# Nursing Care Teaching System Based on Mixed Reality for Effective Caregiver-Patient Interaction

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***Abstract*— In the nursing care tasks such as assistance for transferring and walking, it is necessary to provide appropriate nursing care movements depending on factors such as the patient's pose and the degree of disability. However, for novice caregivers to practice and learn appropriate nursing care, they must practice for a long time under the guidance of skilled caregivers. To solve this problem, we propose a novel framework for a system that teaches appropriate nursing care actions according to the current situation. The realization of such a teaching system requires technology to recognize the current situation and effectively teach the interaction between the caregiver and the patient. In this article, we propose a system that integrates depth camera-based pose estimation of the patient and Mixed Reality (MR) technology to present the target motion of the patient to a caregiver. To accurately present the patient's target pose to the novice caregivers, our system displays an avatar showing the patient's ideal animation overlaid on the actual patient. Experimental results show that our system can accurately instruct the caregiver about the patient's target pose in each movement procedure.**

## I. INTRODUCTION

With the increasing elderly population and low birth rate due to demographic changes, there is an acute shortage of nursing care personnel. In order to address this situation, many researchers have developed various nursing care support systems using robotics, Augmented reality (AR), Mixed Reality (MR) and Virtual reality (VR) technologies. So far, many care support systems have been proposed, including a teaching system to help caregivers learn nursing care [1] [2] [3] [4], a teaching system to support the patient's rehabilitation [5] [6] [7] [8], and a robotic system to support the patient's activities by physically contacting the patient [9] [10].

Examples of caregiving behaviors that are difficult for trainers because they require interaction between caregiver and patient include:

- Assist from a sleeping position in the bed to a sitting position at the end of the bed.
- Assist a patient from a sitting position on the bed to a proper position for carrying to the wheelchair.
- Walking assistance.

One of the reasons why these assisting actions are difficult to learn is the need to understand the appropriate actions for each situation. The current situation that caregivers should consider for appropriate nursing care includes the poses of the patient and nursing care equipment, as well as the physique and physical ability of the patient. To learn appropriate movements, novice caregivers must have extended hours of practice until they can empirically understand appropriate care through simulated nursing care with skilled caregivers.

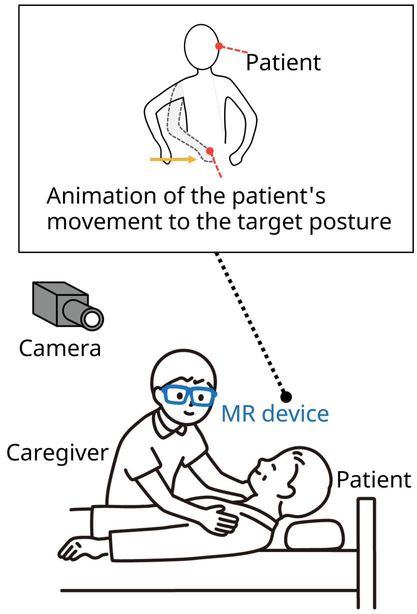


Fig. 1: System Overview: A camera mounted above the bed estimates the patient's pose, and an MR device worn by the caregiver displays the next nursing operation to be performed based on the estimated results.

In acquiring nursing care actions described above, it is desirable to develop a system that can teach nursing care actions appropriate to the current situation. Such a teaching system can supplement the experiential knowledge that caregiving novices have acquired through long hours of practice. Nevertheless, to the extent of our knowledge, a system that teaches appropriate care based on the actual situation has yet to be proposed. Thus, we propose a novel framework for a teaching system that can instruct appropriate caregiving actions using the camera and MR device (Fig. 1).

This paper is organized as follows. After describing related studies in Section II, we mention the concept of our system in Section III. Next, we briefly explain the caregiving proce-

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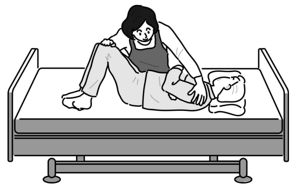
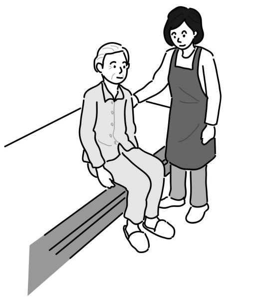


(a) Bend both arms and knees of the caregiver.

(b) Make a caregiver turn over.

(c) Raise the patient up using the patient's knees as a fulcrum.



(d) Check to see if the caregiver is in a sitting position.

Fig. 2: Procedure for assisted movement from lying in bed to sitting on the edge of the bed.

dures that is the focus of this study in Section IV, and then we introduce the system configuration and User Interface (UI) in Section V. Finally, we show experiments in Section VI and discussion in Section VII.

## II. Related works

Research and development of nursing care teaching systems are underway to alleviate the shortage of nursing care personnel. For example, C. Lin et al. proposed an approach to help novice caregivers learn nursing care motions by having a humanoid robot perform simulated nursing care motions for caregivers [1]. R. Kurazume et al. proposed a system that teaches dementia using a mannequin equipped with tactile sensors and an MR device [2]. While these systems were demonstrated to improve learning efficiency in a training environment, they could not teach care in the context of actual nursing care motions.

J. P. Kopetz et al. proposed a system that provides nursing care motion instruction through images, videos, and textual information using smart glasses attached to the caregiver [3]. M. Dürr et al. proposed a system for teaching nursing care motions using a tablet device [4]. In this system, kinaesthetics-based patient transfers are taught in three steps: (i) interactive instructions, (ii) training of transfer conduct, and (iii) feedback and reflection. Although the usefulness of the teaching system has been demonstrated, the teaching of nursing care motions appropriate to the current situation recognized using sensor information has not been realized. In addition, these teaching systems mainly present 2D information in the form of text and video information. We believe that more detailed and intuitive guidance can be presented by recognizing the environment using sensor information and 3D information using MR.

Many teaching systems have been proposed in sports, rehabilitation, factories, and other fields where a specific motion is trained in the actual environment. These teaching systems can be divided into tactile-based, auditory-based, and visual-based.

In a system using tactile sensation, J. V. S. Luces et al. proposed a position guidance system using a vibrating device based on phantom tactile sensation consisting of six oscillators, which are attached to the wrist and provide a 360-degree directional presentation [11]. Tactile systems have the advantage that they require less attention than visual systems and can present information more effectively than sound systems without being affected by the surrounding environment. However, the disadvantages are that the amount of information that can be conveyed is smaller than that of visual or auditory information and that there are individual differences in how tactile information is perceived.

In an auditory-based system, R. Okugawa et al. proposed a bicycle pedaling training system with auditory feedback [12]. In this system, the trainee can keep the pedaling speed constant by synchronizing pedaling with the feedback sound. A teaching system using auditory information can provide more information than tactile information but less information than a system using visual information.

Because a large amount of information must be presented to teach caregivers and patients about the interaction appropriately, we focus on a system that uses AR/MR to teach based on visual information. Systems that use AR/MR to teach while a person acts include a system that supports inspection work at a manufacturing site [13], a system that helps improve piano playing [14], and a system that teaches dance steps [15]. However, not many teaching systems have been established for teaching in a situation where multiple people interact with each other, and thus, this system cannot be applied to teaching nursing care actions that require interaction between a caregiver and a care recipient.

## III. Concept of the proposed system

In this study, we aim to teach appropriate interaction between a caregiver and a patient accordingly to the current situation. Therefore, the teaching system must recognize the current situation and appropriately teach the caregiver about the interaction between the patient and the caregiver. In this study, we developed a UI that can accurately present the target pose of a patient to a caregiver wearing an MR device by constructing a system that integrates pose estimation of the patient and MR technology. In order to accurately present the patient's target pose to the caregiver, our system displays the patient's target motion superimposed on the actual patient. This article focuses on the caregiving action of moving a patient from lying to sitting on the bed (Fig. 2). This nursing care action is not easy to learn because it requires the appropriate nursing care action according to the current situation in multiple steps [16]. In this study, we propose a system that can teach appropriate nursing

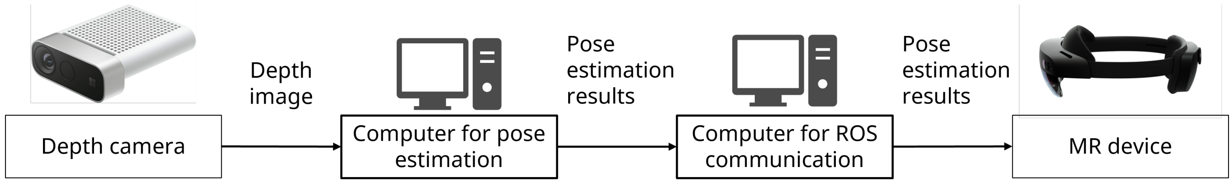



Fig. 3: Device configuration.

care actions according to the current situation in multiple procedures by combining pose estimation of a patient using depth camera information and teaching using an MR device.

## IV. Procedure for assisted movement from lying in bed to sitting on the edge of the bed

In this chapter, we briefly describe the procedure for nursing care actions from lying to sitting in the nursing care setting (Fig. 2). This caregiving procedure is expressed as follows:

1) Bend both arms and knees of the caregiver. This step reduces the area of contact between the bed and the patient, making it easier for the patient to turn over (Fig. 2a).
2) Turn the patient toward the side where the wheelchair is placed (Fig. 2b).
3) Using the knee as a fulcrum, raise the body using the principle of leverage to guide the patient into a sitting position at the edge of the bed (Fig. 2c).
4) Check to see if the caregiver is in a sitting position (Fig. 2d).

The system uses the pose estimation results of the patient to recognize the current situation at which stage the patient is at in the above caregiving operation procedure and displays instructions according to the patient's pose using an MR device worn by the caregiver.

## V. Overview of the proposed system

### A. System configuration

The proposed system consists as follows (Fig. 3):

- An MR device that displays instructions to the caregiver
- A depth camera mounted above the bed where the patient lies (Fig. 4)
- A PC for pose estimation of the patient using information from the depth camera
- A PC for Robot Operating System (ROS) communication

The ROS communication is used to transmit the pose estimation results of the patient obtained using the depth camera information to the MR device. We adopted ROS communication to provide extensibility, such as linking with other robot systems. The MR device used was the HoloLens 2, made by Microsoft Corporation.

Our system uses Azure Kinect as a depth camera. In addition, the Azure Kinect Body Tracking SDK developed by Microsoft Corporation was used for pose estimation of the patient using the depth camera [17]. In order to reflect

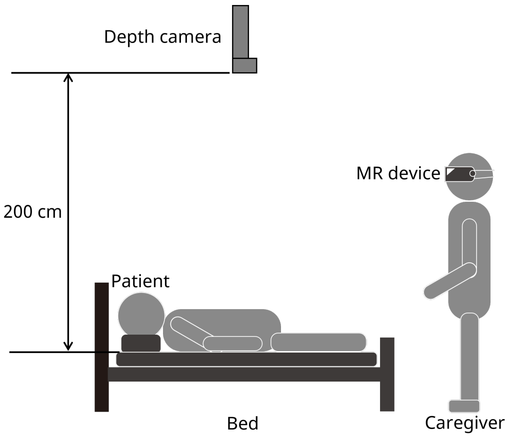



Fig. 4: Location of devices.

the coordinates of the joints of the patient obtained from the depth camera information on the MR device, a QR code attached to the depth camera was read by the camera mounted on the MR device, and the coordinate systems of the depth camera and the MR device are matched.

### B. User interface

The proposed system projects a hologram using an MR device, which is worn by a caregiver, using the results of the patient's pose estimation obtained from the depth camera, and instructs the caregiver about movements according to the patient's current pose (Fig. 5). We have developed a UI that can present the movement to the target pose in an easy-to-understand manner by superimposing an animation of the change to the next target pose on the actual patient's body. The UIs that caregivers can see are shown in Fig. 6 and Fig. 7.

The human avatar was acquired using Goodsize's iPhone application, in3D:Avatar Creator [18]. The human avatars acquired here are equipped with bones, and the human avatars can be moved freely by giving arbitrary joint angles to the avatars. The system acquires the joint angles of the patient in the appropriate pose using the depth camera in advance and then uses them to teach the patient the appropriate pose for each nursing action.

## VI. Experiments

We conducted experiments to verify whether the caregiver could guide the patient to the correct pose using the information presented by the proposed system. The information displayed on the experimental run was a sequence of motions

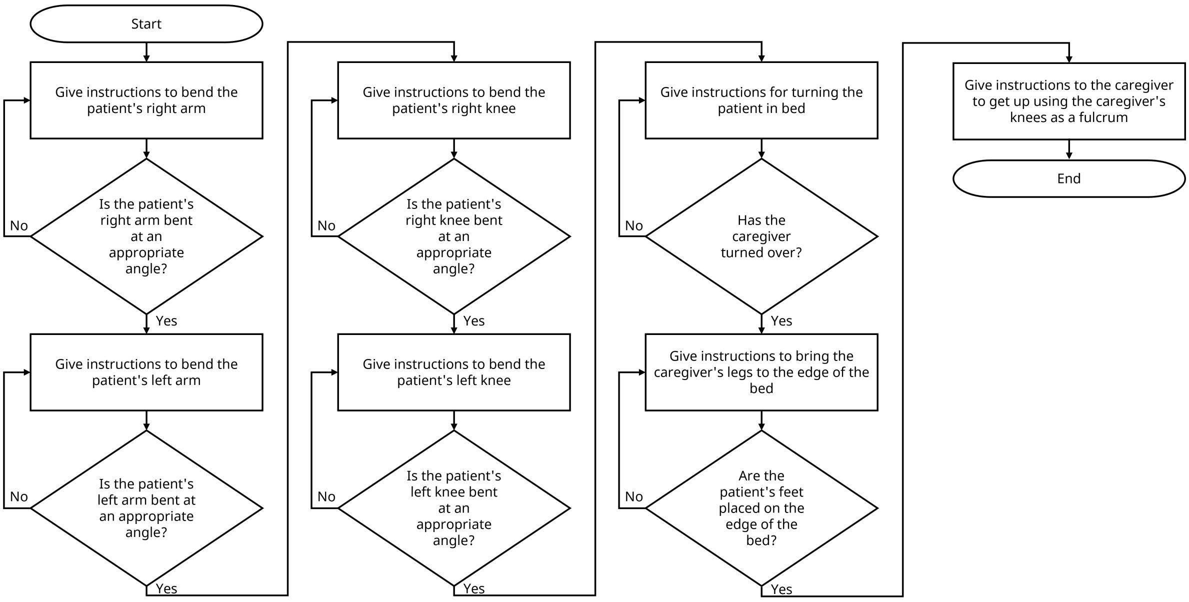



Fig. 5: Flowchart for teaching according to caregiving movement procedures.

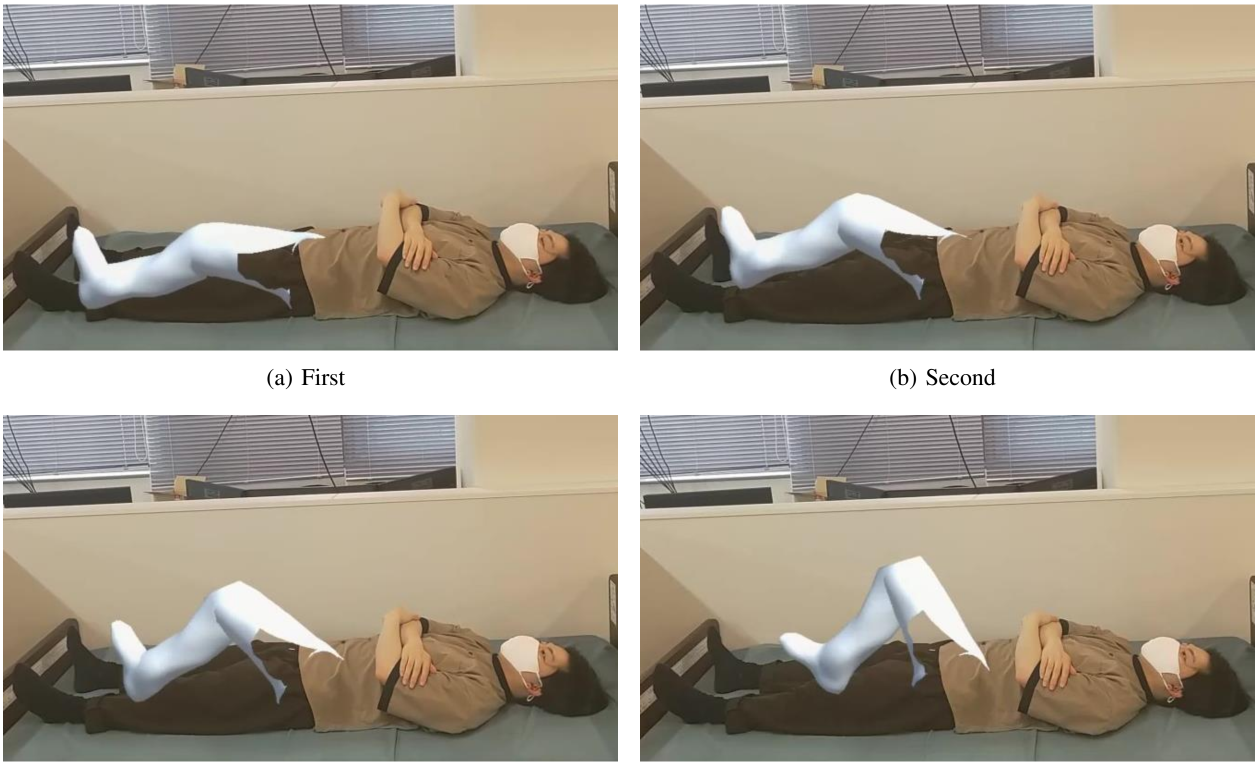
(a) First

(b) Second

(c) Third

(d) Fourth

Fig. 6: Example of a UI with a humanoid avatar that can be seen by a caregiver wearing an MR device. In this example, the instruction is to bend the patient's left arm.



(a) First (b) Second

(c) Third (d) Fourth

Fig. 7: Example of a UI with a humanoid avatar that can be seen by a caregiver wearing an MR device. In this example, the instruction is to bend the patient's right knee.

to assist a patient from a supine position (laying down in bed) to an end-sitting position. This sequence of motions, as well as the conditions to switch instructions, are shown in Fig. 5.

As preliminary experiments, we had an occupational therapist, and a novice caregiver tests the system and confirm the system's usefulness. After the physiotherapists experienced the system, they commented that the proposed approach is suitable for teaching beginners in nursing care. We also verified that the system could correctly assess which stage of the moving procedure the patient is based on the patient's pose and subsequently display information on the next nursing care movement. In addition, there was no significant delay in switching the display of nursing care actions, and there were no practical problems with projection errors when the display was superimposed on the patient's body.

We conducted a quantitative evaluation to assess the precision of the provided instructions. In this evaluation, we present a target motion to 8 different participants with no previous experience in caregiving. The motion consisted of guiding a patient from a supine position to a position where the right knee is bent about 90°. We evaluate two different modalities: a text-based UI where the instruction is given via a text prompt (Fig. 8) and the proposed avatar-based UI. To avoid learning bias, the participants were separated into two groups (text-based UI and avatar-based UI), and each participant performed the motion four times. Fig. 9 shows the results of the experiments. From the results, it can be confirmed that the error in the knee's angle is significantly reduced for participants using the avatar-based UI.

## VII. Discussion

We can see that the angle of the patient's knee is much closer to the desired value when the avatar-based UI is used, thus making the error smaller. This is attributed due to the fact that there's a clear visual cue that enables the subject to know the desired position. On the other hand, text-based information might be subject to interpretation. For example, while one subject might think that there should be a 90° between the back of the calf and the back of the thigh, other subjects might think that there should be 90° between the tibia and the thigh bone. Overlaying the target position on top of the subject, as well as evaluating the final state, enables the subjects to perform the task accurately and in an intuitive manner.

## VIII. Conclusion

In this paper, we propose a novel framework for a nursing care teaching system that can recognize the current situation using sensors and teach appropriate nursing care actions according to the current situation based on the recognition results. In addition, we propose a system that integrates depth camera-based pose estimation of the patient and MR technology to present the target pose of the patient to a caregiver wearing an MR device in each nursing care motion procedure in the guidance of a patient from lying in bed to

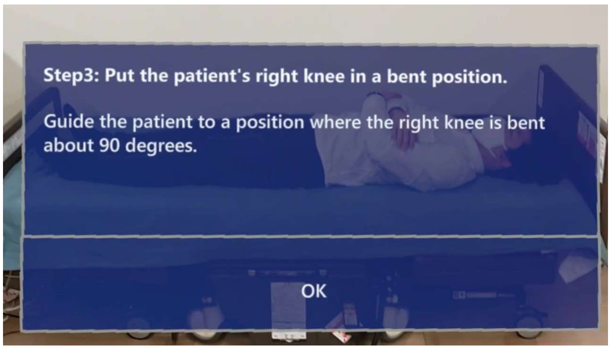



Fig. 8: Example of a UI using a dialog viewed by a caregiver wearing an MR device.

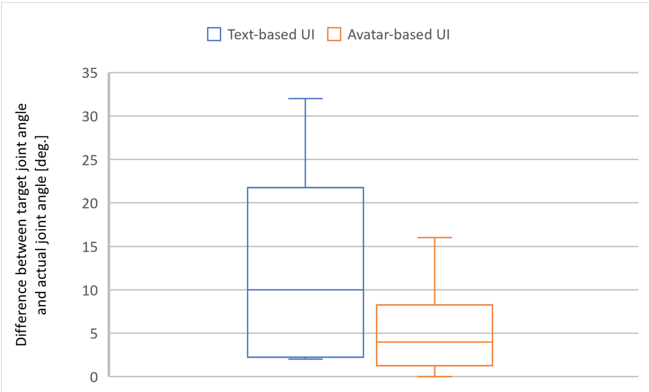



Fig. 9: The difference between the care recipient's target right knee angle and the care recipient's right knee angle is assisted by the caregiver when using the text-based UI and the avatar-based UI, respectively.

sitting at the edge of the bed. Moreover, we have developed a UI that can present the movement to the target pose in an easy-to-understand manner by superimposing an animation of the change to the next target pose on the actual patient's body. We confirmed that our system could judge which stage of the moving procedure the patient is in considering changes in the patient's pose and display information for the next nursing care movement. Furthermore, there was no significant delay in switching the display of nursing care actions, and there were no practical problems with projection errors when the display was superimposed on the patient's body. In addition, we conducted experiments to demonstrate the usefulness of the proposed method by determining how accurately the caregiver can guide the patient to the target pose when using both a text-based UI and an avatar-based UI. In the future, we plan to address nursing care support system that take into account the physical ability and degree of disability of the care recipient, as well as extending the teaching to other nursing care actions.

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