Geometric Analysis of Wheelchairs Compared to Universal Docking Interface Geometry

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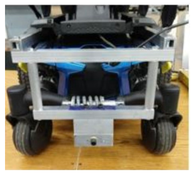
INTRODUCTION

As transportation continues to evolve and the rise of autonomous vehicles is imminent, adjustments need to be made in this industry to accommodate people who must remain seated in their wheelchairs during travel. This project supports work to create a wheelchair securement system that allows wheelchair users to secure their wheelchairs to the vehicle independently so they can ride alone in autonomous vehicles (AVs), which are vehicles without drivers who could assist these passengers.

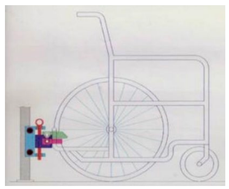
This project evaluates how wheelchair attachments meeting a Universal Docking Interface Geometry (UDIG) could be installed on different wheelchairs to allow securement with a compatible vehicle anchor. UDIG describes the docking interface shape and location.

UDIG Attachments Consist of 2 cylinders 75mm long 22±1 mm diameter

Example UDIG Attachment on a Wheelchair



UDIG Docking and Anchor System Diagram



UDIG Research Timeline:

1

The UDIG was initially designed and tested decades ago (Hobson et al 2007, van Roosmalen et al. 2003, 2011) for use on large buses.

2

More recent research has evaluated UDIG systems in smaller vehicles like vans and minivans, expected to be similar size to future AVs (Klinich et al. 2021, 2022a, 2022b, 2022c).

3

The UDIG specifications are included in voluntary wheelchair crashworthiness standards developed by ISO and the Rehabilitation Engineering Society of North America (RESNA).

METHODS

To ensure the inclusivity of both power and manual wheelchair users, this research had to account for differences in these wheelchair types. Each scanned wheelchair was individually tested according to the methodology below to identify where the UDIG attachments could be located.

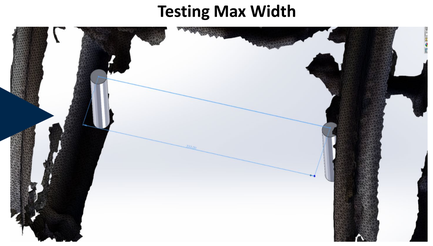
1. UDIG Attachments Assembled with Wheelchair Scan

First, we created CAD versions of the UDIG attachments, consisting of two 75 mm long cylinders with a 23 mm diameter. Each wheelchair scan was then imported into Solidworks CAD software and merged with the UDIG attachments.

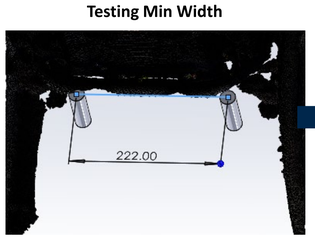
2. Minimum and Maximum Widths are Tested

The UDIG attachments were then placed in the narrowest and widest positions allowed by the specification and adjusted as far forward as possible without interfering with other wheelchair hardware, defined by a 2-cm clearance to other components. The fore-aft depth was recorded relative to the rearmost point of the wheelchair. Each of these measurements was done with the 3D sketch tool in Solidworks, which allowed for hypothetical placement of the attachments and recorded the location in millimeters.

Testing Max Width



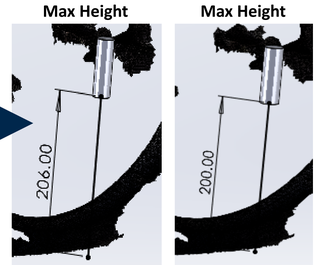
Testing Min Width



3. Minimum and Maximum Heights are Tested

Then, the minimum and maximum height constraints were tested to ensure the height requirement was fulfilled at the maximum fore-aft distance. Following this, the data were compiled in a Google spreadsheet containing all of the scans.

Max Height **Max Height**



RESULTS

63 manual wheelchairs and 25 power wheelchairs were evaluated during this study. This research identified a fore-aft zone where UDIG hardware could be located on a range of wheelchairs. On average, manual wheelchairs were easier and had significantly more space for the UDIG attachment, allowing for a larger and deeper distance for the placement of the UDIG attachment from the rearmost point of the wheelchair, shown in figure 2. The presence of batteries on the power chairs provided a barrier by taking up space under the wheelchair, which generally complicated and restricted the potential placement of the UDIG attachment to be closer to the rear footprint of the wheelchair. Every wheelchair that was scanned had three potential outcomes. Both widths could be supported at the same location on the wheelchair, the maximum width required a more rearward location than the minimum width (Figure 3), or the possible location could not be determined due to a blockage on the scan, such as a backpack.

Figure 2

Below displays and quantifies an instance of the manual wheelchair having a significantly larger maximum fore-aft distance than a power wheelchair.

Manual Wheelchair (606 mm fore-aft distance)

Power Wheelchair (41 mm fore-aft distance)

Figure 3

Below displays an instance of the fore-aft distance being greater with the minimum width compared to the maximum width due to width restrictions further toward the front of the wheelchair caused by the wheels

Minimum Width

vs.

Maximum Width

Figure 4

The graph below shows the maximum fore-aft distances possible for positioning UDIG attachments at the high location at the wide and narrow widths allowed by the specification. Manual wheelchairs generally allow more forward locations of UDIG compared to power wheelchairs.

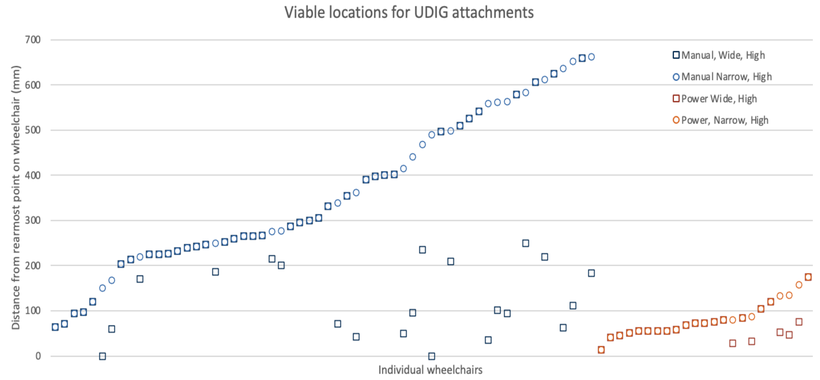


Figure 5

Examples of implementations of the UDIG attachments on wheelchairs.

DISCUSSION

In conclusion, these results will allow modification of the UDIG specifications to include a range of fore-aft locations for the hardware.

- The fore-aft locations for the manual chairs are significantly further forward than those of the power wheelchair, shown in figure 4. For about one-third of wheelchairs, the narrow width allowed a more forward placement of the attachments compared to the wider width, but it was the same for the remaining 2/3 of wheelchairs. Figure 3 displays the minimum width producing larger fore-aft distances amongst both types of wheelchairs when compared to the maximum width measurements.
- By identifying a zone that could work with both power and manual wheelchairs, it will identify the range of attachment locations that would need to be accommodated by the vehicle anchor hardware. This will allow placement of the UDIG attachments closer to the center of gravity on manual wheelchairs, making them easier to operate under other conditions besides travel.
- In addition, should this type of securement system be adopted for AVs, it could also be implemented in other transportation modes such as aircraft, transit, and rail, simplifying wheelchair users' lives in multiple areas of transportation.

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