Designing a Human-Robot Collaborative Interface for Nursing Robots Failure Recovery

Lorena Maria Genua[1] and Zhi Li[1]

I. Introduction

In recent years, many mobile manipulators and humanoid robots have been deployed all over the world in hospitals, nursing facilities, and homes [1]. The introduction of robotics in healthcare addresses the significant challenge posed by a rising aging population, alongside a reduction in available nursing staff. These nursing robots are expected to perform some general-purpose assistance tasks to alleviate nurses' workload, such as fetching and delivering medical supplies, preparing and cleaning nursing workspace and patient rooms, and taking vital sign measurements. However, robots operating in unstructured environments face frequent failures and must rely on nurses to understand and resolve these issues. For this reason, in our prior work, we have developed an innovative multilateral multimodal human-robot (MMHR) collaboration prototype system that enables effective collaboration and communication between the robot and both remote and local nurses (Fig. 1). In this paper, we develop a user-centered recovery procedure, allowing the robot to receive guidance and learn from professional nurses in case of failure. Therefore, we propose a **human-robot collaborative interface** to facilitate robot **recovery from failures**. Through the interface, nurses can utilize high-level control commands to leverage the robot's primitive skills for manipulation to recover from the failure states. We also establish communication between remote and on-site nurses, using Augmented Reality visual cues to exchange action information. By combining these elements, our approach offers a comprehensive solution to effectively support nursing robots in overcoming failure scenarios and learn from nurses' correction.

II. Related Work

Nursing robots operating within unstructured environments pose significant challenges due to the unpredictable and complex nature of these settings, which might lead to frequent failures in robot autonomy. This underscores the necessity for an effective human-robot collaboration framework to facilitate recovery efforts [2]. While some robots and multi-robot systems have the capabilities to autonomously resolve failures through pre-programmed corrective actions, these solutions are often inadequate when encountering complex or unexpected errors, and therefore necessitate human intervention [3]. Methods such as teleoperation and corrective shared-autonomy allow for direct and real-time human corrections [4]. These approaches can increase the operator's workload and might not leverage the full potential of human guidance, impacting the operator's trust in the system [5]. In contrast, high-level teleoperation interfaces have been shown to improve task performance and perceived mental and physical workload compared to low-level control interfaces [6]. However, a gap exists in utilizing manipulation actions for failure recovery within a collaborative framework that also enables robots to learn from human inputs. Our proposed approach is to develop a human-robot collaborative failure recovery system that leverages the robot's primitive skills for manipulation to recover from failure states. By incorporating high-level human commands during failures, the robot can learn to autonomously execute these skills in future similar situations, thus improving its adaptability and ability to recover from failures independently.

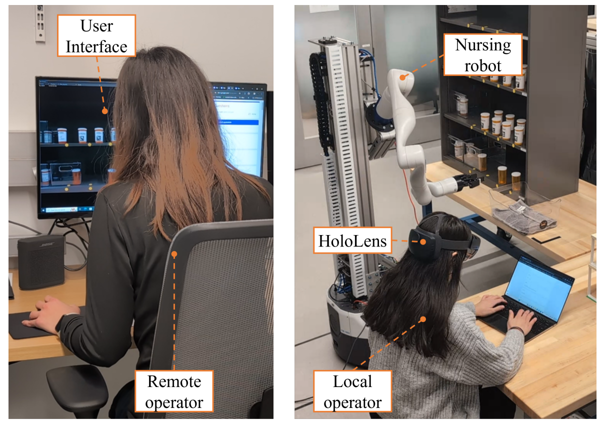

Fig. 1: MMHR system includes a remote user employing a screen-based interface and a local user wearing a mixed-reality headset to interact with each other and with the robotic system.

III. System Overview

Our system integration enables the multilateral collaboration among *nursing robots*, *local nurses* sharing the robot's workspace, and *remote nurses* operating the robot from a different location. The nursing robot IONA (Intelligent rObotic Nursing Assistant), a mobile humanoid nursing robot developed in our recent work [7], is equipped with multiple Kinova Gen3 manipulator arms and RGB+D cameras for autonomous manipulation and perception in cluttered environments. The remote nurses utilize a screen-based graphical interface, while the local nurses use a mixed-reality headset (Microsoft HoloLens 2).

The robotic system comprises essential modules for task execution and communication with remote and local nurses (See Fig. 2 (b)). The **Task State Manager** tracks the

[1] Robotics Engineering Department, Worcester Polytechnic Institute (WPI), Worcester, MA 01609, USA {lgenua,zli11}@wpi.edu

a) Remote User Interface for failure recovery

b) System architecture

Fig. 2: a) The User Interface for failure recovery includes two camera views and control panels to command high-level actions to the robot. b) System architecture and communication framework to command target pose to the robot and to visualize AR cues.

task progress and sends information related to the current target to the **Object Tracker** for object detection. The **Pose Estimation** module computes the 3D object position of the detected object in the camera view and handles all frame transformations. It uses Azure Spatial Anchor to set a common coordinate reference system between the robot and the local operator. Given the target pose, the **Motion Planner** plans robot arm motions.

IV. Interface Design

Our proposed Graphical User Interface (GUI), shown in Fig. 2, incorporates two camera views: a primary view from a camera mounted on the robot's chest, and a secondary view from a standalone workspace camera. Any information pertinent to the robot's current status, such as operational states (e.g., in action, paused, fault, homing) and ongoing actions (e.g., grasping, placing), is displayed in an **Information panel**. Beneath this panel, toggle buttons offer options to enable or disable the secondary camera view, as well as to reveal the task list and progress status. In the event of a detected failure, the information panel displays an error message describing the issue. The remote operator can use the provided buttons in the **Control panel** to engage with the robot and issue high-level action commands. The interface provides users with a flexible method for selecting target objects or placement locations. Specifically, the user can click and drag the cursor across the screen to define a rectangular area around a specific point of interest (See Fig. 2 (a)). Subsequently, the user can utilize the buttons in the *Object Manipulation* panel to command the robot to:

- **Grasp:** Grasp the selected object on the screen;
- **Place:** Place in the selected location on the screen;
- **Set Aside:** Move the object to a designated disposal area;
- **Try again:** Re-attempt the previous action (i.e., grasping or placing).

The *Robot Control* section includes buttons to adjust the camera view by **Moving the camera** up and down, and button to **Home** the robot to a predefined initial configuration. Should the robot fail to recover with human input from the remote user interface, the *Local Operator Interaction* panel can be activated to establish communication with an on-site operator sharing the robot's workspace. When this panel is enabled, any command initiated through the *Object Manipulation* panel will be directed to the local operator and will not be sent to the robot. The available functions are:

- **Call:** Send a notification to the local operator with a standardized message with a request for assistance;
- **Input text:** Write a custom message for the local operator;
- **Define actions:** Select a sequence of actions for the local operator to execute. For instance, they can select a target object on the screen for grasping, then press "Grasp". Subsequently, they may designate a placement location for the object and press "Place". This process sends augmented reality (AR) visual cues to guide the local operator in task execution;
- **Send:** Sends the input message and/or the AR visual cues to the local operator;

The *Task control* section allows the user to **Pause** the robot, **Continue** its action, or **Cancel** the ongoing action.

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