CARETAKVR: A Virtual Reality Environment to Train Alzheimer's Caregivers

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Abstract: The number of patients diagnosed with Alzheimer's disease is significantly increasing, given the boom in the aging population (i.e., 65 years and older). There exist approximately 5.5 million people in the United States that have been diagnosed with Alzheimer's, and as a result friends and family often need to provide care and support (estimated at 15 million people to the cost of $1.1 trillion). Common symptoms of Alzheimer's disease include memory loss, drastic behavioral change, depression, and loss in cognitive and/or spatial abilities. To support the growing need for caregivers, this project developed a prototype virtual reality (VR) environment for enabling caregivers to experience typical scenarios, as well as common strategies for managing each scenario, that they may experience when providing care and support, thereby providing. For instance, a patient may turn on a gas stove and then leave, forgetting that the stove is on. The caregiver then would be required to turn the stove off, to minimize any potential dangers.

The prototype environment, CARETAKVR, was developed as an undergraduate research project for learning the process of research as well as the Unity programming environment and VR. The prototype provides a gamified training tool, masking scenarios as objectives and success with a score, to enable the potential caregiver to feel rewarded for correctly supporting the patient. The virtual patient is controlled via artificial intelligence and follows an initial set of guidelines to behave as a patient with early-stage Alzheimer's may behave. The caregiver is provided with a set of tasks to perform, in VR space, to achieve their goals for each scenario. Common tasks include Check Refrigerator, Check Stove, and Comfort Patient. This project has been demonstrated to colleagues in the health care domain and has seeded future collaborations to iterate the capabilities of this tool. All project artifacts have been open-sourced and are available online.

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1. Introduction

A major concern with patients who have Alzheimer's Disease (AD) is that their cognitive faculties can degrade at varying rates, leading to caregivers who may be unprepared to manage the patient's symptoms. Such symptoms can include short-term memory loss, loss in physical and cognitive abilities, drastic behavioral changes, and aggressiveness.[1,2] Moreover, the population of people aged 65 and older will grow roughly by 60% over the next 12 years, leading to an expected increase in patients with AD.[3,4] Given the rising costs of health care, there exists a critical need to develop methods for supporting patients in home.[5-8]

In recent years, there has been a push towards leveraging virtual reality (VR) applications to provide training for many different domains, including the medical[9] and military domains.[10] Generally, consumer-grade VR hardware is cost effective and small in physical footprint, enabling organizations of varying size and consumers to justify their purchase. Moreover, video games have been used to promote therapeutic recovery.[11]

Caregivers of AD patients tend to be friends and family members, often unpaid, that must provide support at home in their instrumental activities of daily living (IADL, i.e., making meals, managing money, etc.).[4] Moreover, caregivers are often not provided formal training, leading to people who are unprepared to manage such symptoms. To combat this problem, we developed a proof of concept VR application, using consumer-grade hardware (HTC Vive) and open-source programming tools (Unity, SteamVR), to create an environment in which caregivers of AD patients can be exposed to common scenarios and optimal mitigation strategies. This project was structured as a combination of an undergraduate research project, an Honors thesis, and a paid summer project. The rest of this paper is structured as follows. Section 2 discusses the CARETAKVR framework, including an overview of background information, related work, and patient simulation. Section 3 then discusses student training, and Section 4 summarizes our paper and presents future directions.

2. CARETAKVR: Training Caregivers

This section describes CARETAKVR, our prototype training tool for supporting caregivers of AD patients. We next discuss the overall framework, the methods to which we simulated patients, and how we 'gamified' the training process to ensure an enjoyable experience for the caregiver.

a. Overview of Framework

CARETAKVR was developed using the Unity 5 engine[12] with the SteamVR plugin[13] to provide support for the HTC Vive system[14] within Unity. For the purposes and scale of this project, each of these tools are available for free and can be downloaded and used by any developer. Figure 1 demonstrates our physical setup, including two base stations (mounted on the walls), a VR headset (worn on the user's head), and two controllers (held by the player). These devices connect to a VR-ready computer that runs the Unity simulation.

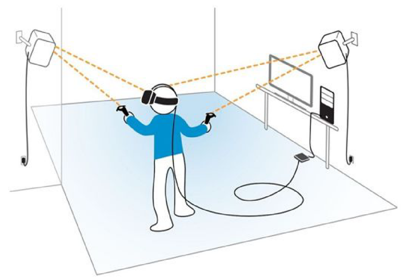


Figure 1: HTC Vive 3D spatial tracking using base stations.[15]

The intent of this project is to fully simulate the environment in which an AD patient and a caretaker would occupy and therefore the student simulated the first floor of a typical house, including a living room, bedroom, garage, and kitchen. Figure 2 presents a screenshot of the kitchen environment in which the stove has been accidentally left on. Note that, for the purposes and scope of this project, the functionality rather than aesthetics were the focus of development (i.e., we used basic assets instead of full textures and 3D renders of a home environment).

Figure 2: Example of kitchen environment.

Figure 2 comprises countertops, a functioning stove, a refrigerator whose door can open and close, and a sink. Sample scenarios that a caretaker may face in this room would be that the AD patient opened the refrigerator door and forgot to close it, or that the patient turned the stove on to cook and walked away without turning it off. Such scenarios, including those that are quite dangerous (e.g., turning on a gas stove without igniting the gas), can be common situations for a caregiver. To provide more details, Figures 3a and 3b demonstrate the task of turning on/off the stove. In Figure 3a, the stove is on and there is a button to switch its state. The user, using the Vive controller, may then turn off the stove (Figure 3b), completing the objective of the scenario. Note that the AI-controlled patient can also use this button to turn the stove on or off at any given time.

Figure 3a and 3b: Turning off the stove.

The caregiver can interact with any object in the virtual home, including the ability to drag or push objects that are heavy, as well as to pick up, carry, throw, and place smaller objects. The AI patient can also interact with objects in the same fashion.

b. Alzheimer's Disease

AD is one of the top five leading diseases with no cure, where early intervention is one of the best strategies for prolonging the descent into dementia.[1-3] Caregivers, often unpaid friends and family members, must provide on-site care at all hours of the day to maintain the patients IADLs.[4] Caregivers must be able to manage the symptoms of AD, including sudden mood changes, forgetfulness, and resolution of dangerous situations (e.g., turning on a stove to cook and then walking away). As such, cost-effective training tools can go a long way for providing even a basic level of training, thereby reducing caregiver stress.

c. User Interface and Caregiver Tasks

To ensure that the caregiver understands their goals and objectives, a user interface was developed to visually relate such information. In CARETAKVR, this interface is represented by a virtual clipboard that the user may pull up at any time. The clipboard dynamically displays the user's current tasks/objectives, as well as the status of current tasks, as is demonstrated in Figure 4a. For instance, Figures 4b and 4c demonstrate completing the objective of turning off the stove. In Figure 4b, the patient is moving to a different location (specified internally by the AI), having recently turned on the stove. The caregiver must then turn off the stove, as indicated by

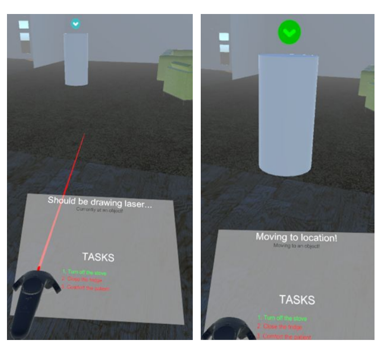
`Task 1`. Figure 4c illustrates that the caregiver has successfully turned off the stove by pushing the button, as indicated by the green text.

Figures 4a, 4b, and 4c: User Interface and Completing an Objective.

d. Simulating a Patient

We provided an initial prototype patient, controlled by a limited AI, to facilitate the caregiver's training. This patient is intended (as future work) to be fully AI-controlled, exhibiting common behaviors as an AD patient would express. For this particular paper, however, the AI is limited to wandering around the house and accepting actions from the user. Such actions include moving from place to place and interacting with objects. This limitation was put in place as a stepping stone towards the full AI.

Figure 5a illustrates how the player can direct the patient (represented by the gray cylinder) to move from place to place. The indicator over the cylinder represents the current state of the patient, with Figure 5b demonstrating that a `Move to Location` directive was accepted and completed. Future indicators include hunger status, mood, and any other indicator that would be helpful to the caregiver.



Figures 5a and 5b: Directing the "patient."

e. Gamifying Training

A common trend with training applications is to "gamify" them, or to add objectives, achievements, and scores.[9-11] Such metrics provide the player with a sense of achievement, or that they are progressing in their skills. This is not intended to trivialize the activity, but to ensure that the person being trained remains focused on their progression. As such, our approach to gamification is to include objectives to fulfill, achievements to unlock, and a progression of increasing difficulty. At present, we have implemented basic objectives (e.g., turn off stove), with future objectives including calming the patient, preparing a meal, and assisting physical rehabilitation activities.

3. Student Training and Project Artifacts

To develop this project, an undergraduate student (and co-author) performed an undergraduate research course, a paid summer project, and an Honors thesis to develop this project. Each activity was structured appropriately to provide manageable and achievable tasks towards the delivery of a completed project. Initially, the student was interested in learning how to program in VR and was transitioned to this project. The student was incorporated in research meetings relating to this project, including discussions on development of a smart home that supports AD patients (with the intent being to eventually fold in CARETAKVR into the ecosystem of the smart home). Moreover, the student participated in research meetings with external collaborators who specialize in health care and helped to also guide this project. Figure 6 demonstrates a sample research meeting in which the undergraduate student is guided by graduate researchers.

Figure 6: Student development meeting in which senior members of the research lab support the undergraduate in prototyping and development of CARETAKVR.

This project was developed as open source and is therefore available for download on the author's GitHub repository (source code)[16] and FTP website (project assets).[17]

Threats to Validity. This paper presents a proof of concept VR application, and as such, may suffer from the 'reality gap' that plagues VR. The reality gap generally implies that simulations are not always reflective of reality, and as such, any techniques presented in a simulation only apply to that simulation, discounting real-world concerns. The same issue applies to VR in that we are simulating a real-world environment, including a person. As such, CARETAKVR is not intended to be a complete recreation of the real world, but to be an approximate representation of the concerns with AD patients and enable methods for learning coping and/or mitigation techniques that may then be applied to the real world. To ensure that we do not present incorrect or false information, we have collaborated with experts in the health care domain.

4. Conclusion

This paper presented CARETAKVR, a proof of concept VR application intended for training caregivers of AD patients. This project will expose a caregiver to typical scenarios that they may face while supporting an AD patient, including managing IADLs, gamifying each scenario to give the caregiver with a sense of achievement and forward progress while communicating the necessary mitigation strategies or support techniques for the patient.

Future Work. This project provided a proof of concept VR environment for training AD patient caregivers. As such, there exists several avenues of research that we intend to pursue. First, the AI that controls the simulated patient must be strengthened, as only a rudimentary implementation currently exists (for instance, via an expert system or trained neural network). Second, we intend to improve the aesthetics of the system, as placeholder objects were used (e.g., cylinders to represent people, untextured surfaces, etc.) to enable quick development of the entire framework. Third, we will incorporate simulated smart devices that will be featured in the AD patient's smart home, leading CARETAKVR to also provide a simulation environment of a patient smarthome. These tasks will be explored in future undergraduate research projects.

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