

Towards robotic manipulator assisted positioning in care

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Abstract: In nursing, nurses are burdened with many physically demanding tasks. Especially in ambulatory care, nurses are alone with their patients and are under great time pressure. Due to long journeys, no second nurse can be called in. Also, a suitable nursing aid is not always available or at hand for the patient. A flexible robotic solution can help here. In this paper, we consider the positioning of the patient on the side. In particular, the patient mobilized on the side should be held in this position. We analyze how a nurse would perform this activity and how a robot can be used for this. For this, we use Whole Arm Manipulation (WAM). WAM is a suitable means of ensuring that a manipulator can apply the necessary forces and reduce the risk of injury to the patient. We developed an algorithm for WAM based on the kinematics of the manipulator and the geometry of the scene. For simplification, an elliptical cylinder is used as a human model. The results show that the algorithm delivers valid results in different constellations.

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I. Introduction

Outpatient care is the largest area in nursing, and it continues to grow. The resulting, increasing demand for nursing staff cannot be met in full. More and more relatives are also taking over care in this area [1]. Many nursing activities are very physically demanding [2]. This leads to the early retirement of nurses from their profession [3]. Technical solutions such as robotics can help here [4]. However, the use of fully autonomous systems in nursing is not desired [5]. Therefore, we propose a remotely controlled system.

Positioning the patient on the side is a common activity in nursing, as it is a basic prerequisite for many other activities. In previous work, we have shown that nurses can imagine being assisted by a robot [6]. In this work, we focus on stabilizing the patient on their side. This is done by the robot. A remote nurse controls the robot in consultation with the nurse on site. For the robot to stabilize the patient in the lateral position, it must touch the patient at least two points. Therefore, we decided to use whole arm manipulation here (WAM). This is usually used for the manipulation of large or heavy objects [7]. Unlike other work [8], we do not want to transport the patient and therefore only use a manipulator and not a humanoid. In order not to create hazards for the patient we do not use learning methods but use an algebraic solution of inverse kinematics for the generation of the robot pose.

Remote control of the robot by the remote caregiver is made as simple as possible. She only defines the position on the patient's longitudinal axis where the robot is to hold.

II. Material and methods

In this section, we first describe how the patient body is modeled as an elliptical cylinder and how the robot configuration is computed depending on the user's input.

The user is shown an image of the scene with a movable marker for input, as shown in Figure 1. This can be moved by the user along the longitudinal axis of the patient. This allows the location of the hold to be determined.

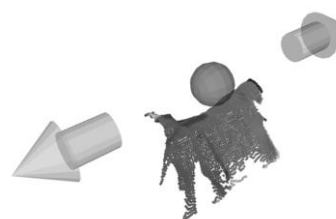


Figure 1: The input option for the remote user is a movable marker. This is displayed above the body extracted from the overall scene.

II.1 The modeling as an elliptical cylinder

The elliptical cylinder, which serves us as a simplification of the human body, is parameterized by visual perception.

We use a 3D camera to capture the scene. From this, the body is extracted with the help of a Plane Model Segmentation. The point cloud of the body is then reduced to the area where the robot is to be placed. The remaining points are projected onto a 2D plane. In this representation, the elliptical parameters for the elliptical cylinder can be calculated. These include the lengths of the semi-axes, as well as the center point.

II.II Robot pose generation

The robot pose generation is developed here for manipulators that have combined rotary and scanning joints or equivalent kinematic. Depending on the center of the cylinder and the lengths of the robot links, three cases must be considered:

- 1) The cylinder can be reached by the first moving part of the manipulator
- 2) The cylinder can be reached with the second moving member of the manipulator
- 3) The cylinder cannot be secured with the manipulator.

In the first case, starting from the first link, the tangential plane is determined in which the second link l_2 must lie. The rotation in the first joint is selected in such a way that the second link is at the level of the specified position. Based on the position of the second link, the tangential plane for the third link can now be determined. This is aligned orthogonally to the longitudinal axis of the body. The position of the last link follows analogously.

In the second case, the position of the last link is determined first. Based on its length and a safety area at the end of the link, which must not be used for holding, the position of the third link can be determined. It is taken into account that links 3 and 4 should be applied symmetrically to the body so that the forces are distributed equally on both sides. This also results in the tangential plane in which link 3 must lie. The position of joint 2 is now determined so that this condition is fulfilled. This is also shown in Figure 2.

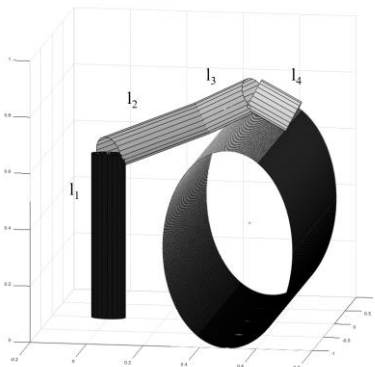


Figure 2: Schematic of the manipulator holding the elliptical cylinder, with its links $l_1 - l_4$.

In the third and last case, it is not possible to calculate the robot pose.

III. Results and discussion

Laboratory experiments were performed using a patient simulator, a Franka Emika Panda model manipulator, and an Intel RealSense D435 3D camera.

The results for the modeling of the patient's body show that in the area of the upper body, over 90% of the surface of the body lies on the elliptical cylinder. Thus, this model is considered suitable.

The developed algorithm for the WAM of such a body produces valid results. The robot can hold a patient in a

resulting configuration, as also shown in Figure 3. This algorithm can also be used to evaluate where, from a technical point of view, the manipulator must be placed next to the body to realize as many different holding points as possible. This investigation showed that a distance of 0.35 m is optimal and that the robot base should be 0.45 m below the center of the body (based on the dimensions of the Franka Emika Panda). These distances are readily achievable when mounting a robot next to a patient bed. The developed algorithm is thus shown to be suitable for the intended purpose.



Figure 3: Robot holding a patient simulator

IV. Conclusions

In this work, we propose a concept for the relief of nurses through the use of robotics. With the help of WAM, a patient can be held in a lateral position. The location of the caging is determined by a remote nurse. A suitable interaction concept was developed for this purpose. Our simplification of the human being to an elliptical cylinder is appropriate. We have shown in a proof of concept that the proposed system works. In future work, we will present the algorithm in more detail and develop it further, as well as evaluate it with nurses.

AUTHOR'S STATEMENT

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