Hand position detection during wheelchair propulsion with vision system

E. Ferlinghetti[(1)], T. Rietveld[(2)], M. Ghidelli[(3)], RJK Vegter[(2)], M. Lancini[(4)]
[(1)] DIMI, [(3)] DII, [(4)] DSMC, Università degli Studi di Brescia,
Via Branze, 38 - 25123 Brescia, Italy
[(2)] Center for Human Movement Sciences, University Medical Center Groningen,
Antonius Deusinglaan 1- 9713 AV, Groningen, The Netherlands
email: matteo.lancini@unibs.it

1. INTRODUCTION

In wheelchair propulsion shoulder injuries can be related to efficiency in propulsion (Boninger et al., 2000; Churton & Keogh, 2013). They even increase for wheelchair tennis athletes, discipline in which the (de)coupling of the hand with the handrim is made more difficult as a consequence of the presence of the racket in the hand. (Mayrhuber et al., 2022).
At the current state of art, efficiency in propulsion is assessed measuring power output, torque and speed through an ergometer. A derived measurand is the push time, defined as each period of continuous positive power. On the other side, ergometers don't provide any information regarding the pose of the hand and the contact with the handrim.
This project aims to track the hand in 3D space by means of two cameras placed on the right side and behind the participant, as showed in Figure 1.
The cameras can record both RGB images, on which hand detection algorithms, such as Mediapipe hand (Zhang et al., 2020), can be used to identify the hand by means of the identification of 21 landmarks, as shown in Figure 2, and DEPTH image, that can assess the distance of each object from the camera.

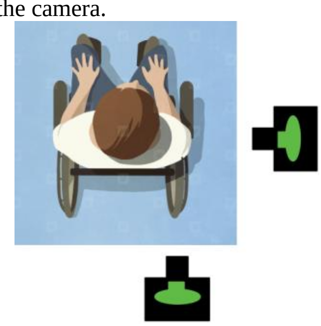

Figure 1: position of the two cameras

Figure 2: RGB image acquired by the camera placed on the right with hand landmarks detected by Mediapipe. The origin of the reference frame is placed in the centre of the wheel

2. AIM

The main relevant measurands describing hand (de)coupling are: the position and the trajectory of the hand, the initial and final contact angle (all of them expressed with respect to the reference frame placed in the centre of the wheel, as showed in Figure 2), the joint angles of the fingers during the pushing and the point of contact of the hand with the handrim.
Furthermore, differences in performances of the measurement system according to the situation in which the test is executed eg: the required speed that the participant should reach or whether the participant is holding the racket are investigated as well.

3. MATERIAL AND METHODS

Nineteen able-bodied non-wheelchair users performed a total of four submaximal tests (at 4 km/h and 5.4 km/h) of 1 minute and 30 seconds and two sprint tests of 10 seconds with and without holding a tennis racket. The tests were executed on a Esseda ergometer manufactured by Lode BV (Groningen, The Netherlands) recording the torque applied and the speed at a frequency of 100 Hz. RGB and DEPTH images were collected using Intel RealSense D435i cameras, manufactured by Intel (Santa Clara, United States) at a frequency of 60 Hz.
Through the camera placed on the right side of the participant, it is possible to recognize the hand. The hand detection algorithm gives the possibility to also assess the joint angles of each finger.

Through the camera placed behind the participant it is possible to determine the moment in which the hand and the handrim collide.

These information are synchronized with the ergometer data in order to understand at which angles is the max power is exerted, the contact and pushing phase starts and ends.

4. RESULTS

First of all, percentage of frames in which the hand was recognized are analyzed: as Figure 3 shows, the easiest condition for the algorithm is 4 km/h (condition 1) without racket (block NR), the hardest one is the sprint test (condition 3), either with the racket (the hand is holding the racket) or without the racket (the hand is moving fastest).

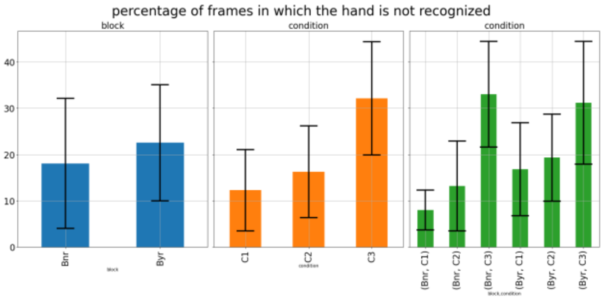

Figure 3: percentage of frames in which the hand is not recognized according to the test: block (the participant is holding or not a racket) and condition (the required speed is 4 km/h, 5.4 km/h or the maximal one)

Once the hand is detected, it's possible to compute its angle with respect to the centre of the wheel. Mediapipe hands estimates the 3D position of each landmark, allowing to measure the angle of each joint of the finger, as depicted in Figure 4.

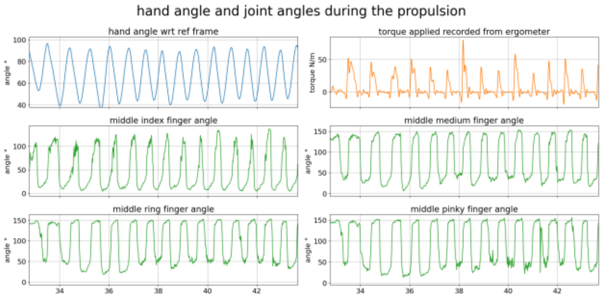

Figure 4: in blue, the angle of the hand with respect to the centre of the wheel. In orange, the torque applied during the propulsion. In green, the angles of four different fingers.

The start and the end of the contact is still under investigation.

REFERENCES

Boninger, M. L., Baldwin, M., Cooper, R. A., Koontz, A., & Chan, L. (2000). Manual wheelchair pushrim biomechanics and axle position. Archives of physical medicine and rehabilitation, 81(5), 608-613.

Churton, E., & Keogh, J. W. (2013). Constraints influencing sports wheelchair propulsion performance and injury risk. BMC sports science, medicine & rehabilitation, 5, 3. doi:10.1186/2052-1847-5-3

Mayrhuber, L., Rietveld, T., de Vries, W., van der Woude, L. H. V., de Groot, S., & Vegter, R. J. K. (2022). A Scoping Review on Shoulder Injuries of Wheelchair Tennis Players: Potential Risk-Factors and Musculoskeletal Adaptations. Frontiers in Rehabilitation Sciences, 3. doi:10.3389/fresc.2022.862233

Zhang, F., Bazarevsky, V., Vakunov, A., Tkachenka, A., Sung, G., Chang, C.-L., & Grundmann, M. (2020). Mediapipe hands: On-device real-time hand tracking. arXiv preprint arXiv:2006.10214.