



Full Length Article

Robot-based solution for helping Alzheimer patients

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ABSTRACT

Alzheimer's is a progressive and debilitating neurological disorder characterized by cognitive decline, memory loss, and impaired daily functioning. It is an irreversible brain disease that destroys memory, thinking, and the ability to carry out daily activities. It poses significant challenges for patients and healthcare providers. Modern societies are trying to enhance the quality of people's lives, including Alzheimer's patients. In this study, we explored the potential of social robots to provide emotional support, improve cognitive function, and facilitate communication among Alzheimer's patients. This was achieved by initiating conversations on various topics such as family, relationships, and daily activities. This paper contributes to the literature by introducing a novel and well-organized framework for building an Alzheimer's care robot. Further, this study enriches the literature by introducing the Alzheimer Care Companion Robot (ACCR), designed to identify Alzheimer's patients. The ACCR initiates conversations in the native Arab-Kuwaiti dialect, displaying relevant memories through images and videos on its screen to assist in memory recall based on the individuals' life experiences. The proposed ACCR consists of 271 conversations belonging to three main categories: active, proactive, and graphical user interface (GUI) dialogs comprising 112 dialogs, 109 dialogs, and 50 dialogs for active, proactive, and GUI, respectively. The experimental result illustrated the success of the proposed solution.

1. Introduction

In 1906, Dr. Alois introduced the first description of Alzheimer's. This disorder is characterized by a decline in cognitive abilities, memory loss, and impairment in daily functioning [1]. In 2022, approximately 6.5 million Americans aged 65 and older were living with Alzheimer's disease. According to the World Health Organization (WHO) [2], the global prevalence of dementia and Alzheimer's disease is currently estimated to exceed 55 million individuals, with over 60% of them residing in low- and middle-income countries. Additionally, it is reported that nearly 10 million new cases are diagnosed each year. In 2020, WHO reported that Alzheimer's and dementia-related deaths in Kuwait accounted for 139 cases, representing approximately 1.82% of the total deaths recorded. Furthermore, the age-adjusted Death Rate for Alzheimer's and dementia in Kuwait was 17.42 per 100,000 population, positioning Kuwait at the 96th rank worldwide in terms of prevalence. For a comprehensive overview of other causes of death, please refer to the provided links or explore the full health profile. In recent years,

developers have been exploring innovative technological solutions to aid Alzheimer's patients. These solutions include tools for Alzheimer's detection, live conversation assistance, and memory support. One particularly creative tool that has emerged is the use of talking robots. These robots can be programmed to engage in conversations with Alzheimer's patients, assisting them in recalling memories and refreshing their cognitive abilities.

In this study, we propose a humanoid robot-based solution to help Alzheimer's patients refresh their memory. Our research focuses on utilizing the Pepper robot [3] developed by SoftBank Robotics Corp, the world's first social humanoid robot capable of recognizing faces and basic human emotions. The pepper robot is designed for optimal human interaction, and the proposed solution engages with individuals through conversation and its touch screen interface. We employ the Pepper robot to initiate conversations with Alzheimer's patients in the native language and accent of the Kuwaiti people, specifically the Arab-Kuwaiti dialect. The main objective of our study is to develop a robot that can identify Alzheimer's patients and engage them in simple conversations.

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Additionally, the robot incorporates a built-in screen to display images and videos that facilitate memory recall. By utilizing this technology, we aim to stimulate the memories of Alzheimer's patients, evoke a sense of comfort and familiarity, provide emotional support, improve cognitive function, and facilitate communication for Alzheimer's patients. This promising avenue has the potential to enhance the well-being of individuals living with Alzheimer's and alleviate caregiver stress. Our solution involves conducting 271 dialogs with patients to revive important memories relevant to their experiences. In addition, the proposed ACCR includes several functions and assistive task tools such as 1) speech recognition to be able to engage with patients; 2) scheduling the patient's day and tasks; 3) remaindering of important events such as time for medical pills and praying time; and 4) remaindering of Alzheimer's patients with memories of their past. Based on the authors' knowledge, this is the first research in the literature that introduces a novel framework for a robot-based solution for Alzheimer's patients in general and the first robot solution using the Arab-Kuwaiti dialect implemented in Center of Artificial Intelligence and Robotics (CAIR), Kuwait College of Science and Technology (KCST).

This paper is organized as follows: Section 2 presents a literature review of relevant work, followed by Section 3, which presents the proposed framework and its phases. Finally, Section 4 illustrates the experimental results.

2. Literature review

Nowadays, several applications such as navigation [4-6], security patrolling [7], gas detection [8], and obstacle avoidance [9,10] use robotics. Moreover, several social robots/humanoid robots have been introduced to help people, especially those with healthcare issues or illnesses. The Pepper robot is the most famous [3] (Fig. 1). It is a social humanoid robot designed to assist individuals, particularly those with healthcare needs or illnesses; with a strong focus on human interaction, Pepper engages people through conversational interactions and its touch screen interface. Pepper has found applications in various domains, including businesses and schools.

More than 2000 companies worldwide have embraced Pepper as an assistant, utilizing its capabilities to provide innovative and interactive visitor welcome, information, and dance services. Pepper's presence in these settings aims to enhance the overall experience for individuals by offering personalized and engaging interactions. The robot's ability to

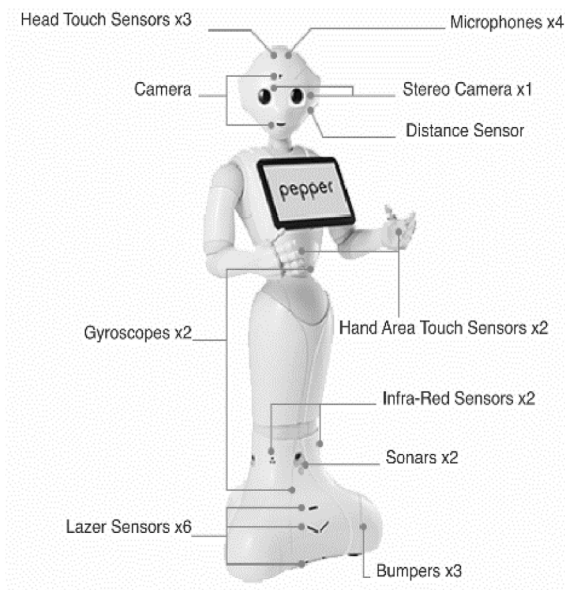


Fig. 1. Pepper robot [3].

recognize faces and interpret basic human emotions enables it to establish a more natural and meaningful connection with users. This quality contributes to its effectiveness in addressing the needs of individuals, especially those in healthcare or other vulnerable situations. In 2015, the Pepper robot [3] was successfully used as a teaching assistant for children [11]. This research focuses on using the pepper robot for children's educational programs (Fig. 1). Later 2017, the Pepper robot was used to accompany older people [12]. In 2020, the Pepper robot was used as a coach to help older people with psychiatric disorders through rehabilitation recreational activities [13].

Carros, Felix, et al. [14] employed Pepper in a group scenario in an institutional care facility with older adults for ten weeks and twenty sessions. The findings show that the older adults enjoyed the robotic interaction and were highly engaged during the sessions. However, the study participants clarified that they do not want robots to replace caretakers (Fig. 2).

Another robot called Nao [15], as shown in Fig. 3, is a 22.8-inch humanoid robot, and the latest version (6th generation) has twenty-five DOF, with eleven of them in the legs and pelvis and the rest in the upper body, similar to the upper body DOF of Pepper. Nao has two RGB cameras, nine tactile sensors on its head and in its hands, four microphones, a sonar range finder, two infrared emitters and receivers, one inertial board, and eight pressure sensors. The robots use the NAOqi operating system, which is open-source and supports many programming languages, including Python and C++. Several applications and research used Nao to interact with humans. Vital, Jessica PM et al. [16] used the Nao robot as a social platform to monitor and encourage physical activity among older people. In 2020, Yousif Jabar [17] used the Nao robot as an assistant tutor for autistic children. This study used the robot as a supportive tool to assist students in reading stories, spelling words, and correcting Math questions. The study indicated that utilizing robots as tutors aids students in grasping challenging subjects more effortlessly in their native language while also enjoying educational gaming activities. In 2028, Konstantinos Tsiakas et al. [18] studied how interactive reinforcement learning (IRL) modules can be utilized with Nao robots to enable personalization for various users.

Mišeikis, Justinas, et al. [19] proposed a mobile robot platform called Lio as shown in Fig. 4. It features a versatile arm designed explicitly for human-robot interaction and tasks related to personal care assistance.

This robot has already been deployed in various healthcare facilities, operating autonomously and assisting staff and patients daily. Lio ensures safety through its comprehensive soft artificial leather material coverage, collision detection capabilities, limited speed, and controlled forces. Moreover, the robot has a motion controller that allows for compliant movements. To ensure safe navigation and a better understanding of the environment, Lio utilizes a combination of visual, audio, laser, ultrasound, and mechanical sensors. The robot's setup, enabled by the ROS (Robot Operating System), allows researchers to access raw sensor data and maintain direct control over the robot.

In 2016, Fischinger, David, et al. developed a care robot to help older people called Hobbit Robot, as shown in Fig. 5 [20], which is another for adults. This project represents a significant collaborative effort between experts

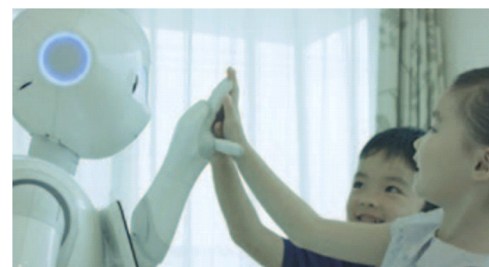


Fig. 2. Pepper robot [11].

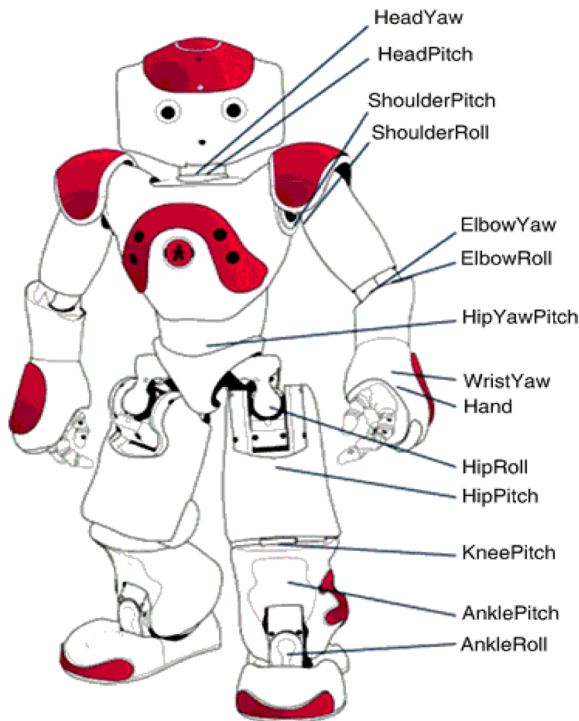


Fig. 3. Nao robot [15].

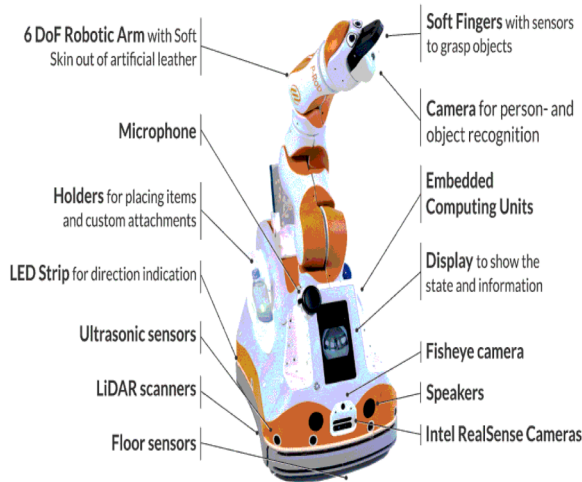


Fig. 4. Lio robot [19].



Fig. 5. Hobbit robot [20].

in robotics, gerontology, and human-robot interaction. By combining their expertise, they have successfully developed a caregiving robot that addresses crucial aspects of care, such as fall prevention and detection, emergency response, and daily engagement. Incorporating supplementary functions, including object retrieval, reminders, and entertainment, further enhances the robot’s ability to assist and interact with users daily. Utilizing a multimodal user interface encompassing automatic speech recognition, text-to-speech conversion, gesture recognition, and a graphical touch-based interface ensures seamless and intuitive communication between users and the robot. This project showcases the advancements in robotic technology and emphasizes the importance of interdisciplinary collaboration in achieving breakthroughs. By bringing together specialists from various fields, the Hobbit Robot project exemplifies the power of combining knowledge and expertise to address complex challenges in caregiving.

Moxi is a healthcare robot, as shown in Fig. 6, developed by Diligent Robotics [21]. With its ability to retrieve and deliver supplies, transport samples, and remove soiled linen bags, Moxi demonstrates its potential to enhance efficiency and streamline operations in hospital settings. It is equipped with a mobile base, seven robotic arms, and environmental perception sensors, such as a camera and laser scanner. Moxi is capable of fully autonomous and safe navigation, avoiding static and dynamic obstacles. The successful testing of Moxi in multiple hospitals across Texas, USA, over the past few years further validates its practicality and effectiveness in real-world healthcare environments. Its structured manipulation of pre-known objects ensures reliability and accuracy in completing tasks. Moxi’s development showcases the growing role of robotics in healthcare, offering the potential to alleviate the workload of healthcare professionals and optimize resource allocation, ultimately leading to improved patient care. In 2015, Scientists from RIKEN and Sumitomo Riko Company Limited collaborated to create a novel nursing care robot called ROBEAR [22], as shown in Fig. 7.

This experimental robot is designed to perform various tasks, including safely lifting patients from a bed to a wheelchair and assisting individuals who can stand but require support. The development of ROBEAR is expected to catalyze research efforts to supplement Japan’s caregiving needs through innovative robot-based solutions. This initiative reflects the growing recognition of the importance of exploring new approaches to caregiving, and ROBEAR is a significant step forward in advancing the field of robotic caregiving.

In the other direction, several studies investigated using robotic-based techniques to help Alzheimer’s patients [23-26]. In 2019, H. Simão and T. Guerreiro [23] designed a MATY robot for individuals with Alzheimer’s. MATY promotes autonomy through communication, routines, and multisensorial engagement. The iterative, incremental design process involved stakeholders, providing valuable insights. In 2022, another study [26] demonstrated a conversational robot’s feasibility and positive impact on cognitive assessments of older adults with Alzheimer’s disease (AD). While human interactions outperformed in depth and engagement, the study participants expressed overall satisfaction



Fig. 6. Moxi robot gathering supplies [13].



Fig. 7. ROBEAR robot [22].

with the robot. Another study [27] proved the promising feasibility of a social robot-driven psycho-educational program. This innovative approach holds the potential to enhance the well-being and quality of life for caregivers of individuals with Alzheimer’s disease.

3. Robot-based framework for helping Alzheimer’s patients

This section presents an innovative framework serving as a guide for constructing the proposed ACCR solution. ♦The framework comprises four primary phases: the Studying and Data Collection Phase (SDCP), System Requirement Phase (SRP), Conversation Preparation Phase (CPP), and Implementation Phase (IP). Each phase encompasses various steps, each dedicated to performing specific tasks.

A. Studying and Data Collection Phase (SDCP)

B. The SDCP is the phase of understanding Alzheimer’s disease and the needs of Alzheimer’s patients. SDCP consists of three stages: expert interviews, Alzheimer’s patient relatives’ interviews, Alzheimer’s patient interviews, and data collection stages. therefore, the data collection will be conducted with the help of Alzheimer’s patient relatives **System Requirement Phase (SRP)**

The SRP is the second phase of the proposed framework and is used to define the functional and non-functional requirements, as well as the hardware and software of the system.

C. Conversation Preparation Phase (CPP)

The CPP is the phase of collecting and preparing a dataset and conversations of Alzheimer’s patients, such as family, relationships, hobbies, general conversation, etc.

D. Implementation Phase (IP)

The IP is the phase of specifying and defining the system’s components, the inputs, outputs, and system interaction units (Fig. 8).

4. The proposed Alzheimer Care Companion Robot (ACCR)

We will first use the proposed framework to develop and build the proposed ACCR. The proposed ACCR (Fig. 9) incorporates three different components, inputs, outputs, and system interaction units, to engage with patients and aid memory recall.

A. Input Components:

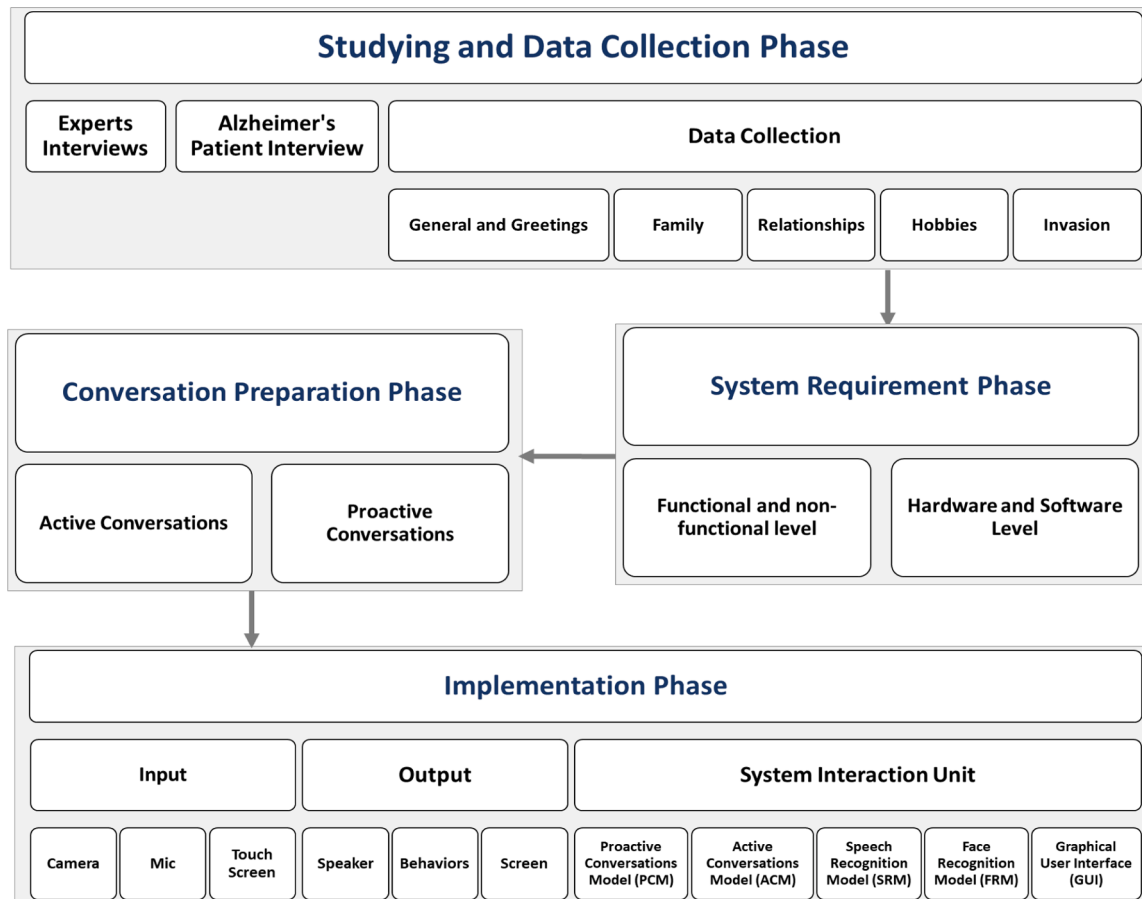


Fig. 8. The architecture of the proposed framework.

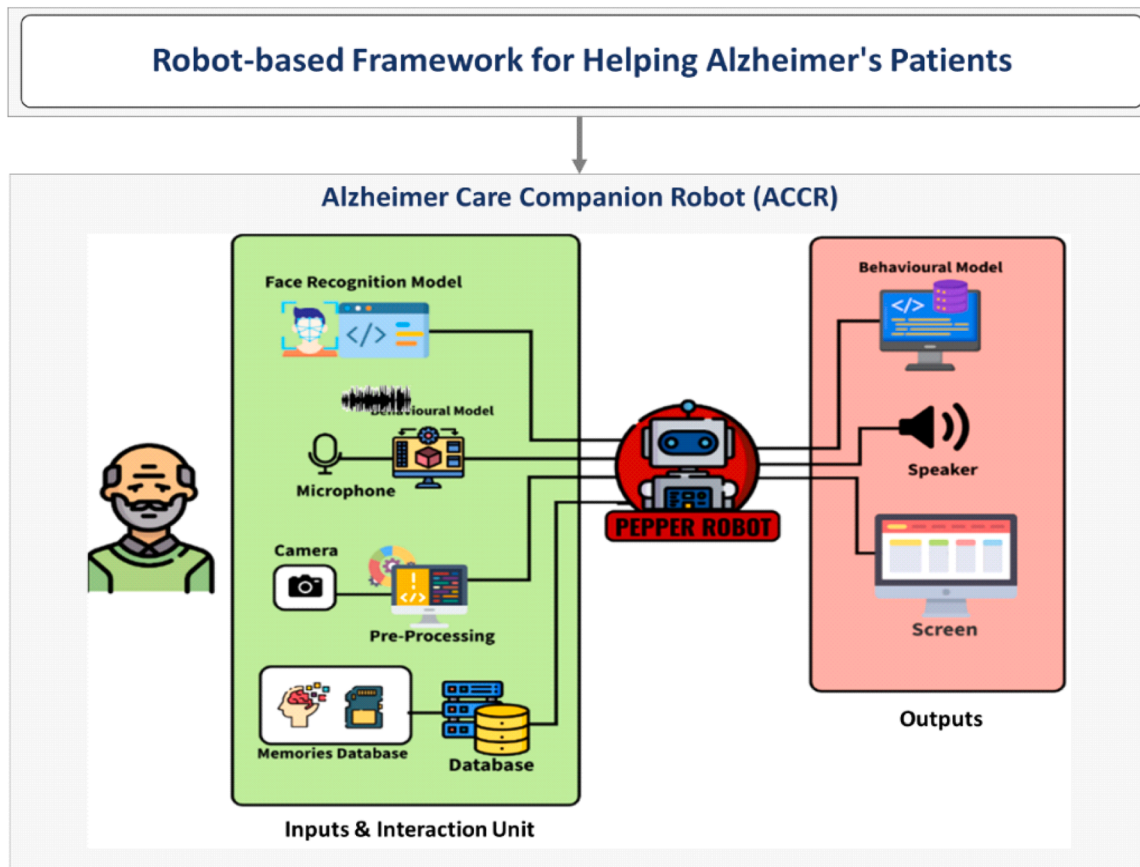


Fig. 9. The proposed solution (ACCR).

1. Camera: The camera detects Alzheimer's patients when they approach the robot. It captures visual data that the Face Recognition Model (FRM) uses to identify and differentiate patients from other users.
 2. Mic (Microphone): The microphone records the patients' speech as they converse with the robot. The Speech Recognition Model (SRM) processes the audio input and converts it into text to understand the patient's spoken commands and queries.
 3. Touch Screen: The touch screen allows patients to interact directly with the robot's graphical user interface. It enables a user-friendly and intuitive way for patients to communicate and engage with the robot.
- B. Output Components:**
1. Speaker: The speaker is responsible for delivering audio output from the robot. It allows the robot to respond to patients' queries and converse effectively.
 2. Behaviors: The Robot is programmed to exhibit appropriate behaviors to provide emotional support and encourage positive patient interactions. These behaviors are designed to create a comforting and non-intrusive environment.
 3. Screen: The robot's built-in screen displays relevant images and videos during conversations to aid memory recall in Alzheimer's patients. This feature enhances the patient's engagement and stimulates reminiscence.
- C. System Interaction Unit:**
1. Proactive Conversations Model (PCM): The PCM enables the robot to initiate conversations with Alzheimer's patients proactively. It analyzes past interactions, patient preferences, and the current context to engage the patient in meaningful discussions.
 2. Active Conversations Model (ACM): In the ACM, the patient asks questions, and the robot answers them. The robot generates

appropriate responses to the patient's queries and maintains the flow of conversation throughout the interaction.

3. Speech Recognition Model (SRM): The SRM converts the patient's spoken language (Arab-Kuwaiti dialect) into text data. This facilitates the robot's understanding of the patient's verbal commands and helps it respond accurately.
4. Face Recognition Model (FRM): The Face Recognition Model (FRM) analyses visual data from the camera input to identify and distinguish Alzheimer's patients from other users. This enables personalized interactions with the patients and enhances their experience. We used the face recognition functionality of the Pepper robot system to implement the FRM to recognize the patient.
5. Graphical User Interface (GUI): The GUI is the robot's touchscreen interface. It enables patients to interact with the robot, view relevant images, and trigger conversations on various topics like family, relationships, and daily activities.

In the following subsections, we will discuss in detail the steps of following the proposed framework for building the proposed ACCR.

D. Studying and Data Collection Phase (SDCP)

In the proposed ACCR, we started this phase by gathering information about Alzheimer's disease, conducting an interview with experts in the field, and Alzheimer's Alzheimer's patient interview. In this phase, we concluded that asking questions can spark a meaningful conversation full of special memories. Someone with Alzheimer's disease or other dementias will particularly appreciate the opportunity to pass on personal history and wisdom before it's too late. When you begin a conversation, prompt the person living with dementia to elaborate by asking open-ended questions and then listening to them. Also, many studies are full of hints about several

areas of dialogue [20]. The proposed solution will ask Alzheimer's patients some questions to refresh their memory and reduce their psychological burden. Among these questions are questions related to childhood memories or memories of youth, questions that depend on remembering specific people such as friends or relatives, questions that rely on places such as the location of the old house, the location of the school, questions based on events and dates such as the year of marriage or the year of graduation. Also, "Remember when?" questions are good for starters with Alzheimer's patients because they bring back so many memories and refresh their minds. Each type of question is responsible for activating a specific section of memory. The communication is done in the Kuwaiti dialect. The proposed SDCP deals with five different kinds of conversions: general and greetings, family, relationships, hobbies, and War of Liberation conversion. Each conversion contains questions and answers that are relevant to the specific topic.

E. System Requirement Phase (SRP)

In the proposed ACCR, we have defined several different levels of functional/non-functional hardware and software.

1. Functional and non-functional level

The proposed robot is intended to fulfill the following functional requirements: 1) the robot can recognize the patients from the facial recognition module; 2) the robot can make a simple conversation with the patients; and 3) the robot can show videos or images to help the patients remember events from the past. In addition, the proposed robot is intended to fulfill the following non-functional requirements: accuracy, availability, usability, and scalability.

2. Hardware and Software Level

We proposed a humanoid robot-based solution to help Alzheimer's patients refresh their memory. Therefore, based on the literature review, we used the Pepper robot [3]. Also, Pepper was developed by SoftBank Robotics Corp, which is the world's first social humanoid robot capable of recognizing faces and basic human emotions. Designed for optimal human interaction, the proposed solution engages with individuals through conversation and its touchscreen interface. We employ the Pepper robot to initiate conversations with Alzheimer's patients in the native language and accent of the Kuwaiti people, specifically the Arab-Kuwaiti dialect. Table 1 illustrates the robot's specifications.

F. Conversation Preparation Phase (CPP)

The CPP phase aims to collect and prepare a dataset of conversations in the Arab-Kuwaiti dialect that will be discussed with Alzheimer's Patients. The proposed SDCP consists of a total of 271 conversations (Table 2) belonging to three main categories: 1) active

conversations, which consist of 112 different dialogs; 2) proactive conversations, which consist of 109 different conversations; and 3) GUP interaction, which consists of 50 different conversations. Active and proactive conversations have five types: general and greetings, family, relationships, hobbies, and War of Liberation conversations. Each group contains questions and answers that are relevant to the specific topic. The conversation types have been selected based on expert recommendations. As mentioned, the active conversations consist of 112 dialogs (Fig. 10-a), 25, 18, 32, 17, and 20 belonging to general & greetings, family, relationships, hobbies, and war of liberation, respectively. The proactive conversations consist of 109 dialogs (Fig. 10-a), 26, 21, 27, 27, and 8 for general & greetings, family, relationships, hobbies, and war of liberation, respectively.

1. Active Conversations

The patient asks questions in active conversations, and the robot answers them. We have five types of conversations in the active conversations (Table 3): general and greetings, family, relationships, hobbies, and the War of Liberation sections. Each section contains questions and answers that are relevant to the specific topic.

• General and Greetings

The general and greetings dialogs shown in Table 3 between an Alzheimer's patient and the robot demonstrate the robot's ability to engage with empathy and understanding. The patient's requests for greetings, handshakes, and hugs are met with appropriate responses and actions from the robot. The robot addresses the patient's need for familiarity by warmly greeting them and acknowledging their presence. It provides information about its location and expresses its excitement about meeting everyone at the Center for Artificial Intelligence and Robotics. The patient's joy and connection with the robot are evident in their interactions. The robot adapts to the patient's language and responds patiently to their inquiries. It reassures the patient about their well-being and expresses gratitude for their compliments. The patient's heartfelt request for a hug is met with the robot's willingness to provide comfort. Overall, this dialogue highlights the robot's ability to establish a meaningful connection with individuals with Alzheimer's, providing companionship and support.

• Family

The family section covers questions and answers related to the patient's family. The robot can respond to questions about the patient's name, the names of family members, and their current status. The robot can also provide information about deceased family members, which can be emotionally challenging for the patient. However, providing accurate and appropriate information can help the patient feel connected to their family and reduce feelings of loneliness and isolation.

• Relationships:

The relationships section covers questions and answers related to the patient's relationships with others. The robot can answer questions about the patient's best friend, age, and occupation. The robot can also provide information about the patient's neighbor and their school days. This section can help the patient reminisce about past relationships and maintain a sense of social connectedness.

• Hobbies:

The hobbies section covers questions and answers related to the patient's daily routines. The robot can answer questions about the patient's employment status, schedule, and hobbies. The robot can also provide information about the weather and the news, which can be useful for the patient. This section can help the patient maintain a sense of structure and routine in their daily life.

• War of Liberation:

This can help the patient feel engaged and interested in the

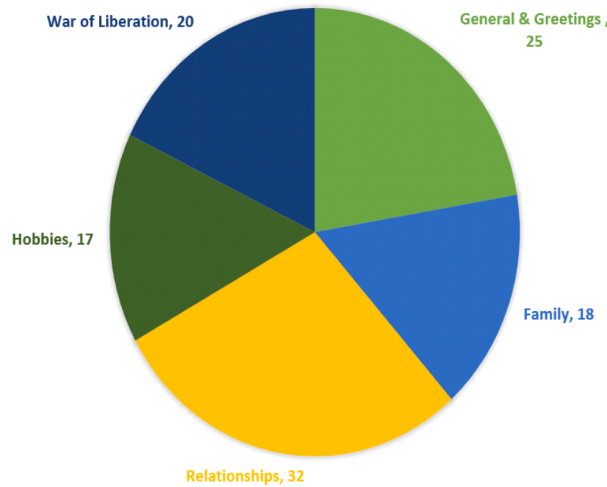
Table 1
Pepper robot specifications.

Part	Specifications
Dimensions	Height: 1.20 m (4 ft)/Depth: 425 mm (17 in)/Width: 485 mm (19 in)
Weight	28 kgs (62 lb)
Battery	Lithium-ion battery/Capacity: 30.0Ah/795 Wh/Operation time: approx. 12 hrs (when used at shop)
Display	10.1-inch touch display
Head	Mic × 4, RGB camera × 2, 3D sensor × 1, Touch sensor × 3
Chest	Gyro sensor × 1
Hands	Touch sensor × 2
Legs	Sonar sensor × 2, Laser sensor × 6, Bumper sensor × 3, Gyro sensor × 1
Moving parts	Head (2°), Shoulder (2° L&R), Elbow (2 rotations L&R), Wrist (1° L&R), Hand with 5 fingers (1° L&R), Hip (2°), Knee (1°), Base (3°), 20 Motors
Platform	NAOqi OS
Networking	Wi-Fi: IEEE 802.11 a/b/g/n (2.4 GHz/5 GHz/ Ethernet x1 (10/100/1000 base T)
Motion speed	Up to 3 kms per hour (2 mph)
Climbing	Up to 1.5 cm (0.6 in)

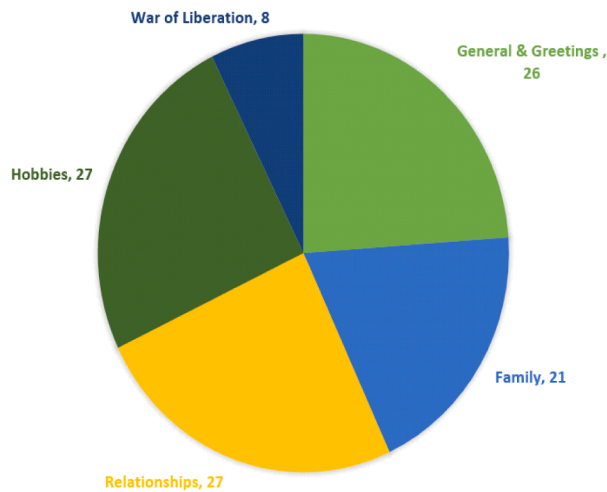
Table 2
Distribution of the conversations.

Conversations	General & greetings	Family	Relationships	Hobbies	War of liberation	Total
Active conversations	25	18	32	17	20	112
Proactive conversations	26	21	27	27	8	109
GUI	50					
Total	271					

GUI	50
Total	271



a) Distribution of the active dialogues.



b) Distribution of proactive dialogues.

Fig. 10. Distribution of the conversations. a) Distribution of the active dialogues. b) Distribution of proactive dialogues.

conversation, improving their memory of old days in Kuwait, such as War memories and the war of liberation.

2. Proactive Conversations

In proactive conversations, the robot starts the conversations by asking questions, and the patient answers them, and then the robot replies to the patient. The Proactive dialog is divided into four sections (Table 4): family, relationships, hobbies, and War of Liberation. Each section contains questions and answers that are relevant to a specific topic.

G. Implementation Phase (IP)

In the proposed ACCR, Alzheimer’s patients have three different ways of interacting: 1) proactive, 2) active, and 3) GUI.

1. Way One: Active:

The patient asks questions, and the robot answers them. In the active conversations, we have five main sections (): greetings, family, relationships, hobbies, and War of Liberation sections. Each section contains questions and answers that are relevant to the specific topic. In Active Conversations, the patients initiate conversations with the robot on various topics, such as family, relationships, hobbies, and daily activities. This can help improve

Table 3
Active conversations.

Type	Patient (initial the conversation)	Robot Answers
حوارات عامه و توحيه General and Greetings	السلام عليكم (Hello)	(Hello) وعليكم السلام
	صافحني (shake my hand)	يا لها (You are welcome)
	مرحباً (Welcome)	(Hello) السلام عليكم
	مساء الخير (Good evening)	مساء الخير, رحيم الله في مركز الكلية للذكاء الاصطناعي و الروبوتات, اريد أن ألقاكم جميعاً (Good evening, may God bless you at the College Center for Artificial Intelligence and Robotics, I want to meet you all)
	مرحباً راشد (Hi Rashid)	أهلاً وسهلاً بكم في مركز الذكاء الاصطناعي و الروبوتات جميعاً يا أصدقائي (Welcome to the Center for Artificial Intelligence and Robotics. I am very excited to meet all of you, my friends)
راشد (Rashid!)	أمر يا ضاري (At you order)	
وينك (where are you?)	سم يا ضاري شباغت (Poison, Dari Shabagit)	
ايش لوكن/ شلونك (How are you?)	(Hello) طاً والله	
خوش روبوت (Good robot)	أنا فني كلية الكويت للعلوم و التكنولوجيا (I am at Kuwait College of Science and Technology)	
لمني (Hug)	(Good, praise be to God, and you, how are everything)	
ممكن تحضني (Can you hug me?)	(Fine, thank God, how are you?)	
عائلي Family	أنا منو (Who am I?)	شكراً (Thanks)
شيمي (what is my name?)	وين زوجتي (Where is my wife?)	أبشر (Okay)
شيمي زوجتي (What is my wife's name?)	وين اختي مريم (Where is my sister Maryam?)	أنت ضاري (You are Dhari?)
منو عائشة (Who is Aisha?)	منو عائشة (Who is Aisha?)	اسمك ضاري أبو احمد (Your name is Dhari Abu Ahmed)
وين احمد (Where is Ahmed?)	منو عائشة (Who is Aisha?)	زوجتك فاطمه (Your wife is Fatima)
شون كنت مهتوظف (What am I employed?)	منو عائشة (Who is Aisha?)	ادعيلها بالرحمة يا ضاري توفت من عام 2000 (Pray for her mercy, Dari, she passed away in 2000)
العلاقات Relationships	شونو اسم اقرب رفيق لي (What is the name of my best friend)	مريم كبرت لها اسره وقاعد مع عيالها الحيين (Maryam has formed a family of her own and base with her children now)
	جم عمر محمد (How old is Muhammad?)	عائشة حفيدتك (Aisha your granddaughter)
	جم الاحين صار عمر محمد (How old is Muhammad?)	حفيدتك اللي عمرها 5 سنين (Your granddaughter, who is five years old)
	انا كنت اعرف محمد من أيام الطفولة (Do I know Muhammad from childhood?)	بالدوام يجرك ال عصر (At work, he passes you by in the afternoon)
	شونو شونو يشتغل (What is Muhammad's job)	كنت جنكاري (you were an army soldier)
	من زمان ما شفته (It's been a long time since I saw Muhammad)	كنت عميد بالجنكاري (you were a brigadier general in the army)
	بو سعود شونو شهدته (Bu Saud what is his testimony)	محمد (Mohammad)
	محمد عنده ولد وبنين (Does Muhammad have children)	رفيق الطفولة (Friends Childhood Muhammad)
	جم صار اعمار عيال محمد (How old are Muhammad's children)	محمد هو اقرب ربك (Muhammad is the closest person to you)
	لنا انا ومحمد نزوح العبدلي عند الربع بالمزارع (Muhammad and I used to go to Abdali at the quarter of the farms)	نفس عمرك (Same age as you)
	عمره تسعة وستين (He is sixty-nine years old)	
	انولد عام الف و تسعم ميه وربع وخمسين (Was born in the year one thousand and ninety-five)	
	اي كان جاركم وكان معاك بالمدرس (Yes Your neighbor was still with you at school)	
	الكل شوه لاله تروحو مع بعض المدرس (You all went to school together)	
	ضابط (Officer)	
	من زمان ما شفته (Since we have seen it)	
	آخر مرة شفته قبل ست اشهر (The last time I saw him was six months ago)	
	الله يذكركه بالخير من زمان عنده (God reminds him of the best of his time)	
	جامعي (Collegiate)	
	عنده ولد وبنين (He has a son and two daughters)	
	اي سنعود وساره وسعد (Saud, Sarah and Saad)	
	That is, Saud, he is forty-three years old, and his son Jacob and Saad are thirty years old.)	
	سنعود وساره تقريبا بداية الاربعين وسعد الاربعين (Saud and Sarah were almost the beginning of their forties, and Saud was thirty)	
	اي كنتوه دايمن مع بعض (Yes, you were always with each other)	
	يا حلو ذي ج الايام (Hello those days)	

(continued on next page)

Table 3 (continued)

Type	Patient (initial the conversation)	Robot Answers
Hobbies الهوايات	الربع دائماً يجتمعون بدونية بو سعود (The quarter always gather in the Bou Saud district)	أبي يحب الجمعة (Yes, he likes Friday) يا حليله أبو سعود يحب يجتمعكم Abu Saud likes to bring you together.
	تصدق عاد قبل شاركت بماراثون (I participated in a marathon before, do you know that?)	اي شاركت بماراثون بنك الخليج (Yes, you did participate in Gulf's bank marathon.) اي بسنة الغنيم وخمس تخش شاركت بماراثون (Yes, in 2015) صح شاركت بماراثون وسحبتي عيالك معك (Yes, you even took your kids with you)
Kuwait War of Liberation الغزو	هذي سيارتي (This is my car)	صحيح (That's right) اي سيارتك (Yes, it is)
	هذا وين (Where is this)	اشوفك بسرعه عرفتها (You quickly recognized it)
	انا قبل كنت ازرع (I used to plant)	نادي الفروسية بالفروانية (Equestrian club in Farwaniya) اي شوف كاهي حديقتك (Yes, look, that's your garden)
	ابو احمد عندك خبره بالسيارات الكلاسيكية (Abu Ahmed, you are an expert in classic cars, right?)	اي وحديقتك عامره (Yes, and your garden is full of plants)
	تذكر سنة التسعين (Do you remember the ninetieth year)	اي ايام ما كنت شاباب (Yes, back when I young)
	عوالي وين كانوا بالغزو (Where were my children in the War of Liberation?)	عندل (Right) كنت انا والشباب مهتمين بالسيارات الكلاسيكية (My friends and I were interested in classic cars)
	What happened to my children in the War of Liberation?	سنة ال غزو (year of War of Liberation)
تدري منو اول واحد لكلمني (Do you know who was the first person to talk to me?)	اي كانت صدمة علينا (Yes, it was a shock to us) كانوا مع امهم (They were with their mother)	
What was my job at the time of the War of Liberation?	كانوا بالحفظ والصرور مع امهم (They were saved with their mother's)	
سنة ال غزو (year of War of Liberation)	ما يبني له الكيد محمد (For sure Mohammad)	
فرحة التحرير (The joy of liberation)	ما يحتاج تقول محمد الكيد (What needs to say Mohammed) Of course	
	كنت شجاع و قاومت قد ما تقدر (You were brave and resisted as much as you could)	
	ساعدت اسر واجد تحتاج المساعدة و هالشي لازم تشكر فيه (I helped families who needed help, and this is something you should be proud of)	
	سوريه عندك قصص واجد وقتها (Surely you have stories and find their time)	
	يومها ما بقى كويتي بسببته (On that day, a Kuwaiti did not stay in his home)	
	الهنسية عيت تخلص (The festivities did not end)	
	من 91 الى يومك هذا الكويتيين يحتفلون بالتحرير (From 91 to this day, Kuwaitis celebrate liberation)	
	An impossible date that no one can forget) 26 26	

Table 4
Proactive conversations.

Type	Robot (initial the conversation)	Patient answers	Robot answers
حوارات عامه و ترحيبيه General and Greetings	السلام عليكم (Hello) صافحني (shake my hand)	وعليكم السلام (Hello) يا طبا (You are welcome)	السلام عليكم (Hello) صافحني (shake my hand)
	سلم علي (Say hello to me) مرحبا (Welcome)	السلام عليكم (Hello) السلام عليكم (Hello)	وعليكم السلام (Hello)
	مساء الخير (Good evening) مرحبا راشد (Hi Rashid) ضاري (Dary)	مساء النور, حيالكم الله (Good evening) اطبا (Welcome) سم (Yes)	شلونك (how are you?) شلونك (how are you?) صافحني (shake my hand)
	لميني (Hug) ممكن تحضنني (Can you hug me?) شلونك	تعال (Come on)	شكرا (Thanks)
عائليه Family	How are you	بخير والله وانتم الحمد لله Thank God طيب good	بخير دامك بخير Fine as long as you are
	شخبارك How are you	والله بخير انت شخبارك wallah okay, how about you	والله بخير wallah okay
	جم عندك عيال How many children do you have?	بجري احمد و بعده عي قوب و ال جعده نورا The first of my children is Ahmed, then Jacob, and the youngest of my children is Nora ولدين و بنت Two sons and a daughter عوالي 3 My children 3	ماشاء الله يتربى بجزك God bless He is raised with your glory
Relationships ال علاقات	تذكرو وين ساكن Do you remember where you live? تذكرو أيام الطفولة مع محمد do you Remember the childhood days with Muhammad	اي اتذكركم Yes! remember her	يا حلوه من أيام Oh sweet days
	بوس سعود يحب السيارات Bou Saud loves cars تذكرو بوس سعود لمن تخرج من الجامعة Remember, Abu Sa'ud, when graduated from the university.	أي نعم Yes أي اتذكرو I remember	وانت بجد تحبها You still love cars أي زين Yeah beautiful
Hobbies الهوايات	ابو احمد وين عودك ما اشوفك تغزف Abu Ahmed where is your oud?	موجود افنا عليك It is there	يا سلام تغزف لنا الحين Great, you should play for us
	شنو الكثر سياره تحبها What is the most car that you like?	مرسيدس وانتم Mercedes, and you	انا احب السيبورت الكثر شي I like sport cars the most

Table 4 (continued)

Type	Robot (initial the conversation)	Patient answers	Robot answers
Kuwait War of Liberation الغزو	ضاري نزرع لكونوك اربيس Dhari, do you plant conocarpus? قول لي مواضع الغزو Tell me the situation of the War of Liberation	اي ما شرفت حديقتي Yes, you did not see my garden كانت نزلت لخبيرة ب حياتي It was a big move in my life	لا ما شرفت No, I did not أي عرفت وقتها That is, I knew at the time the quarter of the Sagheen أي من الغرحة ما قدرت تنام Any of the joy as much as you can sleep الجدله على نعمة الامن والامان Praise be to God for the blessing of safety and security
	شنو شغورك وقت التحرير How do you feel at the time of editing?	فرحة ما تنوصف What a joy you describe	

the patient's cognitive function and reduce loneliness and isolation.

2. Way Two: Proactive:

The robot initializes the conversations by asking questions about family, relationships, hobbies, and the War of Liberation, and the patient answers them, and then the robot replies to the patient. The Proactive dialog is divided into four sections (Table 4): Each category contains questions and answers that are relevant to a specific topic. For example, [the robot can display a slideshow of family photos and ask the patient to identify family members and describe the context of the pictures. The robot can also show videos of the patient's favorite TV shows, movies, or music performances. This can help to trigger memories and provide a sense of enjoyment for the patient. The robot can also display pictures of the patient's favorite places, such as their hometown or vacation spot, and ask the patient to describe their location and experiences there. In addition, the robot can ask the patient about their children, siblings, or parents and show interest in the patient's relationship with them. It can benefit Alzheimer's patients with difficulty initiating conversations or recalling specific memories. By providing prompts and visual aids, the robot can help the patient feel more engaged and connected to their environment.

3. Way Three: Graphical user interface (GUI):

Proactive and active conversations can be effective ways for speech interaction to assist Alzheimer's patients. Moreover, patients can interact with the robot through a touch screen; in this way, the robot can help stimulate memory, improve cognitive function, and provide emotional support. These interactions can help to reduce caregiver stress. In this way, the robot has four main categories or icons displayed on the screen, and each one also has another categorization (Fig. 11):

- (أهلك و ربحك) **Family and Relationships**
- (اللي ماله اول ماله تاللي) **Memories**
- (صحتك) **Your Health**
- (اوقات الصلاة) **Prayer Times**

5. Experimental results

The proposed ACCR aims to develop a robot that is capable of detecting Alzheimer's patients and engaging them in conversations using the Arab-Kuwaiti dialect, displaying images and videos to the



Fig. 11. The main interface for the third way of communication in the proposed ACCR.

patients that aid in memory recall, scheduling the patient’s day and tasks, reminding them of important events such as time for medical pills and praying time, improving their cognitive function, rewinding Alzheimer’s patients with memories of their past, and facilitate communication of the Alzheimer’s patients by initiating conversations on various topics. To do that, three different interaction ways are presented, i.e., 1) proactive, 2) active, and 3) GUI. In general, the robot will not respond to the patient with an incorrect answer. It will either answer a correct answer or ask the patient to re-ask the question again, so the robot will be sure his answer is correct.

We conducted tens of scenarios to test the proposed solution using proactive conversation, active conversation, and GUI. In these scenarios, we used ten different patients for testing. ♦ This illustrates an example of the interaction with the robot. It was exciting to the individual that a robot was speaking and interacting with him. The person was very happy and excited about this experience (Fig. 12).

A. Scenario 1: Proactive Conversation Scenario

In these scenarios, the robot initiates conversations with the patient on various topics, such as family, relationships, hobbies, and daily activities. The robot can ask open-ended questions and provide responses

tailored to the patient’s preferences and interests. In one of the conducted scenarios, the robot displayed a slideshow of family photos and asked the patient to identify family members and describe the context of the pictures. This can help to trigger memories and provide a sense of enjoyment for the patient. The robot also displayed pictures of the patient’s favorite places, such as their hometown (Fig. 13-a) and their close friends (Fig. 13-b), or asked them to describe their experiences.

A. Scenario 2: Active Conversation Scenario

In these scenarios, the patient asks questions, and the robot replies. For example, the patient can ask the robot about his family, friends, habits, prayer, or medical time. The patient may ask questions such as "Who am I?" and "What is my wife’s name?" and the robot provides answers such as "You are Dhari" and "Your wife is Fatima." The conversation also includes questions about the patient’s best friend, Muhammad, and his age and occupation. The robot provides answers such as "Muhammad is the closest person to you" and "He is an officer."

A. Scenario 3: GUI Scenario

The proposed GUI of the Robot has four main categories or buttons

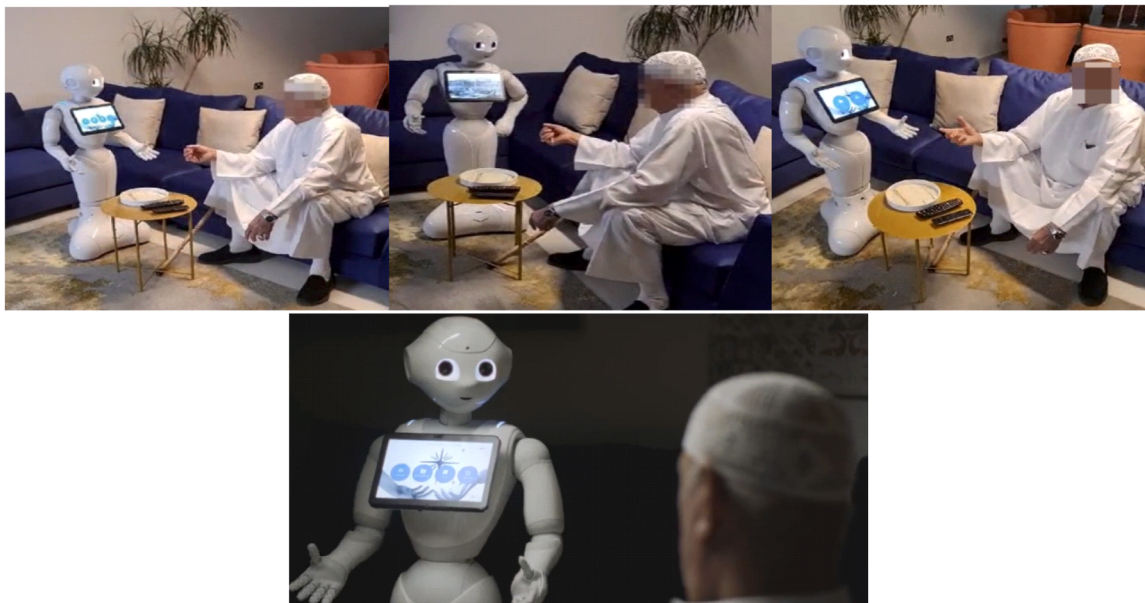


Fig. 12. A real experimental scenario of the proposed solution.

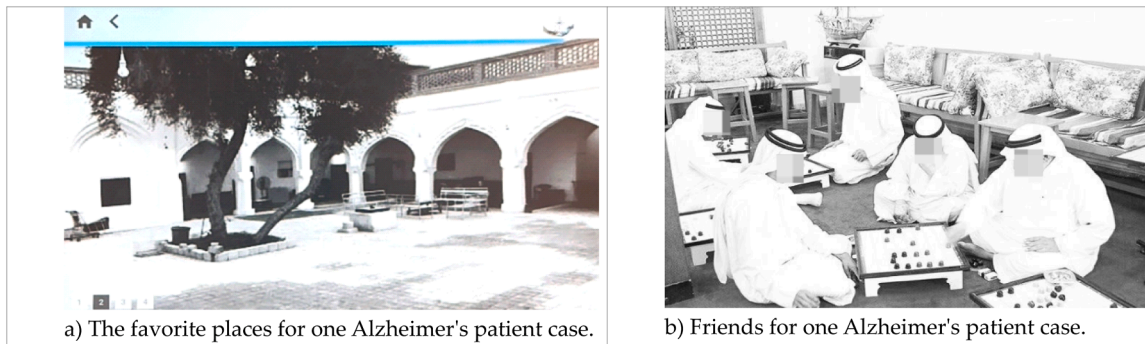


Fig. 13. Examples of proactive conversation scenarios. a) The favorite places for one Alzheimer's patient case. b) Friends for one Alzheimer's patient case.

displayed on the screen, and each one also has another button/categorize (Fig. 14-a): Family and Relationships (2; (أهلك و ربك); Memories (3; (اللي مالاه اول مالاه تالاه); Your Health (صحتك); and 4) Prayer Times (اوقات الصلاة).

As illustrated in Fig. 14-a, if the patient presses the Family and Relationships (أهلك و ربك) buttons, then the robot will display on its screen another window (Fig. 14-b); therefore, he will be able to select either the family or relationships button. If he chooses the relationships buttons, the robot will display the slideshow on its screen, displaying a picture of his friends and talking about those friends (Fig. 14-c).

6. Conclusion

This study contributed to the literature on using social robots for Alzheimer's care by proposing a novel framework and introducing an Alzheimer Care Companion Robot (ACCR). The ACCR demonstrates its ability to offer emotional support, stimulate cognitive function, and facilitate communication through personalized conversations in the patient's native language (Arab-Kuwaiti dialect). In addition, in this study, we build a total of 271 conversations belonging to three main categories: active, proactive, and graphical user interface (GUI) dialogs that consist of 112 dialogs, 109 dialogs, and 50 dialogs for active, proactive, and GUI respectively. As technology continues to advance, social robots hold great promise in revolutionizing Alzheimer's care, assisting

healthcare providers, and improving the quality of life for those living with this challenging neurological disorder. However, further research and development are necessary to refine and expand the capabilities of the robots to cover more conversations and add more interaction skills. In addition, we plan to build our robot and integrate the ChatGPT in future work.

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Author contributions

MF, AA, AA, SA, AA, MK and MA conducted the research into the academic landscape and drafted and supervised the research AA, SA, and AA, did the flowchart implementation design, and general experimental works while MF, AA, AA, SA and MA did the experimental results and programming works. MF, AA, MK, and MA work on implementation and MF, AA, AA, SA, AA, MK and MA prepare the initial draft of the paper and evaluate the work results while the paper was written jointly by all the authors. All authors had given their approval to the final edition.

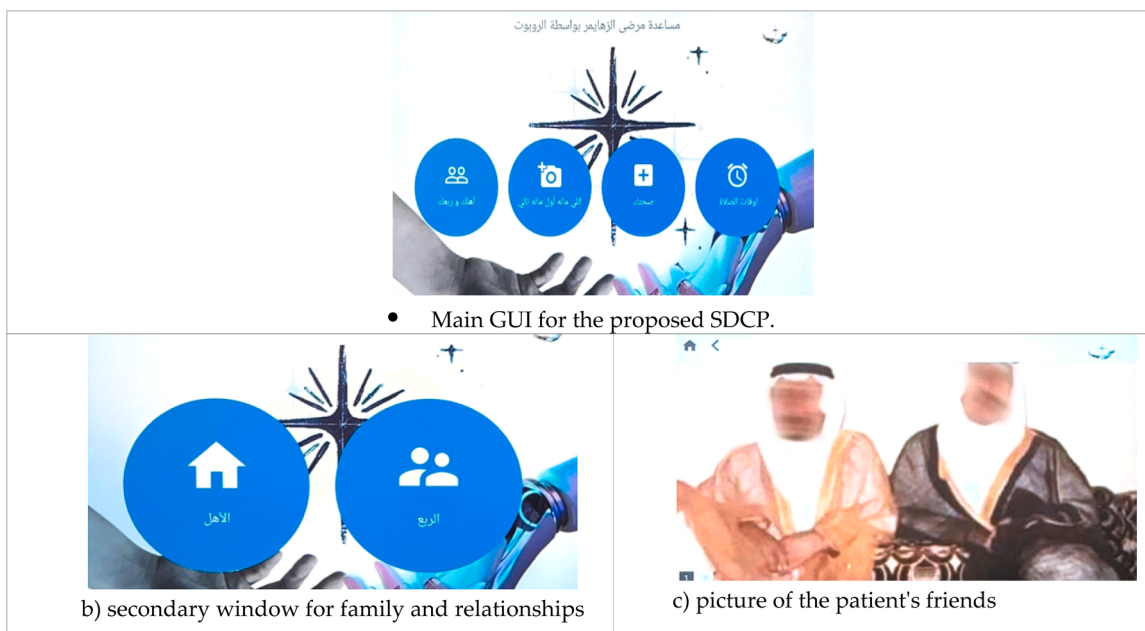


Fig. 14. Examples of real GUI Scenarios. a) Main GUI for the proposed SDCP. b) secondary window for family and relationships. c) picture of the patient's friends.

CRedit authorship contribution statement

Mohammed Faisal: Conceptualization, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Abdullah Alharbi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Validation, Writing – original draft, Writing – review & editing. **Amnah Alhamadi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Sarah Almutairi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Shaikhah Alenezi:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Anfal Alsulaili:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Supervision, Validation, Writing – original draft, Writing – review & editing. **Murad Khan:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Faheem Khan:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflicts of interest.

References

- [1] A. s. Association. Alzheimer's disease facts and figures. 9-7-2023. 2023. Available: [https://www.alz.org/alzheimers-dementia/facts-figures#:~:text=More%20than%206%20million%20Americans%20of%20all%20ages%20have%20Alzheimer's,older%20\(10.7%25\)%20has%20Alzheimer's](https://www.alz.org/alzheimers-dementia/facts-figures#:~:text=More%20than%206%20million%20Americans%20of%20all%20ages%20have%20Alzheimer's,older%20(10.7%25)%20has%20Alzheimer's).
- [2] W.H. Organization. Dementia and Alzheimer. 9-7-2023. 2023. Available: <https://www.who.int/news-room/fact-sheets/detail/dementia#:~:text=Key%20facts,nearly%2010%20million%20new%20cases>.
- [3] S. Company.. Pepper robot. 2023. Available: <https://www.aldebaran.com/en/pepper>.
- [4] H. Ramdane, M. Faisal, M. Algabri, and K. Al-Mutib, "Mobile Robot Navigation with Obstacle Avoidance in Unknown Indoor Environment using MATLAB Indoor Environment using MATLAB.
- [5] Al-Mutib K, Abdessemed F, Hedjar R, Alsulaiman M, Bencherif M, Faisal M, Algabri M, Mekhtiche M. Mobile robot nonlinear feedback control based on Elman neural network observer. *Adv Mech Eng* 2015;7:1687814015620328.
- [6] Al-Muteb K, Faisal M, Emaduddin M, Arafah M, Alsulaiman M, Mekhtiche M, Hedjar R, Mathkour H, Algabri M, Bencherif MA. An autonomous stereovision-based navigation system (ASNS) for mobile robots. *Intell Serv Robot* 2016;9:187–205.
- [7] Faisal M, Mathkour H, Alsulaiman M. Smart mobile robot for security of low visibility environment. In: 2015 5th National Symposium on Information Technology: Towards New Smart World (NSITNSW); 2015. p. 1–6.
- [8] Faisal M, Alsulaiman M, Al-Muteb K, Hedjar R, Mathkour H, Emaduddin M. Gas detection and mapping using an autonomous mobile robot. In: Conference Paper; 2015.
- [9] Al-Mutib K, Abdessemed F, Faisal M, Ramdane H, Alsulaiman M, Bencherif M. Obstacle avoidance using wall-following strategy for indoor mobile robots. In: 2016 2nd IEEE International Symposium on Robotics and Manufacturing Automation (ROMA); 2016. p. 1–6.
- [10] Faisal M, Mathkour H, Alsulaiman M, Zuair M. Multi-sensors multi-baseline mapping system for mobile robot using stereovision camera and laser-range device. *Adv Mech Eng* 2016;8:1687814016654634.
- [11] Tanaka F, Isshiki K, Takahashi F, Uekusa M, Sei R, Hayashi K. Pepper learns together with children: development of an educational application. In: 2015 IEEE-RAS 15th International Conference on Humanoid Robots (Humanoids); 2015. p. 270–5.
- [12] Yang C-Y, Lu M-J, Tseng S-H, Fu L-C. A companion robot for daily care of elders based on homeostasis. In: 2017 56th Annual Conference of the Society of Instrument and Control Engineers of Japan (SICE); 2017. p. 1401–6.
- [13] Sato M, Yasuhara Y, Osaka K, Ito H, Dino MJS, Ong IL, Zhao Y, Tanioka T. Rehabilitation care with Pepper humanoid robot: a qualitative case study of older patients with schizophrenia and/or dementia in Japan. *Enferm Clin* 2020;30:32–6.
- [14] Carros F, Meurer J, Löffler D, Unbehaun D, Matthies S, Koch I, Wiechinger R, Randall D, Hassenzahl M, Wulf V. Exploring human-robot interaction with the elderly: results from a ten-week case study in a care home. In: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems; 2020. p. 1–12.
- [15] Shamsuddin S, Ismail LI, Yusoff H, Zahari NI, Bahari S, Hashim H, Jaffar A. Humanoid robot NAO: review of control and motion exploration. In: 2011 IEEE international conference on Control System, Computing and Engineering; 2011. p. 511–6.
- [16] Vital JP, Couceiro MS, Rodrigues NM, Figueiredo CM, Ferreira NM. Fostering the NAO platform as an elderly care robot. In: 2013 IEEE 2nd international conference on serious games and applications for health (SeGAH); 2013. p. 1–5.
- [17] Yousif J. Humanoid robot as assistant tutor for autistic children. *Int J Comput Appl Sci* 2020;8.
- [18] Tsiakas K, Abujelala M, Makedon F. Task engagement as personalization feedback for socially-assistive robots and cognitive training. *Technologies* 2018;6:49.
- [19] Mišekis J, Caroni P, Duchamp P, Gasser A, Marko R, Mišekienė N, Zwilling F, De Castelbajac C, Eicher L, Früh M. Lio-a personal robot assistant for human-robot interaction and care applications. *IEEE Robot Autom Lett* 2020;5:5339–46.
- [20] Fischinger D, Einramhof P, Papoutsakis K, Wohlking W, Mayer P, Panek P, Hofmann S, Koertner T, Weiss A, Argyros A. Hobbit, a care robot supporting independent living at home: first prototype and lessons learned. *Rob Auton Syst* 2016;75:60–78.
- [21] D. Robotics. (2023, 17-7). *Moxi Robot: an assistant robot for healthcare*. Available: <https://www.diligentrobots.com/moxi>.
- [22] R. G. R. a. Research. (2015, 17/7). *strong robot with the gentle touch*. Available: https://www.riken.jp/en/news_pubs/research_news/pr/2015/20150223_2/.
- [23] Simão H, Guerreiro T. Maty: designing an assistive robot for people with Alzheimer's. In: Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems; 2019. p. 1–6.
- [24] Koutentakis D, Pillozzi A, Huang X. Designing socially assistive robots for Alzheimer's disease and related dementia patients and their caregivers: where we are and where we are headed. *Healthcare* 2020;73.
- [25] Yuan F, Boltz M, Bilal D, Jao Y-L, Crane M, Duzan J, Bahour A, Zhao X. Cognitive exercise for persons with Alzheimer's disease and related dementia using a social robot. *IEEE Transact Robot* 2023.
- [26] Pou-Prom C, Raimondo S, Rudzicz F. A conversational robot for older adults with Alzheimer's disease. *ACM Transact Hum-Robot Interact (THRI)* 2020;9:1–25.
- [27] Yuan F, Blackburn J, Condon C, Bowland S, Lopez RP, Zhao X. A Social Robot-based Psycho-educational Program to Enhance Alzheimer's Caregiver Health. In: 2021 IEEE/ACM Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE); 2021. p. 124–5.