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STS: Robotics and Virtual Worlds for wheelchair users - from ideas to reality: Innovation, Training, and Roadmap to Market (The ADAPT project)

Title of Paper:
Integrating ride dynamics measurements and user comfort assessment to smart robotic wheelchairs

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Background

Individuals relying on wheelchairs for mobility are subject to the risk of injury due to their exposure to whole-body vibrations for long periods of time as per ISO 2631-1. Our study evaluates the feasibility of integrating ride dynamics measurements (i.e. vertical accelerations) as expressions of user travel comfort assessment to smart robotic wheelchairs. This will also help to mitigate the injury risk caused by the continuous exposure to vibrations using real time electronic measurement systems in order to ensure that the wheelchair's movement dynamics (acceleration and speed) and the user's comfort is adapted to the surrounding environment, specifically the type of ground surface type, as per the ISO standard mentioned previously.

Method used

In this study, the INVACARE Spectra XTR2 electric wheelchair weighting 98 KGs was used in seven sidewalk surfaces around the School of Engineering and Digital Arts at the University of Kent [Coordinates 51.298463, 1.064410]. The wheelchair has been driven for around fifteen minutes by one of the authors of this study (body mass 88.6 kgs, 185 cm height) for a distance of 322 meters covering 7 different surfaces (Uneven Pavement Slab, Damaged Tarmac Road, Undamaged Tarmac Road, Pavement Bricks, Carpet Floor, Tiled Floor, and Inclined Concrete) at an average speed of 0.339 m/s.

One circuit board (designed by our research team), consisting a PIC microprocessor, and an MPU6050 Inertial Measurement Unit (IMU) was placed on the lower metal frame of the wheelchair (area without suspension) and another identical circuit board was placed on the seating's metal frame (area with suspension). Data was collected, filtered and stored on microSD cards and then processed using the MATLAB analysis software. In addition to the IMU unit, a VGA Camera has been used to record the terrain along the ride experiment, annotated by real time measurements using a Real Time Clock – RTC integrated on the original circuit board.

Key results

For each terrain type, the mean (m/s^2), standard deviation (m/s^2), minimum (m/s^2), and maximum (m/s^2) for the Z-axis values of the accelerometer have been calculated respectively along with the Maximum Transient Vibration Value (MTVV), which measures the maximum amplitude of the instantaneous frequency-weighted acceleration at the time of measurement, as an indicator of ride comfort:

With Suspension: Uneven Pavement Slab (9.8339, 0.2189 m/s^2, 7.8103 m/s^2, 13.4741 m/s^2, 0.5356 m/s^2);Damaged Tarmac Road (9.8351, 0.2064 m/s^2, 8.8573 m/s^2, 10.9237 m/s^2, 0.5973 m/s^2); Undamaged Tarmac Road (9.8494, 0.1535 m/s^2, 9.0149 m/s^2, 10.9918 m/s^2, 0.4609 m/s^2); Pavement Bricks (9.8236, 0.1874 m/s^2, 8.8973 m/s^2, 10.7429 m/s^2, 0.6757m/s^2); Carpet Floor (9.8472, 0.1308 m/s^2, 8.2468 m/s^2, 10.6184 m/s^2, 0.4952 m/s^2); Tiled Floor (9.8342, 0.1054 m/s^2, 8.9442 m/s^2, 10.6341 m/s^2, 0.7262 m/s^2); Inclined Concrete (9.4226, 0.3718 m/s^2, 6.0273 m/s^2, 11.1282 m/s^2, 0.5449 m/s^2)

Without Suspension: Uneven Pavement Slab (9.5142, 0.2557 m/s^2, 6.6824 m/s^2, 11.7307 m/s^2, 0.5271 m/s^2); Damaged Tarmac Road (9.8206, 0.0928 m/s^2, 9.4119 m/s^2, 10.2691 m/s^2, 0.5793 m/s^2); Undamaged Tarmac Road (9.8285, 0.1456 m/s^2, 8.7807 m/s^2, 10.6592 m/s^2, 0.4606 m/s^2); Pavement Bricks (9.8412, 0.0692 m/s^2, 8.7199 m/s^2, 10.4182 m/s^2, 0.6647m/s^2); Carpet Floor (9.8388, 0.0544 m/s^2, 9.4903 m/s^2, 10.1511 m/s^2, 0.4925 m/s^2); Tiled Floor (9.8360, 0.0655 m/s^2, 9.1849 m/s^2, 10.1051 m/s^2, 0.7271 m/s^2); Inclined Concrete (9.6943, 0.2659 m/s^2, 6.3085 m/s^2, 13.4636 m/s^2, 0.5606 m/s^2)

Conclusion

Our investigations clearly show that different kinds of terrain produce different levels and types of vibrations which are not properly mitigated by the usual wheelchair suspension systems (typically based on dual springs). This affects the user's ride comfort (as express by the corresponding MTVV measurements) and it should be considered in the design of the controller in the smart wheelchair design in order to improve the user's experience preserving his/her safety and wellbeing. Our electronic controller systems integrate these real-time measurements to a shared controlled assistive driving algorithm as part of the credit assignment function of a deep learning artificial intelligence training procedure. This leads to adjustments of the robotic smart wheelchair's speed and acceleration obtained from the shared (user-AI-based) controller to improve ride comfort levels.

Tweetable abstract

A real-time dynamics and ride comfort assessment system and its implementation is evaluated. We demonstrate its effectiveness by integrating its outputs in our smart robotic wheelchair shared control algorithm based on deep learning artificial intelligence training procedure.