Empowering Elderly Care with Social Robots

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Abstract

The increasing trend of global population ageing brings with it an urgent necessity for the introduction of innovative devices to enhance the standard of elderly care. In this context, social robots integrated with onboard systems have promising prospects of improving the quality of life of the elderly by assisting, various forms of entertainment, and health monitoring. The current study presents the interactive or embedded systems used in social robots focusing on elderly care. It also explains how embedded technologies help in human-robot interaction and the behavior of the robots in real-time, including making decisions and carrying out certain tasks autonomously, such as reminding patients to take their medication, assisting with movement, and providing psychological support. Furthermore, the research provides a brief overview of the challenges encountered in deploying such robots and highlights the role of embedded systems in social robotics. This study focuses on the importance of these technologies in minimizing the problems of an aging population.

Keywords: Elderly care, Social robots, Interactive systems, Embedded systems, Human-robot interaction, Autonomous behavior, Medication reminders, Psychological support, Societal issues.

1. Introduction

The ageing of the global population is significantly altering demographic patterns, placing substantial pressure on healthcare systems. As the number of elderly individuals continues to grow, there is an urgent need for innovative strategies that can improve the quality of elderly care while reducing the workload of caregivers and healthcare professionals. One of the most promising solutions to meet this demand is the use of social robots, which are enhanced with advanced interactive and embedded technologies [4,5].

Social robots are specifically designed to engage with humans in a meaningful and interactive way, offering not only practical assistance with everyday tasks but also emotional support and companionship. These robots can enhance the well-being of elderly individuals by providing personalized services such as reminding them to take their medications, monitoring health indicators, and assisting with mobility. Utilizing embedded systems and intelligent algorithms, social robots are capable of making decisions in real-time, adapting their behavior to meet the specific needs of users. This capacity for autonomous operation, paired with natural human interaction, makes them valuable assets in the context of elderly care[6-9].

Integrating social robots into elderly care presents various challenges, including technological obstacles that must be addressed, such as ensuring consistent performance and creating user-friendly interfaces. Additionally, societal acceptance plays an important role, as some elderly individuals may initially hesitate to use or trust robotic systems. Ethical considerations, especially regarding user privacy and autonomy, are also essential to ensure that these technologies uphold the dignity and rights of the elderly[10-12].

This study will examine the role of social robots in elderly care, addressing both the benefits and challenges of this emerging technology. By exploring innovative applications and recent developments, the study aims to demonstrate how social robots could revolutionize elderly care, improving both service quality and the overall experience of ageing [13-14].

2. Related Work

Liang Kok et al. [1] Due to recent global trends favoring reduced travel and increased social distancing, this study introduces a social robot specifically designed to address the physiological and psychological needs of the elderly. It particularly focuses on reducing social exclusion, which has been linked to various health issues such as hypertension, depression, and heart disease. In this regard, it is worth mentioning that this robot is intended for a homecare aid, which is a carefully designed integration of sophisticated AI and embedded microcontroller systems that track facial expressions, recognize emotional states, and respond appropriately to the companionship that is essential for mental well-being. The defining attribute of the robot is the existence of the so-called “emotional” component which uses machine learning to classify emotions into basic groups: happy, neutral, sad, and angry, and further modifying its responses in the course of interaction creating a quite engaging and comforting atmosphere. In addition, over time, it will also learn to further improve the quality of its answers according to how the user behaves reinforcing its function of being an ever-present source of social support. In addition to emotional involvement, the robot also performs basic caregiving functions, which reduces the burden on human caregivers and enhances care settings’ productivity. Focused pilot studies in nursing home settings have been shown to elicit beneficial outcomes in regards to users’ mental health and well-being in addition to solving realistic advances in caregiving such as lack of manpower. The study calls for further research and collaboration with the health care systems to enhance this technology to other uses with the hope of a wider applicability of this technology in a more cost-effective and efficient way targeting the elderly population.

Pedro Bandera et al. [2] This research examines the effectiveness of Socially Assistive Robots (SARs) in addressing the elderly care issues in Ambient Assisted Living (AAL) systems. This need arises due to the increasing elderly population and the consequent strain on the healthcare system. SARs seek to minimize the need for contact with the user and take on responsibilities such as health monitoring, fall detection, periodic reminders, and ensuring social interaction, thus allowing the elderly to enjoy their independence while easing the burdens carried by their caregivers. SARs tend to provide technological aids without losing the care provided by caregivers; however, they experience major difficulties in user acceptance and adaptability. High cost of implementation, complicated structures, and the issue of privacy elements often lead to under-utilization, and such systems are known to be particularly unfriendly and often frustrating to elderly users. To address these concerns, the study recommends implementing a user-centered design approach focusing on elderly technology users and their caregivers in a bid to create practical and easy-to-use SARs. The study proposes that instead of eliminating the need for placement of human caregivers, SARs should be incorporated as an aid that does not interfere with the caregiver’s presence for ethical concerns including preservation of interaction. However, the evaluation of the effect of using SARs in elderly care calls for longer studies in more natural settings. Through adaptation of SARs in aged care, the psychosocial aspects associated with caring for the aged will be improved along with respect for the individual’s right to information privacy thus enhancing the quality of healthcare delivery sustainably, and considerably improving the quality of life of the older adults.

Yang et al. [3] In order to transform healthcare, and particularly homecare, the study explores the idea of "Healthcare 4.0," which integrates ideas and technology like artificial intelligence (AI) and cyber-physical systems (CPS). Using CPS, homecare robotic systems (HRS) enable closed-loop healthcare that is focused on providing care in the patient's home. These HRSs can provide preventive care, real-time health monitoring, and interactive assistance to elderly individuals living alone in their homes. Others look to cloud computing, big data, IoT, and motion sensors to provide intelligent healthcare responsive, and flexible settings for healthcare monitoring. Human-robot interaction, telemedicine, and co-robots that are geared toward everyday living, rehabilitation, and emergency scenarios are ways that telecare is delivered in HRS-centric domains. The study also discusses enabling technologies such as smart stretchable electronics for health monitoring systems, cloud services for turning information into knowledge remotely, and artificial intelligence for imaging and treatment solutions. Also, since it's possible to integrate both physical and digital healthcare into these technologies, they facilitate the provision of long-term care in the home environment. However, these systems also have some controversies that prevent their fast adoption such as privacy and safety issues, real-time data processing requirements, and moral issues regarding the interaction with machines. To overcome these obstacles, the outlook in healthcare 4.0 advocates for improving AI in disease prediction, improving the robots' performance in enhancing human relations and constructing better communication networks. These are expectations geared towards building a flexible healthcare system that is patient-centric and improves availability, and quality of care. The Table .1 presents the summary of the related work studied.

Table 1. Summary of the Related Works

Related Work	1	2	3
Application Focussed	This program of home care intends to prevent a sense of exclusion among older people so that they continue on	Supporting elderly care in Ambient Assisted Living (AAL) systems by minimizing caregiver burdens while maintaining	Transforming healthcare and homecare through "Healthcare 4.0," with patient-centered care in the home environment.

	with their mental and physical l wellbeing.	elderly independence.	
Methodology	Track facial expressions. Integration of AI and embedded microcontroller systems to: Recognize and classify emotional states (happy, neutral, sad, angry).	Emphasizing a user-centered design tailored for elderly users and caregivers to enhance usability and acceptance. Incorporating SARs as an aid to human caregivers, not as replacements, for ethical and practical reasons.	Enabling technologies include cloud computing, big data, IoT, motion sensors, and smart electronics. Applications in preventive care, real-time health monitoring, interactive assistance, and telemedicine.
Technology Used	Machine learning for emotion classification. Advanced AI algorithms for adaptive interaction	Embedded systems for real-time fall detection and reminders. Privacy-preserving mechanisms to ensure user trust and information security	Cyber Physical Systems (CPS) for closed-loop care. Artificial intelligence for imaging, disease prediction, and treatment solutions.
Advantages	Provides company for the elderly, thus enabling them to gain mental support through interaction with others. Carry out general aid tasks for caregiving, lessening the pressure on human caregivers.	Support elderly independence, while maintaining the support of caregivers. Counter the pressure on the healthcare system created by the aging population of the elderly.	Enables health monitoring and interactive assistance in real time. Enables longer-term home care, enabling elderly independence.

Limitations	Restriction of the classification of emotions to rudimentary aspects. Could have very high initial costs for development and installation.	A very complex setup, which involves poor acceptability and adaptability from the users. Privacy issues may discourage use.	Adoption is affected by privacy and security concerns. Real-time data processing requirements pose technical challenges.

3. Social Robots

Social Robots are specialized autonomous robots intended to interact with human beings on a remarkably personal and social level, often providing companionship, assistance, or guidance. It is worth differentiating these robots from the purely industrial ones that perform functional tasks; because here, integration into an ordinary social context is much closer to humans and their social behavior. They use sensors, cameras, and software to enable them to "see" - that is, recognize faces, understand speech, detect emotions, and respond to gestures-making interactions more natural and enjoyable.

3.1 Types of Social Robots

- Companion Robots

These are really companion robots that offer emotional support, primarily to older individuals, children, and people with disabilities. The embedded systems in companion robots is responsible for managing information, operating sensors and actuators, and providing interaction in real-time, which enables the robots to be user-oriented and user-friendly.

Examples:

Paro: A therapeutic robotic seal; a help to hospitals and elderly care.

Buddy: A home companion robot.

- Service Robots

They assist in carrying out a particular task while also engaging their users socially**.** The service robots utilize embedded systems which facilitate real-time performance, sensor integration, and control of the robot's actuators enabling the robot to perform its functions effectively while interacting with its users.

Examples:

Pepper: A semi-humanoid robot for customer service and retail.

Jibo: A conversational personal assistant robot.

- Educational Robots

Educational robots are developed for teaching or aiding in other educative activities, particularly for children. Educational robots are embedded systems that allow the operation, control, and combination of various sensors and actuators and communication technologies. Thus, students can gain experience in programming, robotics, and other STEM issues more interactively and practically.

Examples:

Nao: A humanoid robot used in education and research to teach programming or other subjects (Figure 1).

Robonova: A small robot used to teach engineering and robotics concepts.

- Therapy Robots

In this case, therapy robots are the ones that are developed for cognitive or physical rehabilitation therapy, for instance, mental health therapy, autism therapy, or physical therapy within rehabilitation settings. The integration of embedded systems into therapy robots allows for real-time management, control, and interaction of the robots which further enables these robots to carry out individualized therapeutic activities, track the patient's improvement, and respond to changes in the patient accordingly.

Examples:

Kaspar: A robot that assists children with autism to learn to socialize with others.

Milo: A robot that helps people with Autism Spectrum Disorder(ASD) to communicate.

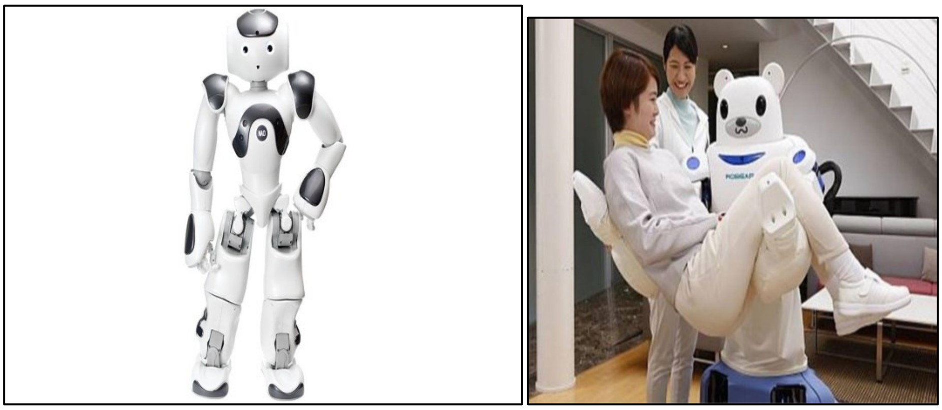
- Healthcare Robots

Robots of this type assist patients or healthcare professionals offering them support both physically and emotionally. In healthcare robots, the incorporation of embedded systems allows seamless control, real-time observation, and device autonomy, which helps in surgery, patient management, diagnostics, etc making it more efficient and better for the patients.

Examples:

Mabu: A health coach robot that helps patients adhere to drug intake, physical activity, and other health-related activities.

Elliq: A health and conversation-supportive robot for elderly users who need regular health updates and interactions.



`**Figure 1.** Nao (https://www.dawn.com/news/1165704/newspaper/column)

3.2 Applications of Social Robots in Elderly Care

Robots designed to interact with seniors can offer both emotional and cognitive support through engagement in conversations, even games, and reminding tasks, which will in turn help reducing loneliness and boost mental well-being, thus improving the quality of life for such individuals. For instance, they support health care management by remotely monitoring a user’s temperature, heart rate, and blood pressure levels, and issuing medication alerts or warnings in cases of a fall, thus safeguarding the user’s health. While encouraging active engagement in physical exercises, these devices also encourage verticalization as well as self-care skills, and communication with the family and other caregivers mediated by technology. They also follow care preferences for customized care, track users’ activity and present the information to the caregivers, and help perform basic activities of daily living which lessens the load on the health care providers. This also helps to create a more positive and active environment for the elderly.

3.3 Technological Components and Design Considerations

Social robots are complex systems created to help develop meaningful interactions with humans, enacting the technologies that will help put machines and people together. They depend on various systems to sense their surroundings and react, such as cameras that can visually recognize, microphones to detect sounds, proximity sensors that tell them how far away another object is, and touch sensors that give them tactile feedback. Actuators are designed for physical activity and enable the robot to present gestures, manipulate objects, and navigate independently. Robots emulate human-like behavior to capture good attention. Artificial intelligence integrates all these features into a whole, allowing speech and visual recognition, emotion understanding, learning, and adaptation behavior, while the connectivity offer by Wi-Fi, Bluetooth, and other means securely connects them with other devices and cloud systems.

In developing a product, several things are important: user-friendliness through simple interfaces, lifelike human characteristics that allow for emotional engagement, use of durable materials to resist wear, and built-in safety that allows safe interactions. In this respect, ethical considerations include, but are not limited to, the protection of users' privacy, misuse of sensitive data, and ways to safeguard such interactions. However, there are still even major challenges that exist: Robots often struggle to understand emotions and context, which can be subtle and vary by region and environment. The use of cameras and microphones also raises privacy-related concerns, reasonable fears about data confidentiality and conduct of ethical use, and possible social acceptance issues will face a social robot on account of skepticism about emotional authenticity, discomfort over human-like appearance, and fear of undue dependence on machines and lost job opportunities.

Despite setbacks along the way, social robots promise tremendous developments in healthcare, education, and customer service, among others. To move towards a more widespread acceptance, developers must work on enhancing emotional and contextual intelligence, along with designing systems that embrace and adapt to different cultures and ensure the principle of ethical transparency. In parallel, innovation should not run against affordable and accessible systems that lead to wider dispersal. In an era when technology is moving rapidly, AI and robotics should take on a transformational role in improving human experiences across various domains.

3.4 Impacts of Social Robots in Elderly Care

Social assistive robots facilitate elder care services by improving emotional health, nurturing independence, and enhancing the general quality of life. They offer companionship and interactive conversations, games, and emotional support in an effort to overcome loneliness and social isolation. They provide safety through health monitoring, fall detection, and reminders to take medications, helping in chronic care management, and taking off the excess load from the caregivers. Working to promote physical activity and cognitive processing with guided physical activities such as exercise and memory games, they enhance both physical and mental health as well. Not only do social robots help keep to a schedule and do not restrict independence in performing basic daily tasks, but they also encourage social interaction through video calls or other shared activities. In this manner, seniors are able to receive comfort care suited to their unique tendencies which allows for a greater degree of independence from family and professional caregivers.

3.5 Challenges and Limitations

There are numerous challenges and limitations addressed by social robots which makes the use and especially the effectiveness of the robots low. Some technical challenges include the restrictions of artificial intelligence and for example the understanding of emotion depiction over culture, social systems, and emotions in general. On the physical aspect, factors such as limited battery life and in some cases, even the durability makes it difficult to use the robots in geriatric long-term care. Cases where individuals trust the robots so much and they fail to compromise their private and sensitive health data become a concern. Robots are too expensive in terms of designing, sustaining, and finding use for them, so the majority of persons and organizations cannot afford them. Also, people’s negative attitudes due to the risk of becoming too dependent on machines, human health workers becoming obsolete, and the types of emotional bonds they are capable of forming raise a red flag. Finally, resentment stemming from living in a country that prioritizes non-elderly demographic-oriented technologies, potential concerns regarding unfair pay, and doubts about the reliability of machine performance may reduce its acceptance among older users

To Overcome these challenges the following recommendations can be implemented**:**

Efforts to enhance the development and acceptance of robots concentrate on several vital factors. To begin with, affective computing is essential as it enriches the cultural comprehension of robots. This entails training AI models on varied datasets to boost their capacity to identify and react positively to human emotions, even when those emotions are subtle or intricate. Furthermore, maintaining privacy and security is essential. This can be accomplished by employing robust encryption, ensuring local data processing, and complying with regional regulations to protect sensitive user data and enhance trust. Additionally, enhancing the reliability of hardware is essential for effective implementation. This involves replacing current systems with environmentally friendly, low-maintenance robots that feature high-capacity batteries, allowing them to operate continuously. Moreover, lowering costs is a significant goal, which can be achieved through modular designs and the use of open-source software, thus making robots more affordable and accessible to a broader audience. Lastly, a design approach focused on users is vital, especially by including elderly individuals in the design process. This guarantees that the robots are intuitive, customized to their particular needs, and suitable for daily use. These initiatives collectively aim to improve the usability, dependability, and cost-effectiveness of robotic systems.

3.6 Role of Embedded Systems in Social Robots

Embedded systems constitute the foundation of social robots, allowing for coherent communication between the robots and the human environment around them. Examples include microcontrollers, sensors, actuators, and software integrated to analyze input and output data in real-time, and hence allow the robots to understand and react to social interaction factors like gestures, speech, and emotions. In this way, embedded systems help social robots in various functions, for instance, facial recognition, voice synthesis and recognition, or navigation. They also manage energy consumption and increase capabilities making them suitable for areas like home, school, or hospital where they can be used reliably. Embedded systems provide a conduit through which hardware meets software, and such please the engagement and adaptability of social robots, increasing their usefulness as interactive users of the environment.

The incorporation of embedded systems in social robots comes with a lot of advantages that improve their functioning, efficiency, and usability. These systems allow processing of data in real-time thereby enabling the robot to interact with external stimuli, for example, voicing a command or waving in motion accurately and instantly. Their small size and low power consumption allow robots to execute intricate operations while remaining lightweight and operational for longer periods. Embedded systems also allow for additional features such as facial recognition, emotion recognition, and language understanding which all help in social interactions with the robots. They also offer support on integration of sensors and actuators which helps in active control of movements and interactions. Attached to the provision of economically viable solutions, which can easily be expanded, embedded systems help solve the problem of social robots in terms of availability and usage in many different fields including healthcare, education, and personal assistance.

Despite the apparent advantages offered by embedded systems in the context of social robots, there are challenges that make their deployment difficult. Firstly, there is the issue of the processing power of embedded systems often leading to limitations on the level of complexity of tasks a robot can accomplish in real-time, especially in scenarios with a lot of sensory data or heavy computational machine-learning techniques. Secondly, power consumption is also significant, as social robots often have to work for a long time, and it is not easy to enhance the battery and the performance at the same time. In addition, the combination of different hardware, for instance, sensors, actuators, and communication devices may present problems of integration and proper placement within the system design. In addition, both embedded systems and external systems (or networks) must have effective and secure communication channels because any invulnerability of these systems can pose threats to either the operation of the robot or the safety of its owner. Lastly, the development of software for the embedded systems of the sociable robots is a difficult task that needs a lot of resources as it involves a lot of expertise and is never static to accommodate changes in technology.

4. Conclusion

Moreover, social robots with greater embedded systems exhibit a significant and revolutionary attitude in improving elderly care systems. These robotics provide emotional, cognitive, and physical health state monitoring which are key components in improving the well-being of the older adults and lowering the stress faced by the caregivers. This aspect of social robots' incorporation simply complements the research strategy in that there are clear demographic shifts towards an aged population and limited healthcare ability. The potential and necessity of using social robots in elderly care services is evident, particularly concerning employment challenges in nursing homes and the overall cost-effectiveness of healthcare. The role of technology is expected to grow with the forecast of their future usage and social robots becoming less tied to fixed schedules but can respond fluidly to contextual demands of interaction. This generational trajectory will result in the proliferation of the robots in the provision of services to the elderly in a way that goes beyond the mechanical provision of care to the meaningful provision of services that nurtures compassion.

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