Dynamics mimicking of wheelchair as a mobility enhancing platform

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Abstract

Traditional wheelchairs have high mobility on even terrain with reasonably high friction coefficients. However, obstacles such as a step, a snowy pavement, an unpaved lane, a staircase or even a steeply inclined surface, become hard or impossible to maneuver. Some solutions exist, most of them concentrate on alternative wheelchair designs. [1] presents a stair climbing wheelchair where each shaft has a triad of smaller wheels, which gives the chair bigger dimensions, compared to traditional wheelchairs. Another approach is taken in [2] where a chain and flippers are used to climb stairs. Smaller climbing wheelchairs such as presented in [3] can only climb a single stair, and [4] presents a climbing wheelchair wider than the traditional wheelchair.

The idea presented here does not offer a new wheelchair. Instead, a robotic platform with ability to overcome obstacles is selected. The existing wheelchair is mounted on top of the robotic platform through an interface unit. This way, the wheelchair user does not need to change wheelchair, and does not need to compromise on the high maneuverability of the traditional wheelchair when indoors. Since each wheelchair user has different physical limitations, and therefore different methods to drive their wheelchair, it is important to maintain the same input method between them and the robotic platform. A concept that maintains the input method of the wheelchair when controlling the carrier robot is presented here as dynamics mimicking. In essence, instead of reading the user input, the suggested platform reads the output of the user's actions and translates them into an appropriate command to the carrier robot. A pictorial representation of such a concept is portrayed in Fig. 1.

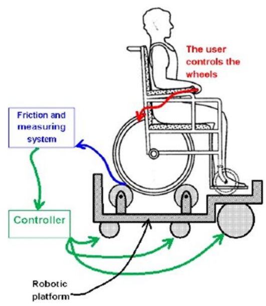

Figure 1: Basic concept of the dynamics mimicking platform

First, the dynamics mimicking system obtains the geometry of the wheelchair and creates its Jacobian. Next, the real-time desired motion of the wheelchair is measured. Thus, the platform performs some initial measurements, then it continuously reads the velocities of the two driving wheels of the wheelchair. Experimental results and simulations are presented for a realistic ideal case.

Kinematically speaking, the dynamics mimicking platform is converting the kinematics of the wheelchair to the kinematics of the robotic platform. This is done mathematically through a transformation matrix that combines the measured velocities of the wheelchair's wheels and the Jacobian of the robotic platform.

The wheelchair kinematics converting the right and left contact velocities of the wheelchair's wheels u_r and u_l to the wheelchair's forward speed u and angular speed ω is described using a Jacobian $[J_C]$

$$\vec{V}_C = [J_C]\vec{u}_C \tag{1}$$

where

$$\vec{V_C} = \begin{bmatrix} u \\ \omega \end{bmatrix}, and \quad \vec{u_C} = \begin{bmatrix} u_r \\ u_l \end{bmatrix} \tag{2}$$

Similarly, for the robotic platform,

$$\vec{V_R} = [J_R]\vec{\omega_R} \tag{3}$$

with corresponding definitions for the components of $\vec{V_R}$, and $\vec{\omega_R}$ holds the angular speeds of the robot's wheels. After some algebra, we have

$$\vec{\omega_R} = [J_R]^{-1}[J_C]\vec{u_C} = [J_{RC}]\vec{u_C} \tag{4}$$

thus, the multibody system's Jacobian is

$$[J_{RC}] = [J_R]^{-1}[J_C] \tag{5}$$

assuming the Jacobian of the robotic system $[J_R]$ is invertible.
The initial results show that for a simple system where there is a good correspondence between the workspaces of the wheelchair and the robotic platform, a good tracking is achieved, provided that the position of the centre of rotation of the wheelchair and the centre of rotation of the robotic platform align. Fig. 2 shows simulation predictions as well as experimental results for an example of trajectory tracking. On the left hand side, the centre of rotation of the wheelchair is not aligned with the centre of rotation of the robotic platform, which results in the two separate trajectories presented in the graph on top. In the middle of Fig. 2, one can observe that when there is perfect alignment between the centre of rotation of the wheelchair and the centre of rotation of the robotic platform, there is an excellent match between the expected trajectory of the wheelchair and the expected trajectory of the carrier robotic platform. The right hand side shows experimental results for the case with coinciding rotation centers which confirms the concept experimentally.

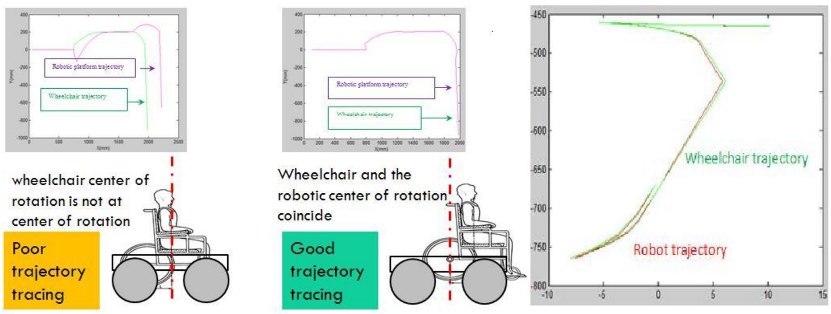

Figure 2: Simulation: Trajectory tracking with non-coinciding (left) and coinciding (middle) rotation centers, and Experimental results (right)

References

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