Hand position detection during wheelchair propulsion with vision system

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Context

When assessing wheelchair propulsion performances, in particular limb trajectory in space, the presence of markers, commonly used, affects the movement, making it slightly unnatural. Moreover, due to their dimension, if neglectable for the shoulder, the elbow and the wrist, their presence on the hand makes their application even more difficult and bulky. Recently developed open-source skeletonization softwares, such as MediaPipe, are giving the possibility to execute marker-less detection in order to estimate upper limb and hand kinematics at an affordable cost. Furthermore, the use of 3D cameras improves the accuracy in estimating the trajectory in space.

Objective

Developing of a marker-less measurement system able to track the hand in 3D space, to evaluate fingers' angle and to detect when is the hand (de)coupling with the handrim for different blocks of exercise (Bnr = without racket, Byr = with racket, in blue) and at different speeds (C1 = 4 km/h, C2 = 5.4 km/h, C3 = sprint, in orange).

The figure below depicts the different percentage of frames in which the hand is not recognized according to the different test conditions.

percentage of frames in which the hand is not recognized
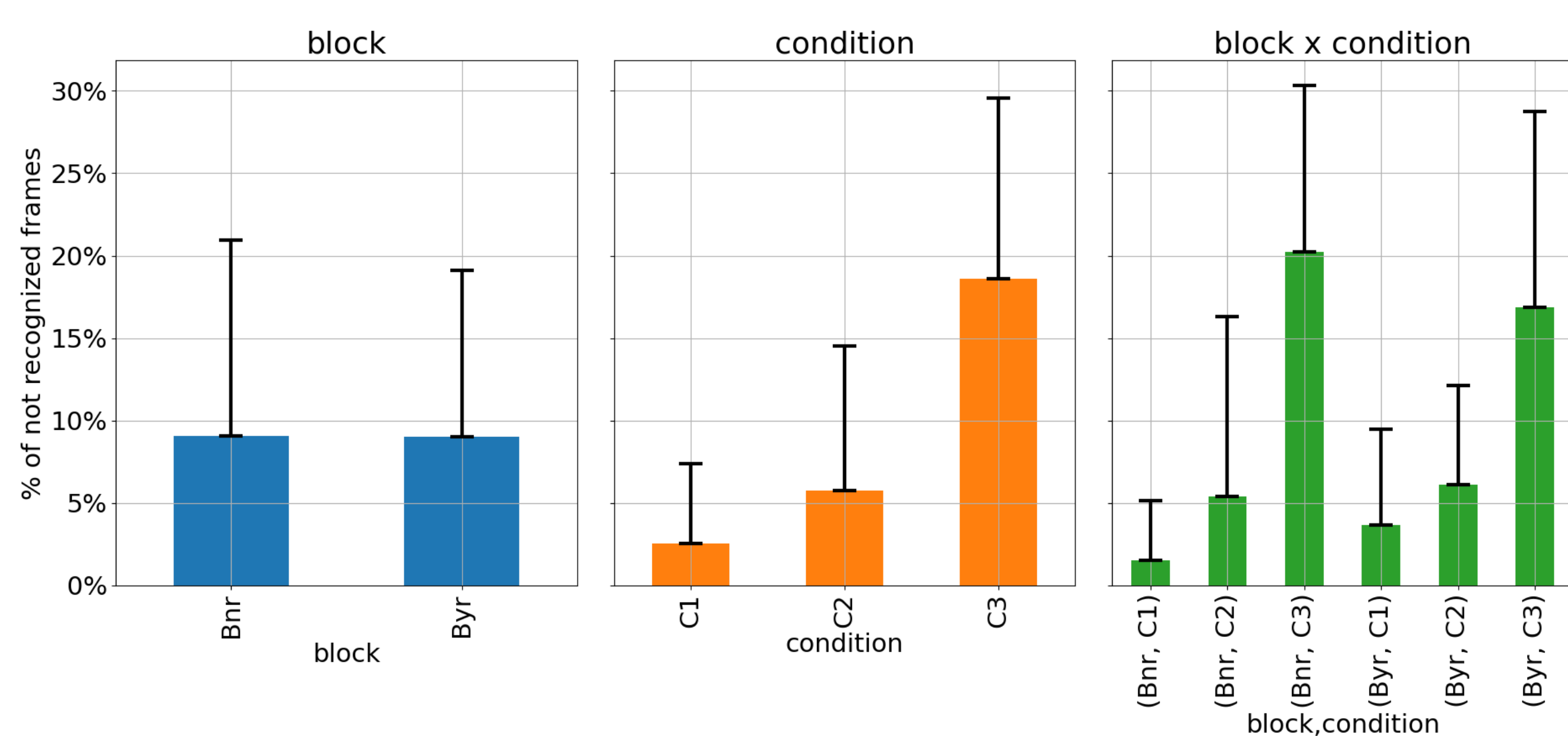
The Acquisition System

Images were collected using a Realsense D435i camera at a frequency of 60 Hz. Torques applied during the propulsion were registered by means of an Esseda Ergometer over which the participant with the wheelchair is placed.
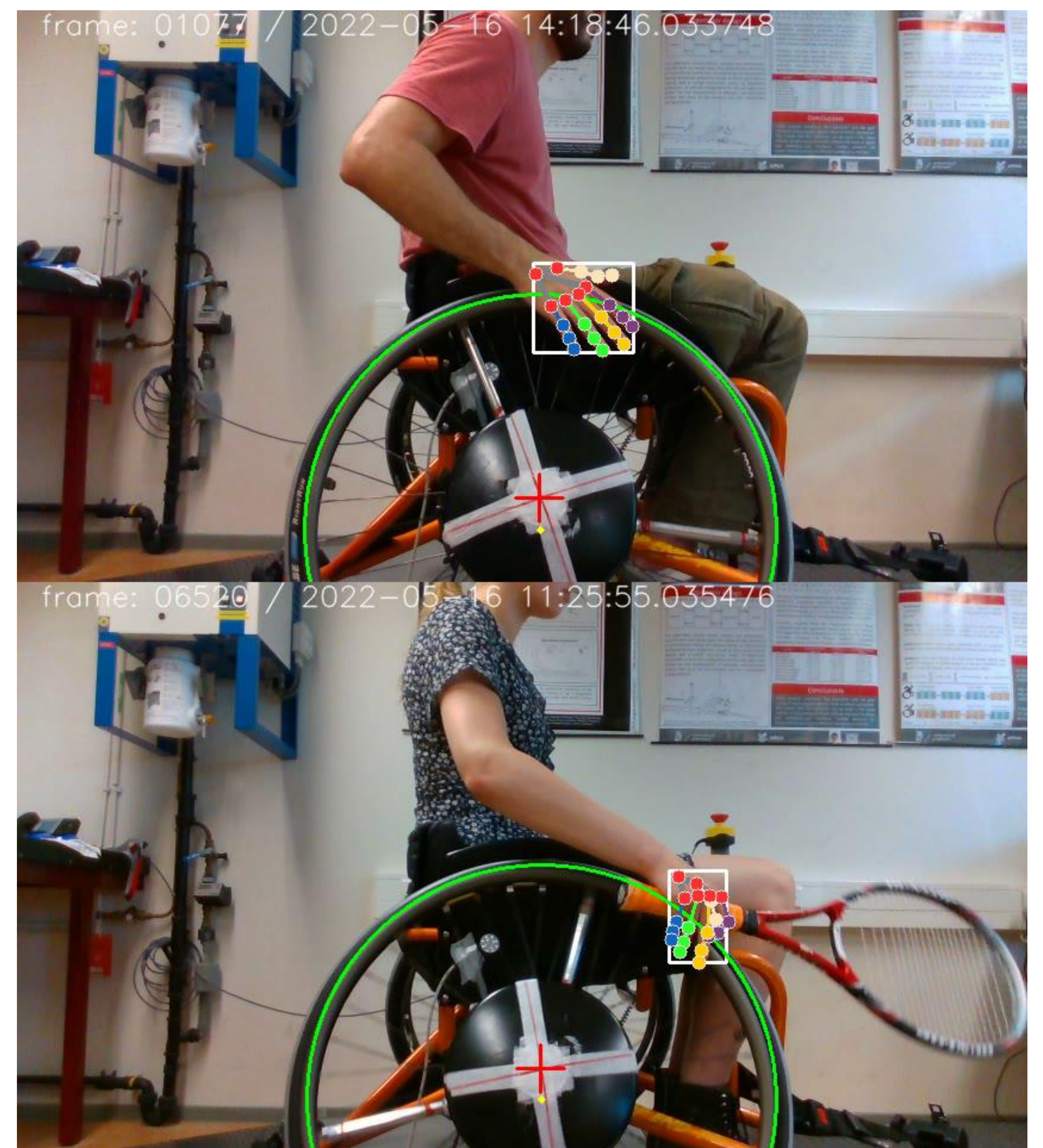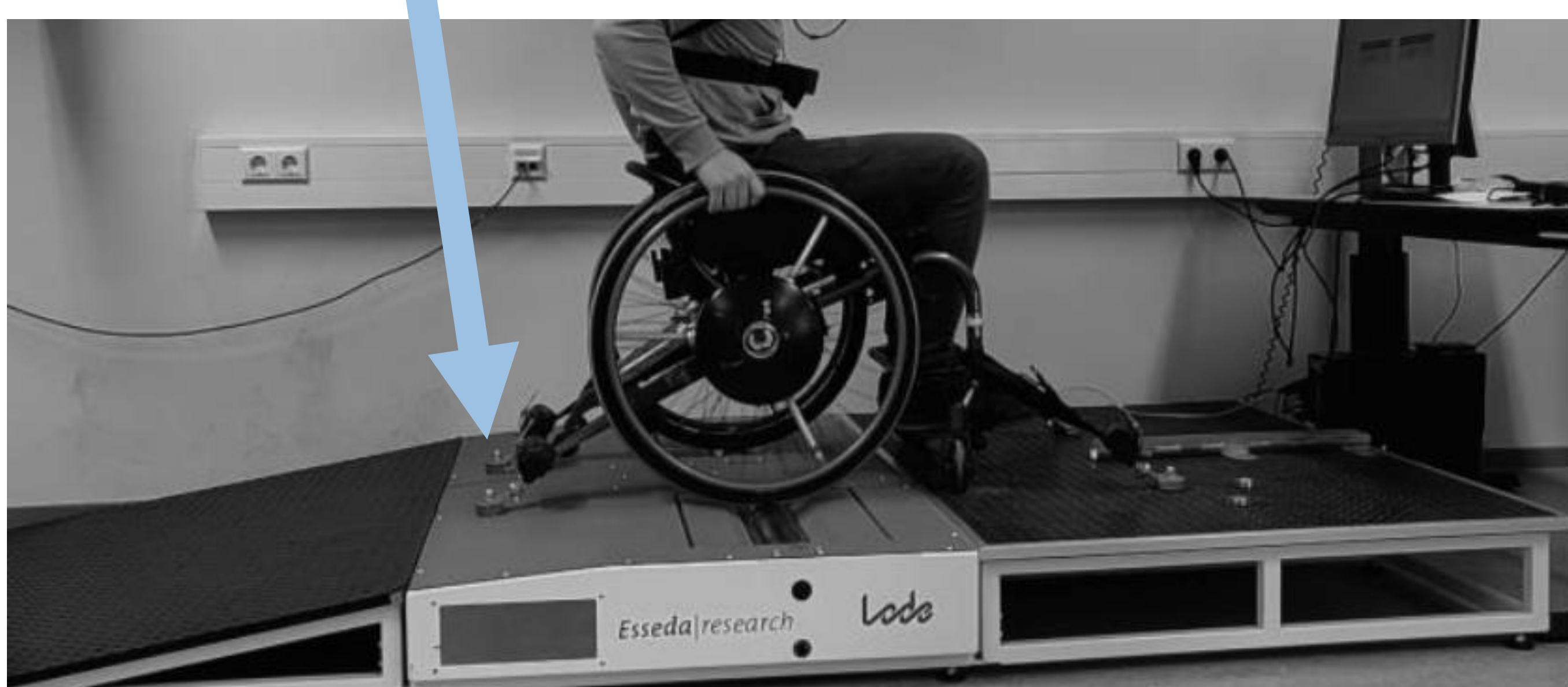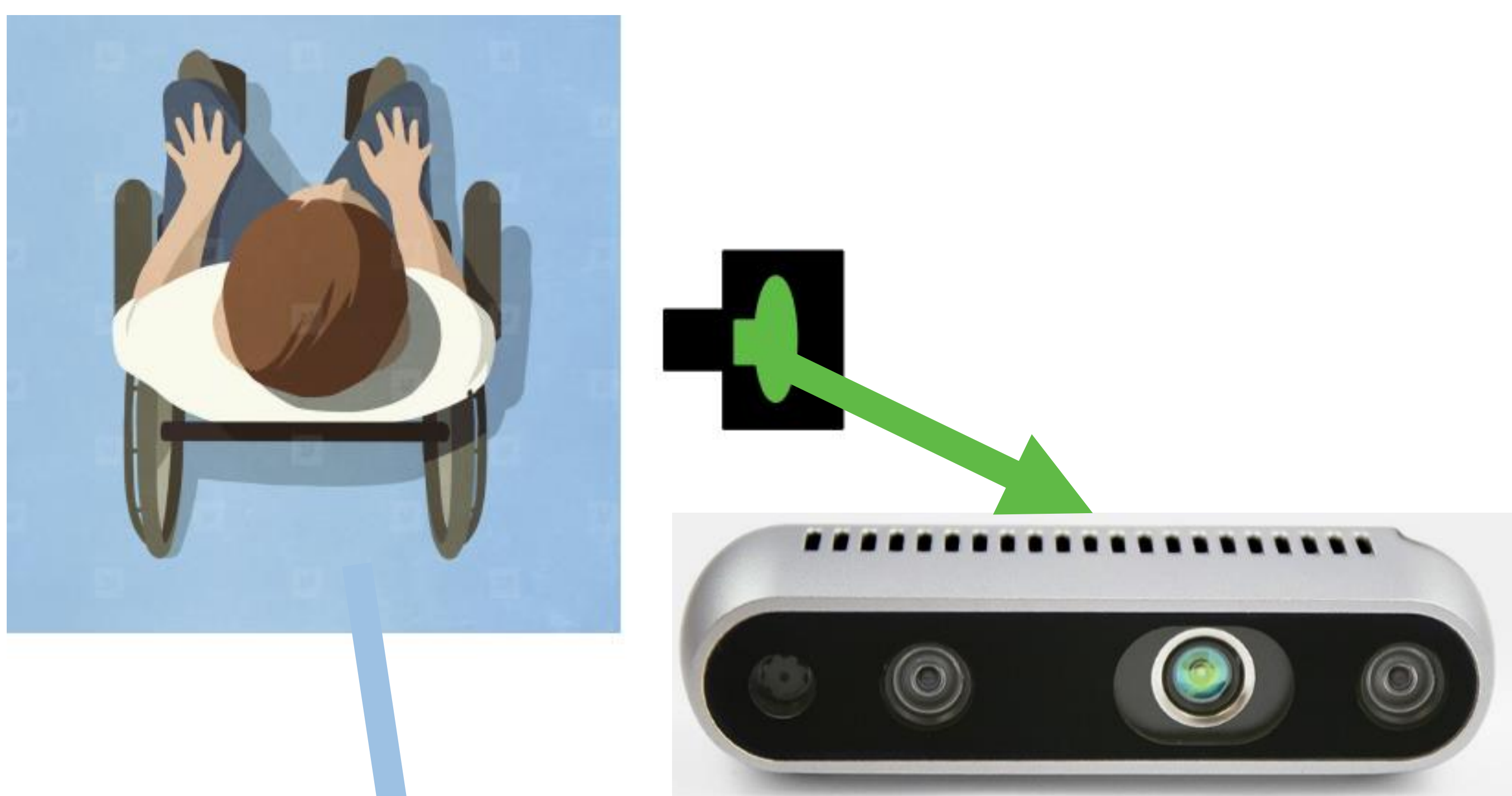
Results

Through the image analysis, the hand and its joints, the handrim and its centre are recognized. Furthermore, using the 3D image, it's possible to locate them in the 3D space.

The following image shows the torque applied collected by the ergometer [in green] and the fingers' angle [orange]. The blue areas depict the contact phase.

contact detected [blu area] with torque applied [green] and fingers' angle [orange]
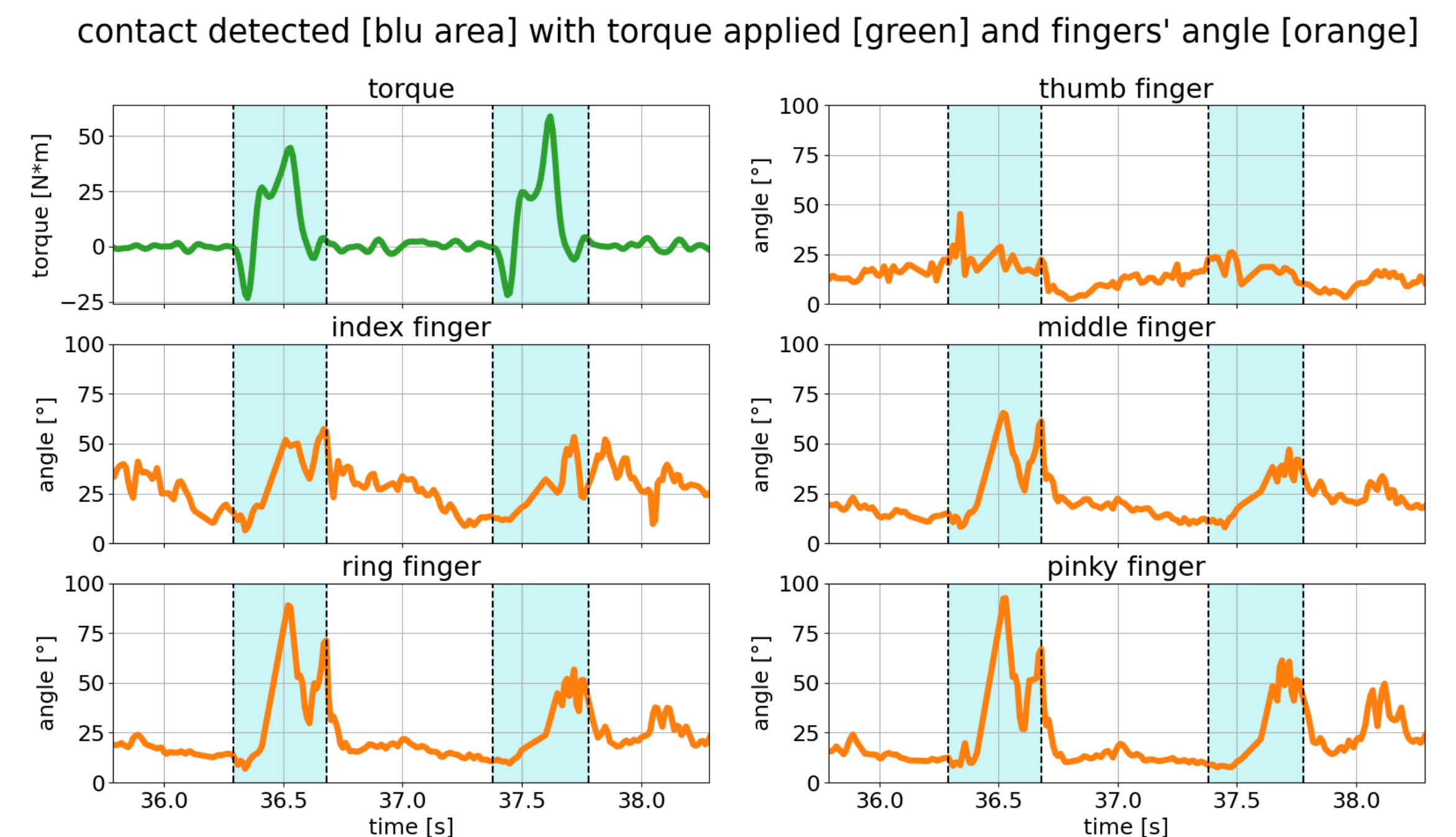
Conclusions

It's possible to detect the start and the end of the contact with the following mean errors and standard deviation (in ms)

condition		C1C2	C1C2	C3	C3
block		Bnr	Byr	Bnr	Byr
start	mean	1.9	-24	-26	-40
	std	121.4	132	76	140
end	mean	-20	16	53	30
	std	128	131	65	137
error in contact detection [ms]					