TASK: PM-2 ADVANCED MECHANISMS

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Rationale

Powered wheelchair maneuverability is critically important to many people that need to maneuver their wheelchair in confined spaces. Most products today use the same control strategy that was used in the first powered wheelchair introduced by Everest and Jennings in the mid 1950s. It relies on the independent control of the two powered wheels, usually in the rear, and the free motion of pivoting front caster wheels. This task and PM6 are investigating alternate methods for enhancing wheelchair maneuverability by changing the fundamental manner is which the steering is accomplished. Application of successful findings to future products will increase the number of environments accessible to persons using these products.

The ability of a powered wheelchair user to maneuver in tight spaces is closely related to the chair's drive and steering configuration. The most common drive configuration, differential rear wheel drive, consists of fixed and driven rear wheels with front caster wheels. Direction changes are made by individually varying the speeds of the rear wheels. In this configuration the point about which the wheelchair pivots lies on the line perpendicular and running through the center of the rear wheels. The minimum turning radius is achieved when the pivot point is directly between the rear wheels. The minimum space required to turn the wheelchair is then determined by the maximum distance from that point to any other point on the wheelchair. This is usually the front corner of the footrests or the user's feet (Figure 5).

To minimize the turning radius for the rear wheel differential drive configuration, the point between the rear wheels must be located as close to the geometric center of the chair as possible. Several commercially available power chairs have achieved reduced turning radius using this approach. Another benefit of this approach is that a larger portion of the total weight of the wheelchair is born by the drive wheels and less by the caster wheels. The more weight there is on the caster wheels, the more difficult it becomes to change directions when caster wheels must reverse directions and rotate through 180°. The approach, however, causes the designer to take extraordinary steps to provide stability. Typically, stability is achieved by counter balancing the user's mass over and in front of the main drive wheels with the center of mass of the batteries located approximately at or just rear of the axis of the main drive wheels. It is often necessary to provide anti-tip wheels in the rear of the chair to avoid tipping backwards while accelerating forward. The addition of these extra wheels may compromise the chairs ability to climb over low obstacles if the wheels are small or close to the ground.

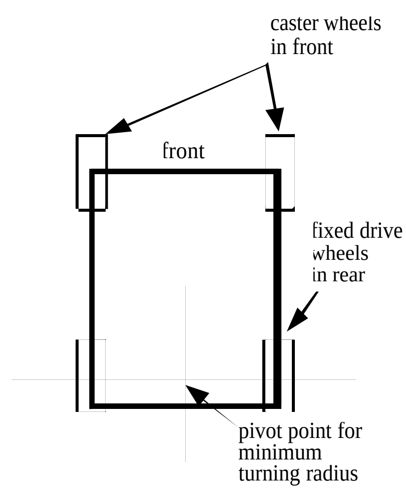

Figure 5 - Rear wheel differential drive configuration

Methods Summary

An alternate approach to minimizing the turning radius is to steer all four wheels. Steering all four wheels avoids the problems associated with caster wheels yet retains minimum turning radius, maximizes stability, provides tracking of the front and rear wheels along the same path, and provides for enhanced obstacle climbing capability.

The challenge in designing a mechanical four-wheel steering mechanism is to design a device with the ability to turn each wheel through 180° while minimizing misalignment of the wheels. Steering linkages such as those used in automobiles owe their simple design to the relatively small turning angles required by that type of vehicle. For highly maneuverable small vehicles such as wheelchairs, the range of steering angle is much greater. Furthermore, the wheels must maintain proper alignment over the entire range of steering angles to avoid undesirable wheel scrubbing when the wheelchair turns. The wheels are properly aligned whenever the perpendicular bisectors of all four wheels intersect at a single point. In four wheel steering, this point lies on a line between the front and rear wheels running perpendicular to the fore-aft direction of the base. This is illustrated in Figure 6. In two wheel steering, the perpendicular bisectors of the front steered wheels intersect at a point along the line through the centers of the fixed rear wheels (Figure 5).

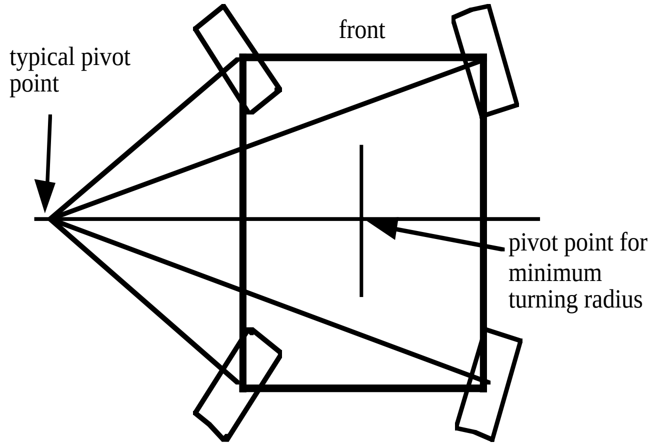

Figure 6 - Wheel alignment for four wheel steering about a single pivot point

Outcomes Summary

A photograph showing a section of the prototype steering linkage is shown in Figure 7.

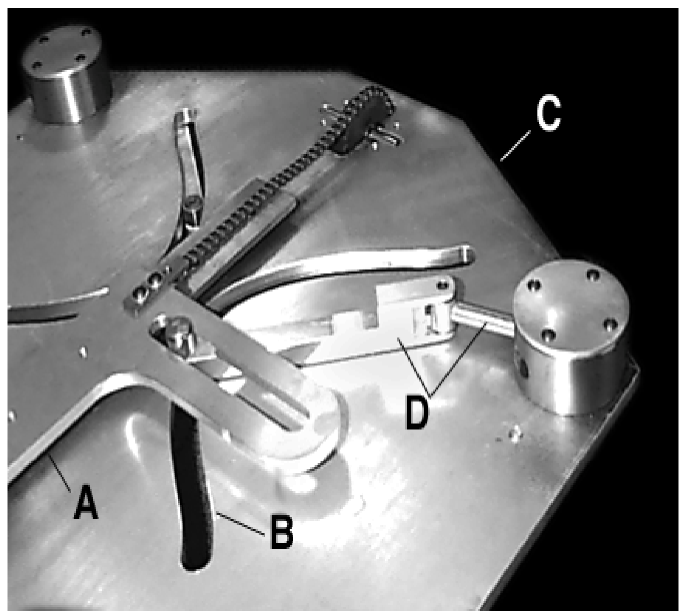

Figure 7 - The complete linkage consists of two sliding members (A), four cam follower slots (B) cut into a flat plate (C), and two links (D) for each wheel.

A working platform that can demonstrate the potential of the four-wheel drive configuration was completed but the testing remains to be completed.

Recommended Future Research and Development

Future research and development should begin by investigating the control issues concerning the operation of a four wheel steered wheelchair. The use of four wheel steering in the wheelchair application introduces a dilemma for the control of that vehicle. Optimum performance is likely attained when the wheels can be left at arbitrary, but a known, steering angle while the wheelchair is idle. Under these conditions the driver knows which direction the chair will initially go and there is no delay in initiating a move. However, to make the direction of the wheels known to the driver while the chair is at rest requires the driver to observe the direction using a visual inspection of the wheels or the direction information must be provided using some other feedback mechanism. Three options come to mind: 1) a visual display on the controller panel; 2) tactile feedback through the control stick using a rotation about either the unused vertical axis or a rotation about the steering axis; 3) no feedback at all. Although no solution is ideal, a rotation of the stick seems more desirable from the users perspective because it will not require the driver to read a display, thereby diverting his or her attention away from the surrounding environment. The rotation option is likely more complex and expensive to implement. The third option, no feedback at all, will require the driver to sense the wheel direction by sensing the direction of travel once motion is initiated; this option is likely to be problematic in confined spaces where the chair is close to obstacles.

The other alternative for control of the vehicle is to program the controller to self-center the wheels each time the chair stops. This solution is also less than ideal. In this configuration, there will be a delay between the time when the user steers the wheels and when the chair is able to travel in the desired direction. If there is no direction feedback for the wheels, the user is required to perform a visual inspection of the wheel direction or sense the direction after initiating a move by observing the direction of travel.

Publications

Brienza, DM and Brubaker, CE. A four-wheel steering mechanism for short wheelbase vehicles. *Proceedings RESNA Annual Conference*, Pittsburgh, PA, June 1997

Brienza DM and Brubaker CE. A steering linkage for short wheelbase vehicles:Design and evaluation in a wheelchair power base. *Journal of Rehabilitation Res & Dev*.1999;36(1)

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