Intelligent Empathic Robots in Elderly Healthcare

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Abstract

This research proposes an intelligent empathic robotic system for elderly healthcare, combining AI, Theory of Mind, and Affective Computing to deliver personalized care. The low-cost robot continuously monitors patients' physical and emotional states through wearable data and neural networks, offering tailored support, therapy management, and emergency responses. By integrating ethical principles and patient-specific profiles, the system fosters trust and improves communication between patients, caregivers, and providers. This approach aims to enhance healthcare efficiency, reduce costs, and improve patient well-being through continuous, personalized interaction.

Keywords

Intelligent agent, Theory of Mind, Affective Computing, Healthcare

1. Introduction

The research focuses on developing an intelligent agent, potentially installed on a low-cost robotic platform, to interact with patients and doctors in a personalized way. This system addresses the growing challenge of an aging society, where many older adults suffer from comorbidities and require home care while maintaining constant contact with healthcare professionals [1].

Many patients struggle to adhere to medical advice and treatment plans, especially for chronic diseases. This can lead to poor health outcomes and frustration for both patients and doctors. In addition, people often turn to the Internet for medical information [2, 3], which can be unreliable and lead to misinformation. The goal is to provide personalized support to patients, ensure that they understand and follow their treatment plans, and improve communication with their physicians.

The intelligent agent will be implemented using Agent-Oriented programming languages based on computational logic, such as DALI [4, 5], defined and implemented by the research group of L'Aquila. Conceptually, however, the agent is based on epistemic logics and will integrate elements of Theory of Mind (ToM), which in Psychology is understood as the ability to attribute mental states to oneself and others, supported by techniques of Affective Computing (AF), which sense the emotional and physical state of a patient. This will allow understanding the physical and emotional conditions of patients, providing personalized assistance such as continuous health status monitoring, therapy support, and emergency responses. In addition, the agent can provide various other types of support, such as dietary advice and basic psychological support. Epistemic logics have been recently defined, able to represent simple ToM dynamics in groups of cooperative agents, that, for instance, can be instructed to devise and carry on together simple plans. Epistemic Logic Programming is a formalism, which extends the very successful paradigm of Answer Set Programming, that, since effective inference engines are available for it, can be usefully exploited as an implementation tool.

The agent will use deep neural networks to interact with the environment, evaluate medical images, and patient parameters. The various elements collected, also through the use of wearables and other monitoring devices, will be integrated to provide preliminary assessments to specialists.

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2. State of the art

The current healthcare technologies designed for elderly patients often do not provide the level of personalized interaction necessary for effective care. Existing eHealth solutions are not integrated into the care processes and value chains, often function as stand-alone add-ons to standard treatment rather than supporting patients effectively with their self-care [6].

Many traditional healthcare services do not consider the human factor and are not adapted to each user's individual needs and capabilities [7]. As a result, elderly people often fail to understand and perceive the benefits of these services, leading to a quick loss of interest. Technologies that can adjust to the particular needs of each patient are urgently needed to provide customized recommendations, follow-ups, and reminders that are necessary for efficient healthcare administration.

Another significant gap in existing healthcare technologies is the lack of attention to the emotional well-being of patients [8, 9, 10]. For elderly patients, emotional support is a critical component of overall health. Loneliness and depression are prevalent among the elderly, often exacerbated by chronic health conditions and reduced social interactions. Current healthcare systems and technologies rarely address these emotional needs, focusing primarily on physical health metrics The lack of emotional support can have significant consequences for palliative care nurses.

Effective healthcare for elderly patients requires continuous and comprehensive monitoring of their health status [11]. The lack of continuous monitoring of the health status of elderly patients is a significant gap that needs to be addressed through comprehensive geriatric evaluations, primary care involvement, and community involvement to effectively manage frailty and improve results for the aging population. This insufficiency may cause delayed reactions to medical problems, occasionally with dire repercussions.

The current healthcare system often imposes high costs on elderly patients, driven by frequent and sometimes unnecessary hospital visits and diagnostic tests [12, 13]. These costs can be a significant burden, especially for those on fixed incomes. By leveraging technology to provide more efficient and cost-effective care, the financial burden on elderly patients can be significantly alleviated.

The proposed system aims to improve patient well-being, optimize the organization of medical work, and reduce healthcare costs through more efficient resource management. In addition, it aims to counteract the unreliable self-diagnosis prevalent on the Internet by providing clear and personalized information and explanations. Once fully developed, the proposed system would bring significant savings to National Health Systems regarding:

- Reducing unnecessary tests, specialist visits, and emergency room visits;
- Conversely, decreasing hospital overcrowding, hospital days, and hospital costs related to patients delaying consultation with a specialist or going to the emergency room;
- Reducing the workload and stress for doctors and caregivers.

The agent will interact with the patient based on a user profile that will include at least the patient's medical history, preferences, and ethical principles. It will also interact with doctors and caregivers to provide them with feedback on the patient and to obtain advice and assistance when necessary. The focus will be on aspects related to the ethics of agent-patient interaction and the trust relationship that should ideally form.

3. Methodology

The methodology involves designing an intelligent agent using logical programming to ensure compliance with safety and ethical standards. The Theory of Mind [14] and Affective Computing [15] will be integrated to enable the agent to understand and respond to patients' emotional and cognitive states. The use of detailed patient profiles, including preferences, medical histories, and ethical considerations, will allow for personalized interactions and adequate support. The platform will be tested on real case studies, with the possibility of continuous refinement of the theory and implementation.

The next phase involves the integration of the intelligent agent with wearable devices [16, 17] that will continuously monitor various health parameters of the patients. The data collected from these devices will be analyzed by the agent to assess the health status of patients in real time. By providing continuous and comprehensive monitoring, the agent can detect early signs of potential health problems and alert healthcare providers or caregivers promptly.

To enable a natural and effective interaction with patients, the intelligent agent is installed on a robotic platform. This platform will serve as a physical embodiment of the agent, enabling it to communicate with patients through speech, gestures and other forms of non-verbal communication. We intend to install the agent on a robot because it has been seen that human users prefer to interact with a humanoid robot rather than with a computer program. Also, a robot is equipped with devices that can detect patient emotional signs that are useful for AF. So, the agent will be able to unobtrusively monitor the patient's health and emotional state, arrange therapies, keep doctors informed, and request the intervention of the physician or caregiver when necessary.

4. Initial phase

The initial step toward achieving these objectives is to develop "Blueprint Personas" [18] , a tool designed to foster person-centered care. This approach identifies patient profiles based on diverse needs, environments, especially within home settings, and a range of health and socioeconomic characteristics. These personas will be created from a questionnaire survay and will serve as detailed representations of different types of users, based on data collected from real patients. We will consider the pathology of Chronic Obstructive Pulmonary Disease (COPD), also taking into account doctors' expectations for the agent.The questionnaire for our research will be structured into several sections to ensure a complete collection of the necessary information. Each section is designed to capture different dimensions of the participants' experiences and needs.

Demographic Data: This section aims to understand the environmental context in which the individuals live. Questions in this category collect information on age, gender, occupation, education level, and geographic location. This demographic information provides a foundational understanding of the population being studied and helps to identify patterns and trends between different groups.

Habits: This category includes questions about the participants' daily routines, dietary habits, and physical activities. Understanding their habits allows for a deeper insight into their lifestyle choices and how these may impact their health and well-being. For example, questions about the type of diet followed and the frequency of sports or exercise can reveal important aspects of their health behaviors.

Pathology and Technological Support: Participants are asked about their specific health conditions and how technology or technological support could help them manage their disease. The questions are designed to explore their experiences with their pathology, the challenges they face, and their openness to using technological solutions. This information is crucial for identifying the needs and preferences for technological interventions.

Expectations from the Intelligent Agent: This includes questions on the functionalities they deem essential, their desired level of interaction with the agent, and any specific features they believe would significantly aid them in managing their health. Understanding these expectations helps in tailoring the intelligent agent to better meet the users' needs and enhance their overall experience.

This will ensure that the personas are complete and accurately represent the unique requirements and interactions relevant to the management of COPD. The creation and use of these personas and ontologies will significantly improve the personalized interaction capabilities of the intelligent agent.

5. Next Steps and Conclusions

As the next step in this project, we will design a complete architecture for the intelligent agent. This architecture will integrate various components to ensure that the agent can interact effectively with patients and doctors, personalize its responses, and provide reliable support. The architecture will

include ontologies to represent ethical and trust aspects and may include a Knowledge Graph to contain the user profile and interaction history with the patient.

To ensure the practical applicability and effectiveness of the intelligent agent, it is essential to test and refine its capabilities through real-world case studies. In these studies, the agent is used in real environments in which users interact with it as part of their daily lives. By observing and analyzing these interactions, we can identify potential areas for improvement, uncover unforeseen challenges and gain valuable insights into the user experience.

Trust is a crucial factor for the adoption and sustainable use of technological solutions in healthcare. The agent must operate transparently and provide clear and understandable explanations for its recommendations and actions. Privacy and data security are also crucial. Users must be assured that their personal and medical information will be treated with the utmost care and confidentiality. In addition, the agent should be guided by ethical principles in its interactions and ensure that it supports users in a respectful and non-intrusive manner.

This research project has the potential to revolutionize home healthcare for all chronic patients, particularly elderly adults with chronic diseases. By combining artificial intelligence, robotics, and medical expertise, this initiative offers a promising solution to a more sustainable and effective healthcare system.

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