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Designing a Smart, Sustainable Elderly Healthcare Ecosystem through Interdisciplinary Innovation in Nursing Homes

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Abstract
The attributed population growth in the aging population necessitates novel, sustainable health care services, especially in nursing homes. The following paper proposes a cross disciplinary design model of an intelligent, interactive old age healthcare system, which can work specifically in a nursing home setting. Combining concepts in the fields of healthcare, engineering, information technology and green sciences, the system that would be proposed would prioritize personalized treatment, real-time care systems and information technology, and sustainable environmental choices. Such characteristics are a focus on sensor-based health monitoring, artificial intelligence-enabled diagnostics, and interactive user interfaces, and sustainable infrastructure. The aim is to make life more comfortable among the older residents, and streamline the processes of caregiving, as well as to minimize environmental impact of long-term care facilities. The integrated nature of this strategy leads to the development of flexible, strength-based, and person-centered model of elderly care in the future.

Keywords: ***Elderly healthcare, Nursing homes, Interdisciplinary design, Smart health systems, Sustainable healthcare, IoT in eldercare, AI diagnostics, Green infrastructure, Assisted living technologies, Health monitoring systems.***

1.Introduction

The swift natural change into an older world, with an increased number of aged people, poses unforeseen difficulties to the healthcare system especially in terms of long-term and effective geriatric servicing. Fertility rates are dropping and life expectancy is on the rise, a factor that is throwing societies into a dilemma about how best to support its ageing population that is increasingly living longer and in most cases alone. The tendency of the younger generations to move to the cities in an attempt to receive better financial opportunities has left numerous elderly people in the rural or suburban towns. This change of population has stimulated the influx of needs in regards to institutional care, particularly in the form of nursing homes that are becoming a widely acceptable and convenient option of accommodation to the aged demanding continuous care. However, such facilities are usually resource-limited and mismodeled and poorly placed to guide the current demands of their elderly residents.

Due to this, there has been an emergence of the concept of smart elderly care as an innovative paradigm working to redesign the nursing homes by innovating their working process. Instead of having human caregivers being the only option, smart elderly care systems are used to keep a check on the elderly; they assist and communicate with the elderly in real time using the innovations in digital technology in terms of sensor networks, data analytics, wearable devices, and indoor positioning systems. In addition to making care high in quality and responsive, these technologies help address the shortage of staff by supporting their interventions remotely and without human assistance. Noteworthy, they enable the ageing people to sustain independence and dignity in their everyday lives, not to mention enhancing the performance of the care givers and minimising the cost of operations.

The secret behind these intelligent systems is sustainability- not in the environmental sense, but in the sense of the whole package including economic feasibility, technological sustainability and the fact that social inclusiveness should be practiced(1). The sustainable healthcare system should be flexible and flexible in most nursing home settings that include adequately funded urban institutions and those that are under-funded in rural settings. It has to be scalable as well as economically viable to be able to be maintained over a period of time without the need of any special equipment or constant expert supervision. Also, a sustainable system should be socially acceptable and friendly to anyone but, more importantly, to the elderly who can have cognitive, physical, or technological blocks.

The second important foundation of the suggested design is interactivity. The classic model of elderly care is usually passive where the care of the elderly relies heavily on concentrated supervision, and care giving. On the contrary, interactive care model encourages peer-to-peer support and active participation of residents. As an example we could say that in the case of medical emergency like fall or cardiac incident, other residents in the area could be alerted and deployed to administer some first aid and till the time professional help is provided. It is a shared solution that shifts aging in place care to a connected, empowered system and every resident is their own first responder. In its turn that decreases the time of response, gives more chances of positive results, and helps to have the sense of community within the facility.

The development of such a system consists of interdisciplinary cooperation that incorporates the skills of computer scientists, medical professionals, environmental engineers, user experience designers, and social controllers. The system should perfectly combine the indoor positioning technologies such as indoor Bluetooth Low Energy (BLE) iBeacons that can show real-time location and movement of the residents. It should also be integrated with wearable health monitor gadgets which measure constantly the vital signs like heart rate, oxygen saturation, and body temperature and send alerts in case abnormalities are present. The data obtained should then be thenforwarded onto intelligent algorithms that are able to make real time decisions, e.g. determination that an emergency has occurred, extraction of the people around the area to be notified, finding the escape routes through the facility which are safe.

In addition to that, the system is to be set up according to the architectural and environmental situation, which occurs in every nursing home. A typical facility will have several areas of activities which include the dining halls, recreation rooms, gardens and medical departments among others hence the facility has a complex spatial configuration making it challenging to keep track of every resident at all times. One could provide a scalable and accurate solution to the above problem using technologies such as fingerprint indoor positioning which is possible using signal strength data and machine learning algorithms. As opposed to the GPS that only performs well outdoors, fingerprinting relies on signal strength of fixed iBeacon nodes to triangulate the whereabouts of the user, allowing precise tracking in the densely built environments(2).

Risk prevention is also equally important. Most of the injuries and accidents else the nursing home happen in the zones which can be foreseen--low-visibility places, stairs, and wet floors. Such areas can be predefined by the administrators on an interactive map and the system can automatically provide audio or visual warnings to residents who are migrating into these areas. This proactive alert system is like a safety net and it is particularly useful to those residents whose cognitive abilities are unable to memorize or recognize physical signs of danger.

Such an integrative solution is also required to discuss psychological and privacy issues. The older people might be obsessed with the idea of being watched all the time, particularly, when the system appears to be intrusive or difficult to grasp. Thus, the interface and experience have to be noncontacting and autonomy friendly. Easy interconnection techniques are needed, e.g. distress signals with a voice command or a double-tap on a wearable device is allowed. Moreover, manual override and consent-based data sharing as options should be integrated into their design to establish both ethical compliance and the trust of a user.

Finally, economic factors cannot be ignored. Such a system must be able to have deployment and maintenance costs that will be manageable by even institutions with less finances. Accessibility can be secured by deploying available, cost-efficient technologies (e.g., smartphones, beacons with Bluetooth Low Energy, off-the-shelf wearable). In addition, the cloud based processing and the modular application programming interfaces (APIs) design the system expandable and integrable with the third party services, including health databases and emergency dispatch systems.

To conclude, when managing the design of a sustainable, interactive geriatric healthcare system to the nursing facility, it is paramount to create a subtle balance between cost-effectiveness, convenience, automatization, and sympathy. The solution should be based on the real world feasibility and should capture the complex aspects of the elderly care. It not only has to respond to crisis, but avoid them; not only observe people, but also relate them; not only stay alive in the concept, but flourish in reality. It needs the smart design, as well as devices, not only interdisciplinary but also inclusive and inspired by the pressing need to take care of our aging citizens in a humane and forward-looking way.

2. Associated Work

The need to offer holistic, long term, and dynamic care to the elderly in institutional settings has been noted extensively in both theoretical studies and practice of health policy. With the emergence of the concept of an intelligent eldercare, a number of interdisciplinary studies have been developed examining how smart technologies, networked devices and intelligent systems can be integrated in the care setting and in a more intuitive

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way serving the needs of aging populations. Although several pilot programs, and technological prototypes do exist, there has been a paucity of a strong synthesis of low-cost, in-real-time and consumer-friendly systems specific to nursing homes(3).

The use of sensor-based systems in the monitoring of solitary elders is one of the oldest and the most powerful trends in the sphere. Another concept is a low-pricing model suggested by Huh (2017) revolving around the work of simple sensor nodes to trace the routine of isolated elderly people. The system revealed that the critical care capabilities necessary--including the ability to detect unusual inactivity--could be run with very little hardware investment and configuration. Such systems were usually not interactive in nature and there was more human involvement in interpreting signals which in turn reduced its feasibility to deploy to nursing homes.

The use of pervasive camera networks to monitor elderly citizens in structured environments has been considerated by other researchers. The system proposed by Bharanitharan et al. (2019) is a reliable camera-reliant management system to be used in old-age centers that allows one to monitor its residents in real-time via video streams. Although this system was very extensive in visual coverage, there are significant questions surrounding issues of privacy and emotional well-being, at the very least on a constituent of the residents that might be hypersensitive to the feeling they are always under observation. In addition, video processing was an energy-intensive job, and thus it was not a good match with under-resourced facilities.

When it comes to wearable technology, Gaddam et al. (2020) presented a cognitive sensor network that would monitor the physiological changes in the elderly. Such wearable gadgets might monitor changes in temperature, pressure and postures to warn against possible health hazards, like falls and strokes. In the same way, Fischer et al. (2021) concerned themselves with the idea of sleeping mats that can monitor urinary incontinence and sleep problems by being situated beneath beds. These developments underscored how complex embedded sensing was becoming, sometime needing custom devices, expert service and personnel; all potential issues within nursing homes with limited resources.

To resolve low cost-effectiveness and ease of use, Hakala et al. (2020) introduced a data management system streaming-based to aggregate the data presented by the sensors to have real-time eldercare feedback. Their contribution to the understanding of how the big data pipelines may be leveraged in order to continuously monitor health parameters and reveal the anomalies was present; nevertheless, the problem of adopting an approach in large institutional environments with IT backbones that may not be sufficiently robust was there(4).

Design wise, the inclusion of indoor positioning systems (IPS) becomes a key study approach since most research work has been concentrated in the high-density environment such as nursing homes. The bulk of IPS applications are founded upon one of three wireless technologies including: Wi-Fi, ZigBee or Bluetooth Low Energy (BLE). All these have different trade offs in power consumption cost and accuracy. The BLE-based iBeacon systems represent one such candidate because they are low-cost, widely compatible with the mobile devices, and easy to implement. The papers by Chen et al. (2020) and Li et al. (2021) have shown the successful application of RSSI-based fingerprinting with iBeacons to deliver optimal indoor positioning, and that is the key factor to real-time, cell-level localization of the most vulnerable members of the population, elderly residents.

When evaluating different indoor positioning strategies, it is important to draw the line between measurement based and fingerprint based systems. The former make use of a high-accurate but hardware intensive methods like Time of Arrival (TOA) and Angle of Arrival (AOA) and cannot be applied to the majority of nursing homes due to this requirement. Fingerprint-based procedures on the other hand are more feasible. They include compilation of a database of patterns of signal strengths at certain known sites (the offline phase) followed by manually matching on site signal readings (the online phase) to produce a location estimate of the user. It has been pushed further by Deng et al. (2019) and Ye et al. (2020) through machine learning models of Support Vector Machines (SVM) and k-Nearest Neighbors (KNN) to demonstrate that even simple algorithms can deliver equally precise results once properly tuned.

Machine learning has been significant to the optimization of these fingerprinting methods. KNN is also a simple and flexible model and therefore one of the most popular. Amirisoori et al. (2019) and Yang et al. (2020) have shown that a modified version of KNN in combination with some preprocessing filters, such as Gaussian smoothing and Kalman estimation significantly helped to fix the location accuracy and noise gains. Other models, like Recurrent Neural Networks (RNNs) or Bayesian-KNN hybrids (Yadav et al., 2021), have demonstrated its potential yet might increase computational cost and restrict real-time responsiveness, which is a crucial aspect, considering that eldercare will require safety-critical solutions.

In addition to positioning and sensing, intelligent path finding is one more fundamental tap in interactive eldercare structures. Nursing home is usually an architecturally complicated facility with numerous rooms, corridors, and floors. In this regard, classical Euclidean distance measures are not enough to know the proximity or the best rescue routes. It has been useful to invoke Dijkstra algorithm and GPU-based versions of it. To offer a specimen, Hoang et al. (2020) demonstrated that parallelized versions of Dijkstra running on CUDA enabled a drastic reductions in the computational response time of computing shortest paths using real-time data computing, which is invaluable when using medical emergencies since every second counts(5).

The last, but the essential area of inquiry, is the user experience and social acceptability. The most high-tech systems can be useless unless they are bought by seniors or their caretakers. Maswadi et al. (2021) and Hernandez et al. (2019) noted that the main principle in making the elderly adopt technology in technology adoption is based on simplicity, trust, and minimum intrusiveness. This does not mean that there should be no interfaces; on the contrary, they should be user-friendly, such as preferably audio, large-scale visual notifications, and their simplicity should intrude into the personal routine of a user the least possible. In addition, any system should be used to solve the issue of data privacy where disclosure policies and user annotations on the sharing of personal health information should be transparent.

Collectively, the available literature describes a solid basis of technical instrumentations and frameworks of conceptualization to create a unified culture of elderly healthcare in nursing homes. Nevertheless, a majority of such efforts deal with addressing specific individuated aspects, e.g., sensing, localization, or data processing, but not as a part of a more rounded, engineered to last, and socially thoughtful solution. This gap contributes to the importance of the current research that does not only improvise on existing technologies such as the ability to pinpoint the location of a victim through the BLE positioning system or wearable health trackers but also proposes interactive rescue procedures, cost-based implementation choices, and concept-oriented design principles that together re-conceptualize the entire care setup in aging societies.

3.Technical Framework, System Design

An efficient, sustainable, and interactive healthcare system with an elderly population in nursing homes will take a strong technical base that will comprise of indoor localization, real-time data gathering, smart warning system, and interactive assistance guidelines. In this section, the redesigned potential system architecture and implementation approach are shown in a systematic format, and there are five main subtopics, as follows: indoor positioning architecture, RSSI fingerprinting, signal preprocessing, real-time tracking and assistance algorithm, and integration of health devices.

1. Localization in Indoors by Bluetooth-based Infrastructure

The proposed system relies on getting accurate real-time localization. Since the spatial structure of nursing homes is quite complicated, the implementation of conventional surveillance and monitoring systems and manual observation cannot be used to follow the movement of elders. Rather, the system is based on the application of Bluetooth Low Energy (BLE) beacons, i.e., the iBeacon framework developed by Apple, to form a dynamic grid of positioning in indoor environments(6).

The strategically placed BLE beacons create a low-power low-cost mesh network throughout the facility. Every beacon is set to broadcast its unique identifier periodically. The residents have mobile devices, or printable wearable sensors, that constantly scan the vicinity of the beacon and the signal strength of the beacon is noted i.e. Received Signal Strength Indicator (RSSI). This information is utilized to approximate the position of the user to the locations of the beacons that are known.

Such a solution has many benefits: BLE beacons work with the vast majority of smart phones and wearables, can be installed easily and taking little energy-therefore, they allow cost-sensitive and large-scale implementations to be executed across healthcare facilities.

2. RSSI Finger printing mapping and database driven creation

The indoor positioning system is centered on RSSI fingerprint database where physical points are related to specific signal profiles. It takes of two stages namely an offline one to collect data and calibration, the initial stage and an online stage to estimate positions in real-time.

In the offline phase, raw RSSI values of the beacons found in each reference location (e.g., the corner of a hall, entry to a room, or a common point) are measured several times by a mobile device. The fingerprint readings are

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summed or stored as fingerprint vectors culminating with the actual coordinates assigned to them. By doing so, a map of virtual signature of signals will be produced.

In the case of an active user in the nursing home, the mobile device reads the RSSI environment and transmits the information to the server. The system would then compare a real-time vector, with the nearest fingerprint record in the database, providing a forecast location of high spatial accuracy.

TABLE 1 Core Components of the Smart Elderly Healthcare System

System Module	Functionality	Technology Used	Benefits
Indoor Positioning	Real-time tracking of residents' locations	BLE iBeacons, RSSI Fingerprinting	Low-cost deployment, accurate tracking in indoor environments
RSSI Data Processing	Cleansing and stabilizing signal data	Gaussian Filter, Kalman Filter	Reduces noise and improves location precision
Localization Algorithm	Estimate user position based on signal fingerprints	Modified k-Nearest Neighbors (KNN)	High accuracy, motion continuity, low computational load
Emergency Assistance	Dispatches peer responders using optimal routes	GPU-accelerated Dijkstra's Pathfinding	Fast response, route-aware, bypasses obstacles in real nursing homes
Wearable Health Monitoring	Tracks vital signs and detects anomalies (e.g., falls, low SpO2)	Smartwatches, Bracelets, Sensor Integration	Real-time health insights, auto/manual alert triggering
Alert & Notification System	Issues warnings to users approaching danger zones or during emergencies	Mobile app notifications, audio/visual cues	Prevents accidents, guides safe behavior
Data Integration & Visualization	Aggregates data for caregiver dashboards and remote monitoring	Cloud-based data handling and mobile APIs	Scalable monitoring, transparency for families and medical staff

3. Signal Smoothing and Data Filtering

Raw RSSI readings revealed in BLE beacons were noisy in nature because of environmental distractions including wall interference, multi-path reflections and radio frequency (RF) congestion. To enhance the accuracy of localization and stability of prediction, a number of preprocessing methods are adopted.

First, Gaussian Filtering is applied in order to eliminate outlier values in the signal distribution, as it is assumed that under normal conditions the majority of the values in the RSSI stay to a normal distribution. Outliers which occur within a predetermined confidence interval are eliminated in order to prevent distortion in the fingerprint vectors.

A second stage of Kalman Filtering (LQE) is then applied to filter out a residual noise. This filter assumes an RSSI reading as a time series and estimates the actual signal strength with time, compensating the changing dynamics such as displacement of furniture or one moving around. Both fingerprint database building and tracking in the real-time are more stable and reliable when the values of RSSI are filtered.

Such gap-filling tools as Spatial Interpolation (Kriging) are also used to complete location data that are not generated through manual sampling(7). This saves the time and efforts of installation of the system in a large-scale building and, at the same time, having an accurate data.

4. Rescue Pathfinding and Real-Time Location Estimation

Upon the creation of the fingerprint database, the online positioning step employs a type of the k-Nearest Neighbor (KNN) type of algorithm to determine the current location of a user. A user enters RSSI vector measured by its device, which is matched against the database and the best k matches (closest ones, using Euclidean distance) are chosen. These reference points are averaged by weighting with the previous known location of the user to maintain the continuity to come up with the final estimated position.

In order to provide interactive peer-to-peer support, a pathfinding engine will also be included in the system which will be capable of calculating the quickest route between the person in distress and the possible helpers. This is an engine that uses an optimized parallel form of Dijkstra algorithm enhanced with GPU processing to achieve speed.

The system does not rely on geometric proximity only but takes into consideration actual travel paths and obstacles in the environment (e.g. walls or stairs) and make sure that the correct responders will be notified.

The facility map is programmed with marked dangerous areas, e.g. slippery floors or poorly illuminated halls. As soon as an elderly person is nearing a danger area, the system sends the warnings to the device of such a person, and it starts sending audio and visual warnings to avoid accidents.

5. Wearable Health Devices Integration

Smart health devices are also added to the ecosystem in order to achieve an even higher responsiveness rate of systems. These are commercial smart-wristbands, smart-watches and glasses equipped with sensors that are able to record important physiological indicators, including:

- Heart rate
- Oxygen saturation of blood
- Body temperature
- Sudden movement alterations (e.g. falls)

These products are combined with the main client application used on smartphone devices of users or directly on operating systems of wearable gadgets (e.g., Android Wear). The software has the ability to gather biometric information and match it with the safety levels on a constant basis. In case of detecting any irregularities, i.e. a drop of oxygen in the blood or a fall without movement, an automatic distress signal can be issued, and surrounding responders are notified by the location tracking module(8).

The system provides redundancy because it does not only supply a detection based on button press or voice activation but can also work through automated detection. Also, family members and other authorized caregivers will be able to view information on the patient in real-time via secure dashboards and provide remote support and telehealth interventions.

Integrating indoor positioning, health tracking, and interactive response methodologies, the offered system can give a multipolar solution to the problem of elderly caretaking at nursing homes. It provides real-time and accurate support and at the same time it is cost effective and flexible in different types of facilities. Above all, it creates a smart and efficient care ecosystem, which is also compassionate and enables older residents to live with more assurance, dignity, and safety.

4.Results

An evaluation of the proposed smart healthcare system was based on the multi-phase testing process simulating the conditions in a nursing home that evaluated its efficiency and effectiveness. The tests were done regarding the technical aspects of indoor positioning, peer-assisted mechanisms of emergency support, time responsiveness in real-time, and the use of wearable health monitoring devices. These findings are good practices to demonstrate the possible deployment of a green, interactive system of elderly care on scale.

4.1 Accuracy and stability of indoor positioning

The RSSI fingerprinting based architecture over the BLE mechanism in indoor positioning acts as one of the core elements of the suggested system. The testbed was placed in a 20 meter by 15 meter area, a typical nursing home layout with corridors and rooms and recreation areas. A number of 25 iBeacon nodes was set and a number of 180 reference points created to constitute a complete fingerprinting database full of fingerprints. The live RSSI was gathered by mobile devices and sent to a central server so that the location could be estimated in real-time.

Two scenarios has been implied to test location accuracy:

Static Positioning: This method kept the subject on a fixed position and 200 location reading was done at each point.

Dynamic Tracking: The subject moved along a linear route of his choice, as opposed to simulating the movement of an elderly person across facility space e.g. a bedroom to a dining area.

The average localization error in the static tests was 1.86 meters with more than 74 percent at the 2.5-meter margin and about 51.5 percent at the 1.5-meter margin. Dynamic tests gives an average error of 1.92 meters which is slightly off due to motion that creates varying RSSI values and server-side processing latency. However, the system was able to provide effective tracking that is always essential in finding a person within a very short time during disasters or in doing routine treatment(9).

4.2 Effect of Preprocess and Algorithm Optimization

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In controlled trials, preprocessing methods were considered in order to maximize the quality of the RSSI data and increase the positioning accuracy. The initial filtering was achieved through Gaussian smoothing, exiting the outliers of the signals by a threshold of the normal distribution. After this the Kalman filtering procedure was used to forecast consistent changes in signals with time.

Also, the system applied Kriging interpolation technique to interpolate spatially a fingerprint database in areas that were impractical to have direct RSSI sampling. This saved a lot of work time spent by manual positioning and collection of data and still gave accuracy.

The modified k- Nearest Neighbor (KNN) approach was applied to the real time matching algorithm. The modified KNN, unlike the traditional one, picked up k nearest fingerprint vectors solely on the basis of distance, but also based on the previous location of the user. Such continuity requirement prevented such fluctuations and leaped predictions in a coordinate value and enabled better reliability in dynamic tracking.

A set of comparative tests was done to use as benchmark the impact of each algorithmic choice:

The average error of the mean-filter-only method was very high, given an average error of 2.30 meters.

When interpolation was disabled, 2.23 meters of error was created.

A 2.18-meter error was obtained when using the standard KNN (no pre-position adjust).

On the contrary, the complete system- with the inclusion of Gaussian Kalman filtering, interpolation, and modified KNN performed better with an error 1.86 meters consistently. This proves that algorithmic synergy can be used to maximize real-time accuracy and usability of the system.

4.3 Cross-Review of Ability to Respond to Emergencies Peer-to-peer

One of the original features of the system is the interactive assistance module that allows providing peer-to peer support in the emergencies. In case of a health risk identification (manual or automatic), the system will identify the closest possible people who can help until the arrival of professional caregivers.

Nonetheless, the use of solely Euclidean-based distance to measure proximity was not enough in space layouts in the real world because of an impeding element like a wall or locked door(10). Thus, the system applied GPU-based pathfinding algorithm that depends on a parallelized Dijkstra approach. In this algorithm the shortest distance between two points is calculated between the actual floor plan as opposed to raw geometric distance.

Pathfinding pathfinding was tested on a CPU and a GPU to use performance. On small graphs (<100 vertices), the CPU and the GPU had good response times. Nevertheless, in larger graphs with simulated more complex or multi-level nursing homes (500+ vertices), the GPU-accelerated algorithm was as much as 6.4 times faster, which can facilitate almost instant selection and notification of immediate helpers.

Also in the system, high risk areas like slippery floor, stairways were labeled in advance. Pathfinding engine determined the times when the residents enter these danger zones and automated proximity warning was issued to avoid accidents.

TABLE 2 Summary of Experimental Results

Test Category	Scenario	Avg. Error / Time	Success Rate	Notes
Indoor Positioning Accuracy	Static	1.86 meters	74% < 2.5m	Stable results across 200 tests
Indoor Positioning Accuracy	Dynamic	1.92 meters	70.5% < 2.5m	Effective even during movement
Signal Filtering (vs. mean)	Filtered RSSI	↓ by ~20% error	—	Gaussian + Kalman most effective
Pathfinding (GPU vs. CPU)	500-node graph	GPU: 32 ms, CPU: 206 ms	GPU ~6.4× faster	Faster peer-assistance in large layouts
Smart Device Alert Latency	Auto-triggered events	3.2 seconds avg.	92% < 5s	Quick biometric-based distress signaling

4.4 Wearable Health Devices Integration

The last assessment was aimed at joining smart wearable health devices in the system. Smart bracelets and watches that were commercially obtainable were used to monitor:

- Heart rate

- blood Oxygen saturation (SpO2)
- Skin temperature
- Accelerometers: fall detection

These gears were being combined with the primary mobile program, obtaining and relaying biometric knowledge to the server. When the physiological parameters reached values beyond the pre-set limits, e.g. oxygen level falling to less than 90 percent of the normal value, or irregular heart rates, alerts would be generated. The emergency signal may also be activated manually by tapping the gadget or activating it by voice.

On the tests, more than 92 percent automated alerts were generated in less than 5 seconds after the detection of events, and the average handling time was 3.2 seconds. This quick alert regime makes sure that there is a prompt mitigation of such instances as fainting or heart attacks.

Simulations of trial versions put both caregivers and elderly respondents through and showed a high rate of acceptance based on ease of use and low invasiveness, as well as comfort in being prepared.

5.Conclusion and Future work

There is an increase in the global need of geriatrics making a paradigm shift in the design, management and operation of nursing homes inevitable. In this paper, it has suggested and analyzed an interdisciplinary, sustainable, and interactive model of elder care that not only accounts to the existing weaknesses of current institutional eldercare but also provides perspective of future needs as well. By a careful selection of affordable technologies, smart data processing, and user-centered design, the system allows real-time monitoring of health, prevention of emergent risk factors, and active peer-based help all of which are unified to form an integrated whole.

The identifying strength of the system is the modular and scalable kind of architecture. Utilizing Bluetooth Low Energy (BLE) iBeacons, RSSI-based fingerprinting, the solution proposed to this research grants low cost and accurate indoor positioning system fit to different conditions of nursing home facilities. Gauzzian smoothing and Kalman estimation, state of the art filtering methods, play a role in improving positioning accuracy, and the usage of machine learning-based approaches to change movement tracking bias, the node-based k-Nearest Neighbors (KNN) variant, modified k-Nearest Neighbors can keep track of the movement, providing responsive action. This localization ability in an indoor setting is the corner stone of all real time monitoring and emergency response ability.

Running in parallel, the peer-to-peer alerting system of the system is an entirely new mode of an interactive care with accelerated pathfinding algorithms running on GPU hardware. In case of distress by an elderly resident, the system will quickly compute the nearest route to send nearby people, instead of waiting until a member of staff intervenes. This greatly improves the response time in case of an emergency, the ability to survive and an improved attitude towards a more collaborative community approach towards the nursing home.

It is also vital to organize flawless incorporation of wearable health metrics. The system can be used by associating the biometric sensors like smart bracelets and watches with a mobile program that monitors abnormal health parameters, such as arrhythmical heart rate or the lack of oxygenation and falls. These units allow sending a distress signal both manually and automatically in case residents cannot call help by themselves, so the response can always be quick. This feature is especially helpful where cognitive impairment or abrupt change of health exists.

The sustainability of this project should be deemed as one of the most remarkable aspects of it. The system has been made keeping in mind cost, complexity of deployment and effort of maintenance. It uses common consumer level hardware, open network protocols and loosely coupled software layers, this makes it feasible to any nursing home with or without resources. Also, it is designed with the sense of long-term viability in mind, therefore it requires less continuous help and support of keeping it available as well as less replacement of the hardware.

The interdisciplinerity of this work - as an odd amalgamation of healthcare, computer science, user experience design, and public policy - supports the notion that good eldercare cannot (and should not) be solved with technology. Rather, it will be necessary to view it in a holistic manner which would take into consideration psychological acceptance, privacy considerations, user adaptability and organizational culture. The system takes these factors into consideration and gives easy to understand interfaces, access to a period where users can share data based on their consent, and minimal use of computing power on the part of the elderly user.

In short, this piece of work has shown that not only are smart, responsive and sustainable healthcare systems possible per the technological dimension, but they are also socially and economically feasible. With worldwide

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aging gaining pace, the systems will become an inseparable part of intelligent nursing home infrastructure. Putting emphasis on the human dignity, technological ease, and support in real-time, the given solution preconditions the new future of elderly care, which can be as humanistic as innovative.

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Conflicts of interest

The authors have no conflicts of interest to declare

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