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Investigation of interaction forces in robotic assistance during the nursing activity of positioning a patient simulator to the bed edge

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Abstract: Nursing is under enormous pressure due to personnel shortage. Physically demanding activities in the context of nursing additionally cause staff to leave the profession prematurely. Assistive technologies such as robotic support systems have the potential to relieve the burden on caregivers. In a study with 21 nurses, we investigated the relief potential of a bed-mounted robotic assistance system when repositioning a 40 kg patient simulator in a nursing bed to the bed edge. The robot's interaction forces applied to the simulator's back during the task execution represent on average only 47.33% of the force limit specified by common standards.

I. Introduction

Interacting with patients in nursing is a physically demanding activity that is associated with an increased number of low back pain compared to other occupational groups. In particular, nursing activities at the nursing bed are associated with the risk of physical overload [1]. In addition, there is a shortage of qualified personnel, which according to forecasts is expected to increase further in the future [2]. As a result, patients are more often treated alone out of necessity, even if the support of another caregiver would be required, for example, for repositioning the patient.

In addition to basic or conventional aids, research is also being conducted into robotic assistance systems that can provide support in transfer and mobilization tasks at the care bed. This research can be mainly divided into exoskeletons [3] and intelligent patient lifts [4]. In the present work, a system is used which is directly attached to the nursing bed and consists of two lightweight robotic manipulators to provide direct assistance through physical human-robot interaction [5].

The safety requirements for robotic assistance systems that come into direct physical contact with patients have not yet been firmly defined in the context of care. Voluntary standards exist only for collaborative robots (ISO/TS 15066:2016 & EN ISO 13482/2014). In this standard, body-area-specific maximum values are determined for forces and pressures that may occur at a maximum during contact between the robot system and the person. A specification tailored to the context of care with the handling of potentially vulnerable groups of people is currently not yet available.

This paper takes a closer look at the forces acting on the robot end-effector during the physically demanding activity of repositioning a patient simulator from the supine position to a sitting position at the edge of the nursing bed.

II. Material and methods

II.I. Robotic assistance system

A robotic assistance system was used for the present work, which consists of two lightweight robots of the model KUKA LBR iiwa7 R800 attached to a nursing bed with customized end effectors (see Fig. 1).

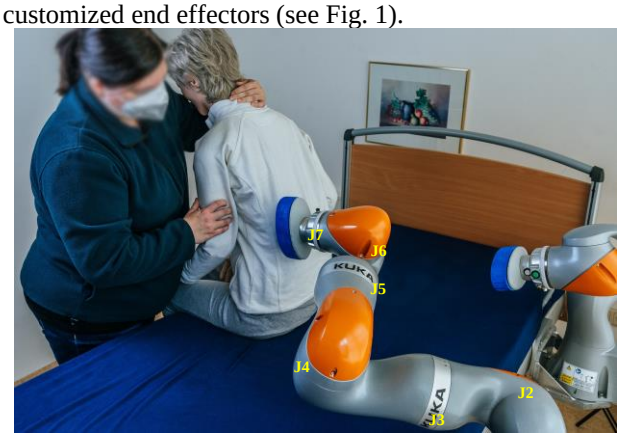

Figure 1: Patient simulator and robotic assistance system at the nursing bed with a padded end effector to support during patient repositioning processes. Individual robot joints are marked.

In addition, additional sensors were used to measure the environment (depth imaging cameras), the caregiver's ground reaction forces (force measuring plate) and the caregiver's muscle activity (surface electromyograph) of the lower back to determine the amount of physical relief. The camera data was used to synchronize the different sensor signals. In this work, we mainly present the robot's force data results based on the end effector's joint torque

sensor. The robotic assistance system uses a preceding impedance controller, which provides compliant behavior during support movements. The trajectories required for the support movement were generated in advance using task execution recordings by caregivers.

II.I. Data acquisition

The data for the work were recorded as part of a study with a total of 21 nursing professionals (16 female, 5 male, average age 49.3 years). In the study, the nursing professionals repositioned a 40 kg patient simulator both conventionally without assistance and with robotic assistance from the supine position to the sitting position at the edge of the bed. This movement sequence can be divided into different phases, whereby for the present observation the last phase, i.e. the raising from the lateral position to the sitting position, was mainly investigated (see Fig. 2). During this phase, the padded end effector on the back of the patient simulator served as a stabilizing support. The nursing professionals were asked to actively use the robot as a supporting element during the raising movement of the patient simulator.

III. Results and discussion

During the repositioning trials with robotic assistance, asynchronous cooperation occurred in some cases. Due to a partial lack of contact between the end effector and the patient simulator, the robot could not provide sufficient support in these cases. These executions were classified as insufficient and excluded from the analysis, so that the subject data of 15 nurses could be used for the final evaluation. In general, a muscular relief could be observed in the back area of the participating nursing professionals due to the support of the robotic assistance system.

II.I. Robotic interaction forces

The most important force in the support movement during the raising phase is in the y-direction of the robot's end effector, which can also be seen in Fig. 2. For forces acting in the y-direction, it must be mentioned that the negative force corresponds to the actual force applied. The task execution duration of the studied phase was on average 5.95 s with a standard deviation of 3.46 s.

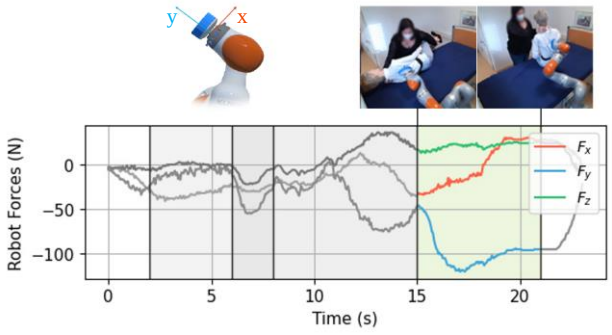

Figure 2: Example phases of the force curve measured at the end effector of the robot when raising the patient simulator from the supine to the sitting position at the edge of the bed. The green highlighted segment is the movement of interest in this work.

Based on the chosen configuration, the 7-DOF manipulator was loaded differently at each joint. On average, the load was 11.41 Nm at base joint 1, 9.86 Nm at joint 2, -14.61 Nm at joint 3, -3.77 Nm at joint 4, -0.20 Nm at joint 5, -1.8 Nm at joint 6, and 0.02 Nm at joint 7 (see Fig. 1 for joint positions). The Cartesian forces at the end effector during support averaged -9.20 N in the x-direction, in the y-direction the value was -64.24 N, and in the z-direction the value was 11.97 N. The average maximum force measured was 19.07 N in the x-direction, -99.41 N in the y-direction, and 48.17 N in the z-direction. The minimum average occurring force was -28.55 N in the x-direction, -39.03 N in the y-direction and -8.46 N in the z-direction. The contact area of the customized end effector is about 125.66 cm². Assuming that the padded end effector is in full contact with the back of the patient simulator, the average minimum pressure in the y-direction was -0.79 N/cm² and the maximum pressure was -0.31 N/cm². If these values are compared with the force limit for the back from the standard ISO TS 15066, they are far below the force and pressure limit for quasi-static contact of 210 N or pressure of 210 N/cm². It must be mentioned that the present forces are based on the 40 kg patient simulator and would be larger for heavier patients. However, the successful handling of heavier patients can also be assumed because the limits defined by the standard were not exceeded.

IV. Conclusions

We conducted a study with 21 nursing professionals as subjects and were able to show that the presented assistance system could offer support by applying forces during the important caregiving task of repositioning a 40 kg patient simulator from the supine position to the sitting position at the edge of the bed. Here, we considered the interaction forces during the final movement phase and compared them against the currently existing force and pressure limits of current standards in assistance robotics. It was found that at the end effector only 47.33% of the permissible force limit was measured for the average maximum force. In future work, the control system will need to be adjusted to better handle the different task execution speeds and individual movement patters of the caregivers. We also plan to use a heavier patient simulator and automate certain segments of the robot movement using the camera data.

AUTHOR'S STATEMENT

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