or usual care. The real-world data analysis will contribute to a better understanding of the AI application in NHs and highlight the barriers and facilitators to healthcare facilities' digitalisation. Furthermore, despite the devices already being used in real-world settings, there needs to be more knowledge about the perspectives and experiences of nurses, who should strive to play an active role in the scientific discourse on AI in nursing.

Conflict of Interest

Daniele Sciarrotta (D.S.) is the Director of Ville Roddolo Nursing Home (Ass.I.S.Te company), where the project was developed. Matilde Piccini (M.P.) and Maria Vittoria Bellotti (M.V.B.) are, respectively, the Project Specialist and the Account Manger for Teiacare s.p.a., the device manufacturer company. The remaining authors declare the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgment

Authors would thank the Ville Roddolo Nursing Home staff for their contribution to the project. We would also thank the Teiacare staff for their support during all the phases of the project, especially for data collection and alarm analysis.

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