Robotic Manipulation to Assist Tetraplegics in a Powered Wheelchair During Activities of Daily Living

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Introduction

People with tetraplegia are restricted in numerous ways during activities of daily living due to their upper limb impairments. Picking up a glass of water from a table and drinking out of it may already represent an impossible task. This thesis is embedded in a BFH project that aims at enhancing tetraplegics' independence with an intelligent assistive robot arm. For this, a robot arm with a camera for object recognition is mounted onto the side of an electrical driven wheelchair. Unlike existing concepts, the pilot (i.e. the person driving the wheelchair) does not have to move the robot manually with a joystick but the robot arm will execute the desired tasks, e.g. picking up a glass of water, autonomously.

Materials and Methods

This thesis consists of two parts: a mechanical and a software engineering part.
First, it is essential that the robot arm is securely attached to the wheelchair. However, in certain scenarios of daily life it would be preferable to have the robot in a stored position or even dismounted from the wheelchair. This required the design of a mechanical quick-mount solution.

Fig. 1 Kinova Gen3 robot arm (1) mounted with the new construction (2) to a Permobil M3 wheelchair (3).

Second, the robot arm must avoid all collisions with the pilot or with any obstacle in the environment. This refers not only to the robot's end-effector but to the complete robot's body. Therefore, a robot controller was developed that can plan a collision free path in advance and can react to changes in the environment. The controller uses the concept of a Probabilistic Roadmap [1]. Thousands of nodes, locations where the robot does not collide with obstacles, are distributed randomly to the environment. To reach a desired goal pose, an optimal path along these nodes is searched. The controller was evaluated based on the quality of the executed path, the accuracy of reaching the goal pose and the time needed to find a solution.

Results

The developed quick-mount solution for the robot arm is compatible with most of the wheelchairs used in Switzerland. It allows the robot to be moved either into an *in-use* position at the front or a *stored* position at the rear of the wheelchair, and to be easily detached within seconds (Fig. 1).
The implemented robot controller demonstrated the ability to circumvent obstacles and, at the same time, to reach the desired goal poses with an accuracy better than 0.4 mm and rotational error of less than 0.7° deg (Fig. 2). The average time to compute an optimal path is less than 1.4 s.

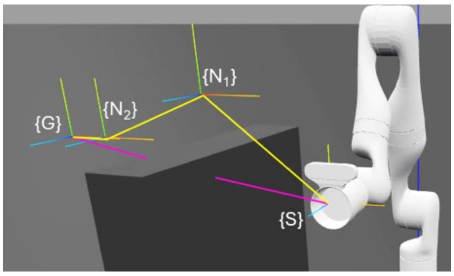

Fig. 2 Simulation of the Kinova Gen3 robot. The direct line (purple) between the start pose {S} and the desired goal pose {G} is blocked by a cupboard. The controller finds a collision free solution passing through nodes {N_1} and {N_2}.

Discussion

The developed controller enables operation in an obstructed workspace without the risk of collisions with the pilot or obstacles in the environment. The computation time of less than 2 s and the high degree of accuracy and precision reached will enable tetraplegic pilots to execute desired tasks, faster and easier than with existing systems.

References

[1] P. Leven and S. Hutchinson, "A framework for real-time path planning in changing environments," Int. J. of Rob. R., vol. 21, pp. 999-1030, 2002

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