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Wheelchair Mobility A Novel Approach

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Abstract*:* This paper reviews how to build a accurate mobility enhancing device for wheelchair users. The basic idea is to mount the wheelchair on top of a device that is capable of required maneuvers. A major discussion for this mobility is to allow the wheelchair user to control the wheelchair carrying vehicle utilizing human machine interface (HMI) approach. To achieve this compatibility a dynamics mimicking device is build that interfaces between the wheelchair and the carrying vehicle. The surface device obtains the kinematics of the wheelchair as well as the desired motion and translates it for the command of carrying vehicle such that the carrying vehicle performs the desired action instead of the wheelchair. This review provide the reader to understand how the technology and science can be used to develop the assistive dynamics mimicking and serve as a platform for researcher to work on more complex scenarios.

Keywords: Wheelchair, Robotics, Maneuverability, Human Machine Interfacing (HMI).

I. INTRODUCTION

Autonomy in the area of mobility has always been highly valued but sometimes impaired by some form of disability. In many cases, these results are reliance on some form of external transport mechanism. When it comes to overcoming obstacles such as a step, low-friction surfaces such as a snowy pavement, a staircase or even a steeply inclined surface, they become hard to maneuver or even completely useless. Some solutions exist and most of them concentrate on devising alternative wheelchair designs. Recently, researchers choose a robotic platform with ability to overcome hurdles that can be selected.

The existing wheelchair is mounted on top of the robotic platform through an interface unit that would aid to drive the robotic platform. This way the wheelchair user does not need to change a wheelchair and does not need to compromise on the high maneuverability of the traditional wheelchair indoors to obtain best performance when there are obstacles to overcome[1]. One of the greater challenges introducing to this approach is the human machine interface (HMI). Since people who use wheelchairs are used to drive and navigate themselves in a custom tailored fashion, i.e. each wheelchair user has different physical disability and therefore, different methods to drive their wheelchair. It is essential to maintain the same HMI between them and the new robotic platform so that they would not be needed to learn a new way to operate the robotic platform, which, in some cases due to physical limitation may be impossible [2].

This paper suggests a way to maintain the HMI of the wheelchair when controlling the carrier robot through dynamics mimicking. Instead of reading the user input to the wheelchair, the suggested platform reads the output of the user's actions and translates them into an appropriate command to the carrier robot. To accomplish that, the dynamics mimicking system is required to gather information. Basically, the dynamics mimicking system needs to gather information about the kinematics of the particular wheelchair and build the Jacobian for the wheelchair. Once the system has the Jacobian of the wheelchair, it needs to gather the specific real-time desired motion of the wheelchair.

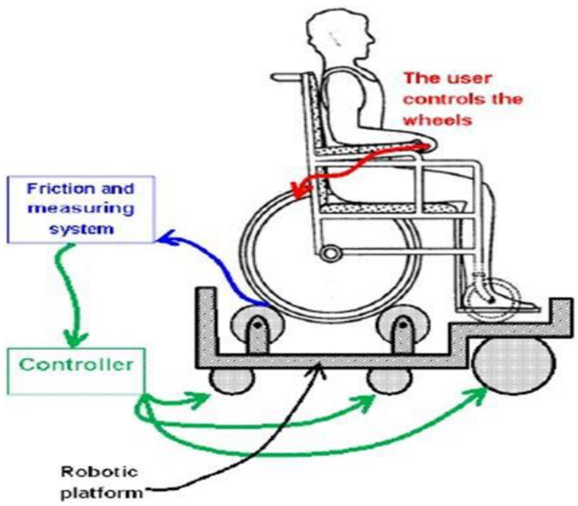

Fig.1. Basic concept of the dynamics mimicking platform

Thus, the dynamics mimicking platform performs some initial measurements that are performed once the wheelchair is mounted on the system and then continuously reads the actions of the wheelchair, namely, the velocities of the two driving wheels of the wheelchair[3].

II. MEASUREMENTS FOR KINEMATICS OF WHEELCHAIR

The first step was choosing the parameters that are required to obtain the information regarding the kinematics of the wheelchair. The basic assumption, supported by surveying the market state for traditional wheelchairs indicates that wheelchairs are controlled through the manipulation of two wheels controlled

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separately but with the same axis of rotation. Controlling the speed of each wheel separately allows us in controlling the speed and direction of motion of the wheelchair[4]. A typical wheelchair Jacobian looks as:

$$\begin{bmatrix} u \\ \omega \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{1}{d} & -\frac{1}{d} \end{bmatrix} \begin{bmatrix} u_r \\ u_l \end{bmatrix}$$

Where, u is the forward speed of the wheelchair's centre of mass, w is the forward wheelchair's angular velocity, u_r is the forward velocity of the right hand side wheel, u_l is the forward velocity of the left hand side wheel, and d is the distance between the driving wheels. It is crystal clear then that the parameters that need to be measured for the construction of the Jacobian of the wheelchair are constant. d, the distance between the left and right wheel of the wheelchair, which may be measured once when the chair is mounted on the system. In addition, the two forward velocities of the driving wheels, ur and ul are needed to calculate the motion of the wheelchair

A. Distance between Driving Wheels

The distance between the driving wheels is measured by keeping a linear array of touch resistive sensors. Such sensors are affected by pressure. Each component is a small circuit and after pressing upon one, it closes an electric circuit, which results in a logical '0' or '1' output. By knowing the location of each and every component, the distance between the two driving wheels can be measured. If the system is dedicated to a specific user, this information is entered manually and save the measuring system.

B. Driving Wheels with Forward Velocities

The forward velocities ur and ul are measured with the help of encoders located at the free-rolling cylinders for each driving wheel. Since, the radii of the rollers is known, these velocities are simply obtained using the basic relation:

$$u_r = r\dot{\theta}_r$$

$$u_l = r\dot{\theta}_l$$

Where, r is the radius of the rollers, ϴr is the measured angular velocity of the right hand side roller, and ϴ list the measured angular velocity of the left hand side roller.

The first two measurements allows to obtain the Jacobian of the wheelchair, whereas the encoders give the real-time input from the user, using the output of the wheelchair, thus allowing to pass the user input to the carrier robot without changing the HMI and the user experience or learning to use a new input device[5].

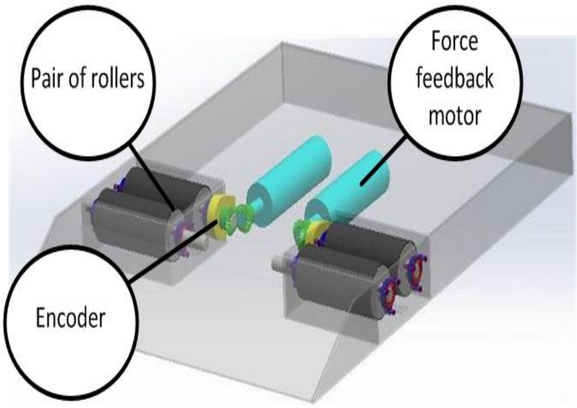

Fig. 2. Dynamics mimicking system

III. EXPERIMENTAL VALIDATION DONE BY (AVI WEISS ET.AL)

The system described in previous sections was designed, constructed, and experimental validation performed. The experimental setup was constructed with dynamics mimicking in mind instead of overcoming obstacles. Since, the idea of controlling the robotic platform through the wheelchair output is the challenge which is under question. Thus, instead of mounting the wheelchair and dynamics mimicking platform on top of a robotic platform, we have differentiated the two and constructed a stationary dynamics mimicking platform where the wheelchair is mounted, which communicates wirelessly with a small mobile robot that is performing the desired motion. The desired motion of the wheelchair is determined using encoders on the driving wheels of the wheelchair and the motion of the robotic platform is measured using a high-speed camera mounted on the ceiling of the room. The basic setup of the system is shown in Figure 3.Kinematically; the dynamics mimicking platform is transforming the kinematics of the wheelchair to the kinematics of the robotic platform. It is done mathematically with the help of a transformation matrix that combines the measured velocities of the wheelchair's wheels and the Jacobian of the robotic platform.

If the wheelchair kinematics is expressed using a Jacobian [Jc] .

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

Where

$$\vec{V}_C = \begin{bmatrix} u \\ \omega \end{bmatrix}$$

and

$$\vec{u}_C = \begin{bmatrix} u_r \\ u_l \end{bmatrix}$$

for the wheelchair, and similarly, for the robotic platform

$$\vec{V}_R = [J_R]\vec{\omega}_R$$

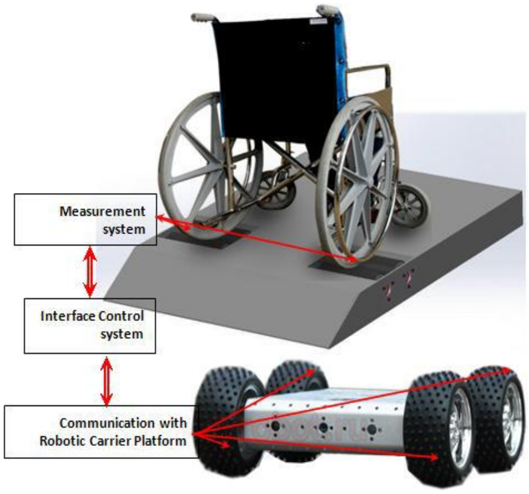

Fig.3. Basic setup of Wheelchair

with corresponding definitions for the components of $\vec{V}_R$ ~VR and $\vec{\omega}_R$ we have

$$\vec{\omega}_R = [J_R]^{-1}[J_C]\vec{u}_C$$

or:

$$\vec{\omega}_R = [J_{RC}]\vec{u}_C$$

Where

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

This is true only if the Jacobian of the robotic system $[J_R]$ is invertible. For the purpose of verifying the concept, a suitable robotic system was selected to accommodate the mathematical convenience presented above [6-8].

IV. CONCLUSION

For basic system, good tracking is gained by providing a perfect position to the centre of rotation of the wheelchair and the centre of rotation of the robotic platform align. It has been analyzed that the experimental results of Avi Weiss et. al validate and when the trajectories are very close together. Future research on the project goes in two main directions. First is to obtained the effects of deviation from the ideal case on the performance of the platform and second its ability to track the one hand and its inverse. This will show what maneuver should be performed to obtain good tracking for a given deviation from the ideal

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