HCARD Project idea

Motorised wheelchair conversion

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My project idea consists of an attachment for non-motorized wheelchairs to allow directional operation by the user without the manual pushing of the drive wheels. This principally serves as a workspace augmentation tool by enabling users to access a broader range of environments with more ease and with less physical exertion. This inherently also incorporates aspects of power augmentation by reducing the manual effort required for mobility.
While this device only becomes assistive in nature when paired with an existing assistive technology, I believe it to be a valuable addition to the assistive landscape as there are approximately 1.2million people with impaired mobility in the UK [1], 64% of those own a normal wheelchair whereas only 12% own a motorized one [2], likely due to financial accessibility. This project idea brings a low-cost solution to an oversaturated market, increasing the capacity of mobility to those who cannot afford the alternative, and to those who do not have the ability to manually push an ordinary wheelchair, Providing greater independence and greater accessibility in both public and private spaces.

Implementation

Method of motorization

A friction drive would achieve the smallest form factor, with the highest level of compatibility as it can easily be installed to the existing wheels of any wheelchair, however the nature of friction brings increased wear and reduced motor efficiency therefore inefficient control, especially in wet conditions.
A belt drive like on a bicycle would allow for torque and speed adjustment but would be noisy and require too much maintenance for those with reduced mobility therefore not suitable. A transaxle drive would be suitable in terms of power and functionality, however not in cost or weight. Considering the above, I believe a direct drive hub motor would be the perfect application for this project, especially a repurposed e-scooter wheel as they are relatively lightweight, compact, does not require much care, and can easily be attached to several parts of an ordinary wheelchair. As they are designed for e-scooters, they will have a robust construction, capable of withstanding a range of outdoor terrains, and with enough torque to pull the combined weight of a user and wheelchair with proven reliability in electric scooter products.

Figure 1: Example of a Direct drive hub motor wheel

<u>Power and torque requirements</u>

Using the wheel in the image as a reference, it contains a 48V 500W motor and a diameter of 10 inches (0.254m) with a no-load RPM of 800 at the rated voltage.

The power supply's capacity to run this motor at full speed for one hour would be $500W/48V = 10.4A$ therefore 10.4Ah (Ampere hours). However using the equation :

$$Speed(km/h)=((Motor\ RPM*Wheel\ circumference)\ /\ 100*60)*Gear\ Ratio*Efficiency\ Factor$$

full power provides a theoretical speed of 38.3km/h, as an electric scooter only requires around 20% of this speed (8km/h) a battery with 48V and 10.4Ah would provide 5 hours of use at 8km/h. It is worth noting that these calculations are based on the no-load RPM, and that the real run time depends on the load, battery health, terrain, and motors power curve characteristics. Although we will continue in theory for this section.

Figure 2: Example of suitable 48V Battery

A 48V 1000W 36Ah lithium-ion battery would be capable of providing two wheels in parallel with enough power to run at 8km/h for a theoretical 17.3

hours. Such a battery would be of size: 240*68*45mm and a weight of 1.3kg meaning it could be easily hidden underneath the seat of the user, which also provides optimal positioning for a hidden design both for the power supply and connection to both motors while also not contributing much to the weight of the entire system.
With both wheels weighing 3.4kg each, the average MWC (manual wheelchair) weighing 14kg, the battery weighing 1.3kg, and a user at 80kg. The total weight considered for torque calculation is 102.1kg.
The weight in newtons would be:
$W = m * g,\ 102.1 \times 9.81 = 1001.6\ N$
The force Fr due to rolling resistance with a coefficient of 0.01 would be:
$F = Fr * W,\ 0.01 * 1001.6 = 10.02\ N$
Therefore the torque required would be:
$T = F * r,\ 10.02 * 0.254 = 2.54\ Nm$
And as there are two wheels, each motor would need to provide a minimum of 1.27 Nm each.

Control methods

The control interface could consist of a handlebar for directional control and triggers or rotating handles for speed and reversing, such a design would be obstructive for the user as its placement means that it would have to be removed and reattached whenever the user enters or exits the seat, meaning they would likely require external help and therefore a reduction in independence and accessibility. The choice of two wheels with differential control leaves the front of the wheelchair as accessible as an ordinary one. However as the control interface and directional control are then separated, the system must include differential control of the two motors to ensure smooth turning with pivot joints above each wheel. The control methods could be adjusted depending on the user's specific requirements. For those with wrist and hand mobility, a joystick can provide an intuitive control with appropriate sensitivity for tight spaces, these can also be accommodated for use with limited strength or dexterity. Younger audiences may prefer a touchpad or smartphone application that provides similar levels of control. Or for those with extremely limited mobility, the wheelchair may be controlled through a sip-and-puff straw device, voice control, or head/eye tracking.

Attachment method

Figure 3 : Motorised MWC system

A 3d printed set of forks must be designed to allow the replacement of the ordinary caster wheels with the motorized direct drive wheels. This 3D-printed attachment must obstruct the existing pivot joint of the wheelchair to ensure the wheels are always pointing forward as the directional control will be operated through a differential drive. The diagram displays red lines and a translucent battery to depict how the power supply and connection between the control interface and motors can be hidden.

[1] Right chair right time right now. (n.d.). Available at: https://www.england.nhs.uk/improvement-hub/wp-content/uploads/sites/44/2017/11/My-Wheelchair-My-Life-eDigest.pdf.
[2] Reference Wheelchair Research Full report Specialist Professional & Technical Services 2 (SPaTS 2). (n.d.). Available at: https://assets.publishing.service.gov.uk/media/6230946ce90e070ed04a1d6f/reference-wheelchair-report.pdf.