

Preliminary Experimental Results from the Paediatric Robotic Lower-Limb Exoskeleton

1. Results without Dummy

This section presents the angular position, velocity, and torque provided by each joint of the Lower-Limb Exoskeleton (LLE) when it is mounted on a frame, without using a dummy. Fig. 1 depicts the LLE as it is mounted on the frame.

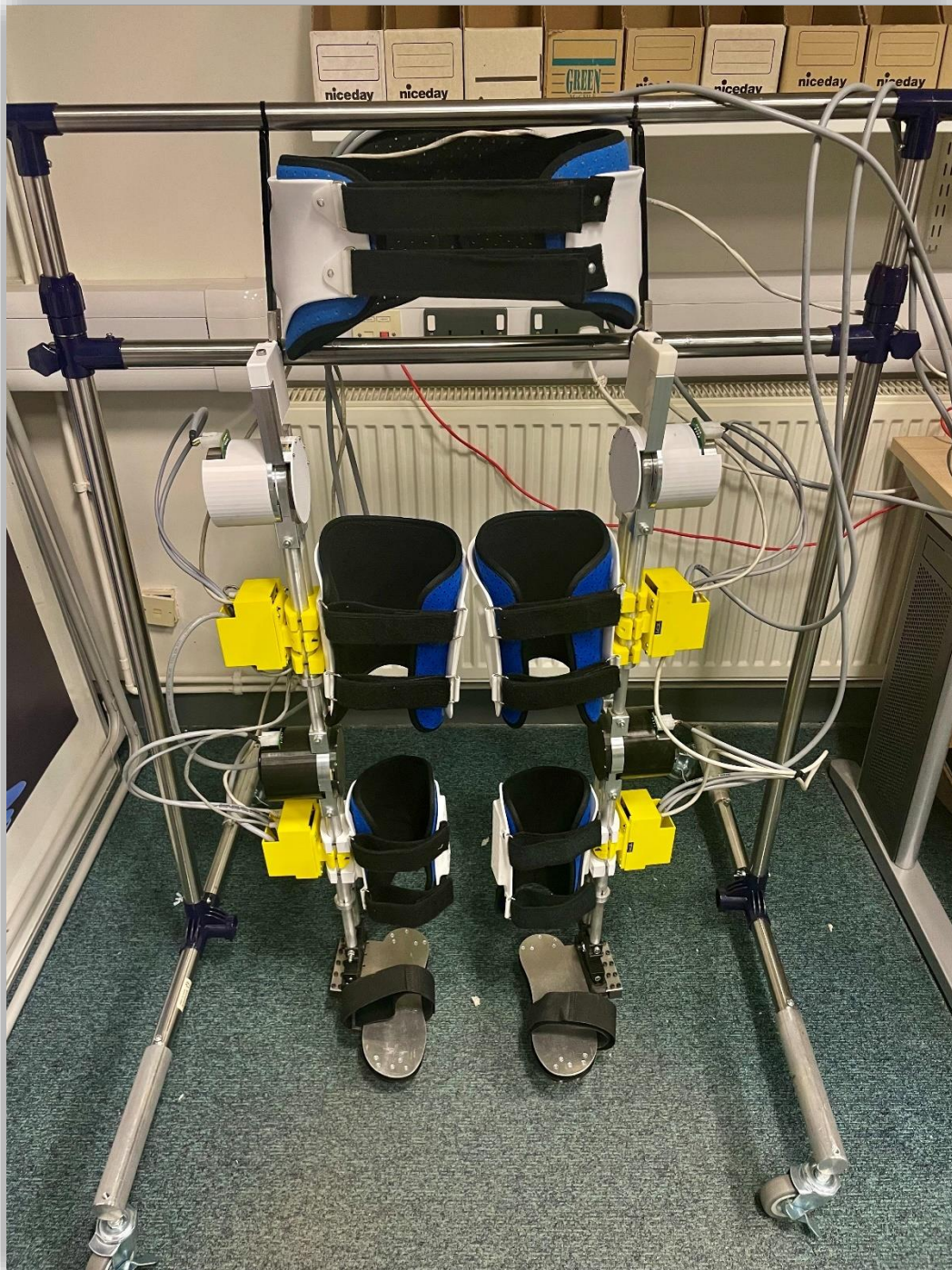


Fig.1. Frame-Mounted LLE without Dummy

Fig. 2 presents the desired and actual angular positions of the hip and knee joints for both the right and left legs of the LLE, which is attached to a frame without a dummy. The hip joints demonstrate a range of motion from $+20^\circ$ to -20° , while the knee joints vary between 0° and -50° . This figure effectively illustrates how the actual angular positions of the joints closely align with the desired angular positions. Given that the motors are configured in position control mode, it is anticipated that the actual positions will closely track the desired trajectories. Fig. 3 displays the angular velocities corresponding to the angular positions depicted in Fig. 2, for the LLE mounted on a frame without a dummy.

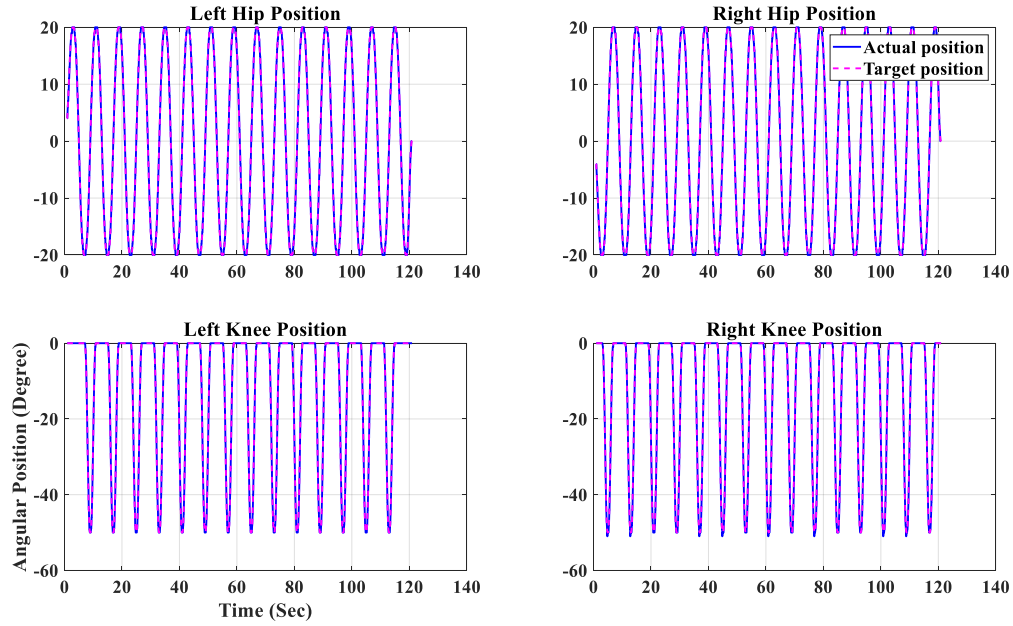


Fig.2. Desired and Actual Angular Positions of Each Joint for the Frame-Mounted LLE without a Dummy.

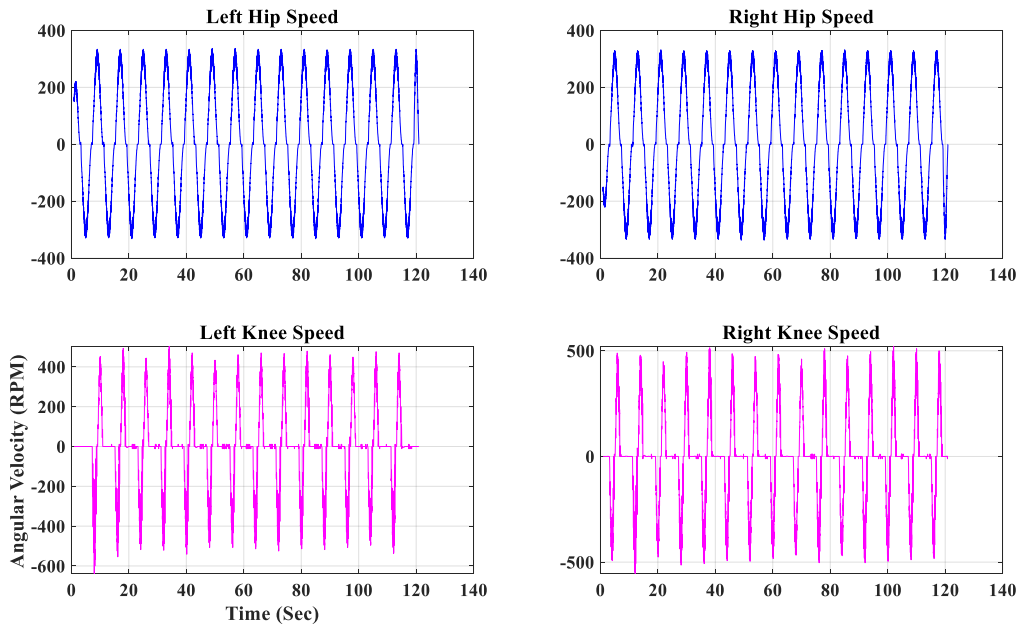


Fig.3. Angular Velocities of Each Joint for the Frame-Mounted LLE without a Dummy.

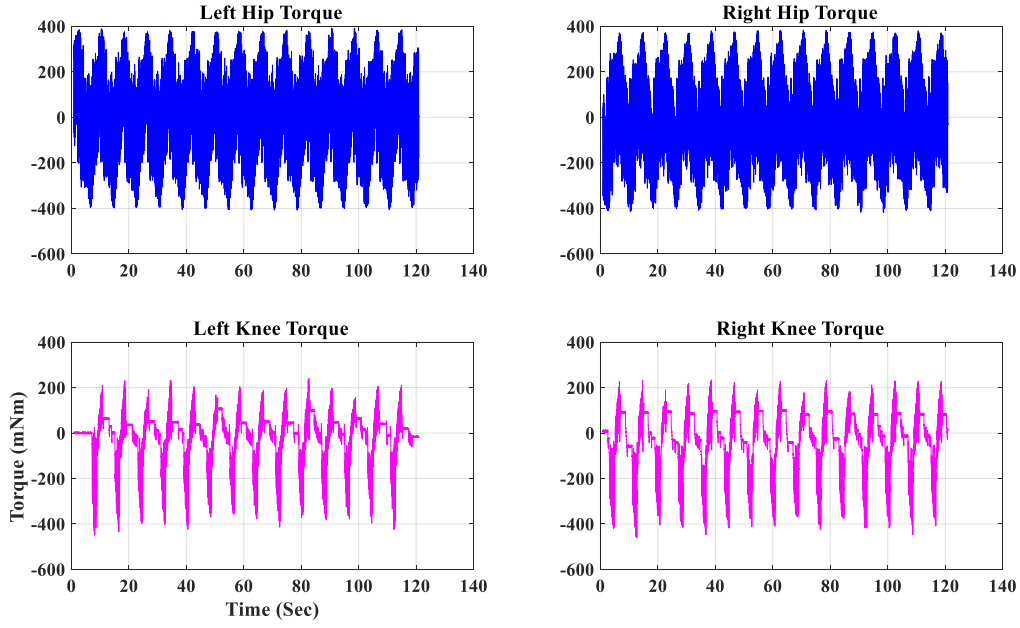


Fig.4. Generated Torques of Each Joint for the Frame-Mounted LLE without a Dummy.

Fig. 4 presents the generated torque values for the hip and knee joints for both legs of the frame-mounted LLE, depicted without the inclusion of a dummy. While hip torques vary between +400 mNm and -400 mNm, knee torques range from +200 mNm to -400 mNm. This stems from the trajectories of the hip and knee joints, where the hip's range of motion varies from +20° to -20°, and the knee joints range between 0° and -50°. Since the motors are set to position control mode, the actuators apply the necessary torques to ensure the motors follow the desired trajectories.

2. Results with Dummy

This section details the angular position, velocity, and torque generated by each joint of the LLE when mounted on a frame, including the use of a dummy. Figure 5 illustrates the LLE as mounted on the frame. Currently, due to funding constraints, we have utilized foam to fabricate a dummy for the system identification of the LLE with a passive user.



Fig.5. Frame-Mounted LLE with Dummy

Fig. 6 displays the desired and actual angular positions of each joint in the frame-mounted LLE with a dummy. The outcomes are akin to those in Figure 2, where the actual position precisely follows the desired trajectory, and the hip and knee exhibit a similar range of motion. Given that the motors are set to position control mode, different torque values were anticipated and observed. Fig. 7 shows the angular velocities corresponding to the angular positions presented in Fig. 6, for the LLE when mounted on a frame with a dummy.

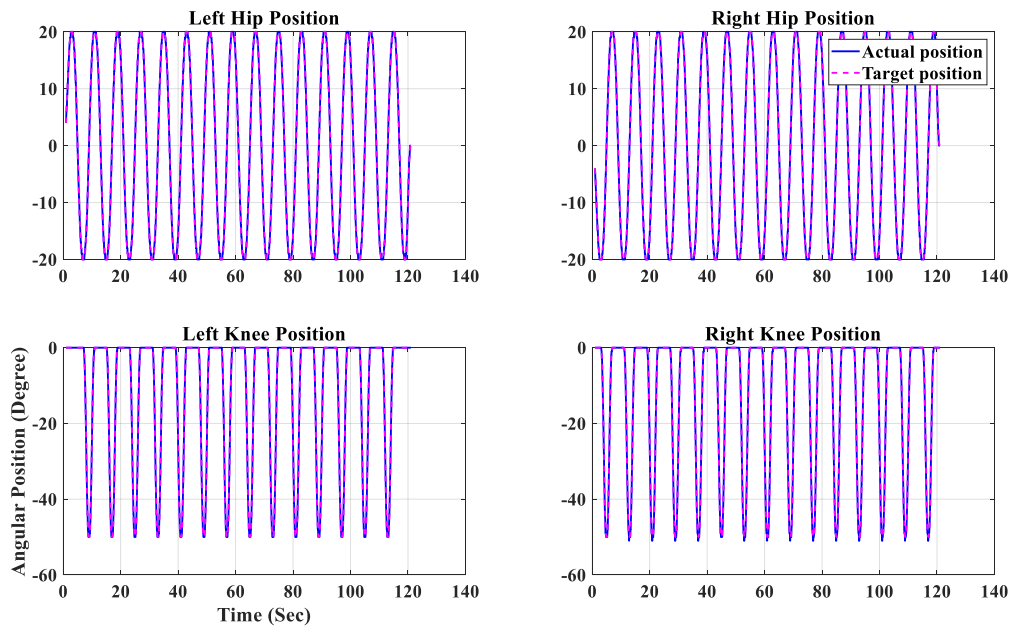


Fig.6. Desired and Actual Angular Positions of Each Joint for the Frame-Mounted LLE with a Dummy.

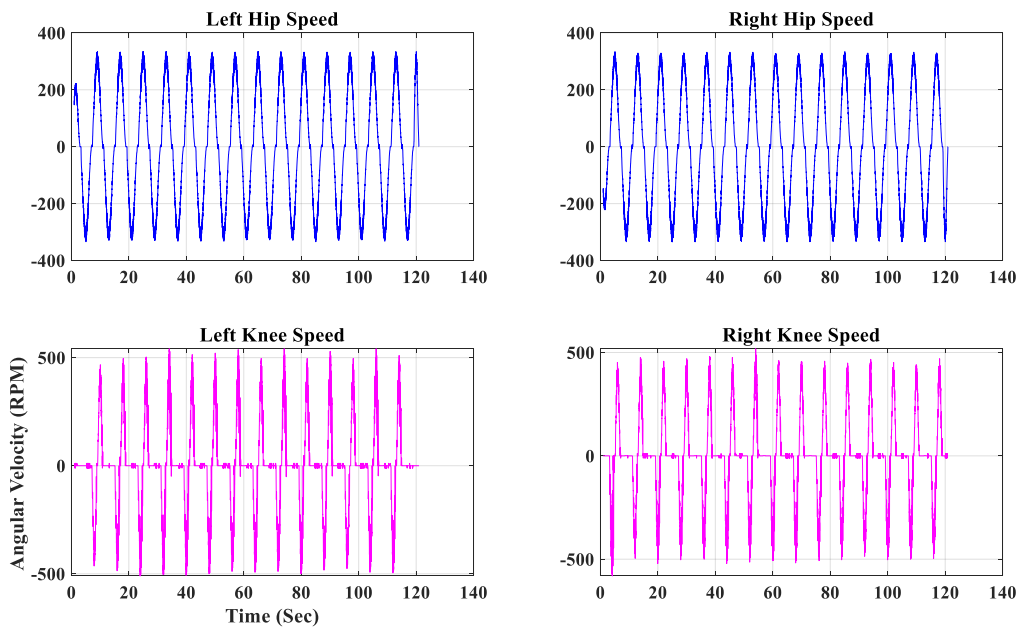


Fig.7. Angular Velocities of Each Joint for the Frame-Mounted LLE with a Dummy.

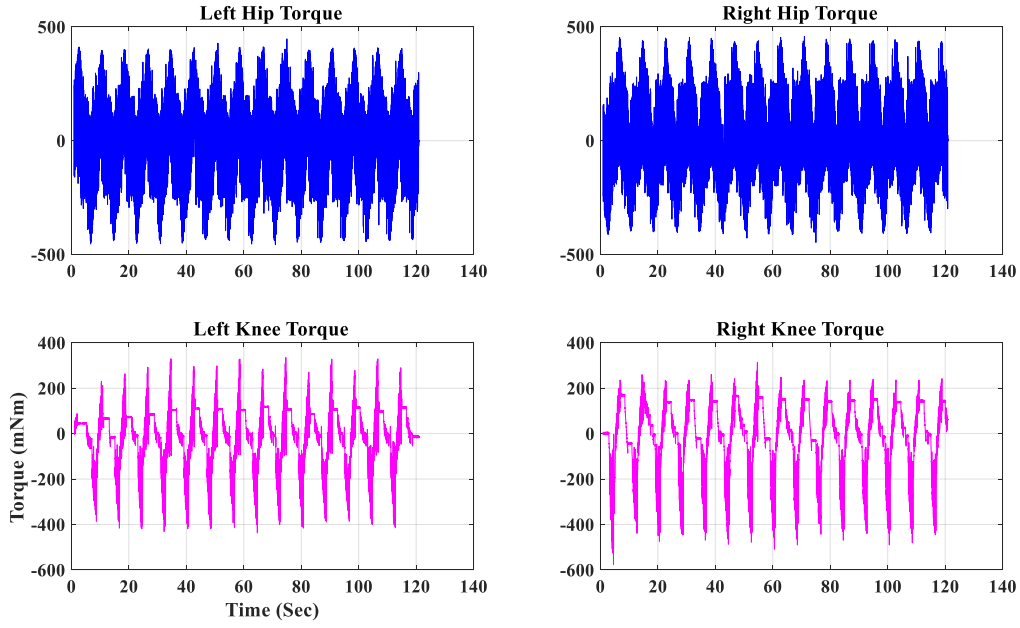


Fig.8. Generated Torques of Each Joint for the Frame-Mounted LLE with a Dummy.

Fig. 8 illustrates the generated torques for each joint of the LLE with a dummy. While the hip torques for the LLE without a dummy ranged between -400 mNm and +400 mNm, for the LLE with a dummy, this range is approximately between -500 mNm and +500 mNm. Furthermore, while the knee torque of the LLE without a dummy varied from +200 mNm to -400 mNm, for the LLE with a dummy, it ranges from +300 mNm to -400 mNm. Given that the right and left legs of the dummy are not exactly similar, slight differences in the results between the right and left legs are expected.

3. Results with a User in the Unengaged Mode

In this section, a user wears the LLE and walks with it while the actuators are in unengaged mode. In this mode, the motors collect signals but do not apply any torque to the user. Fig. 9 displays various views of the LLE while being worn by a user.



Fig.9. LLE Equipped with a User

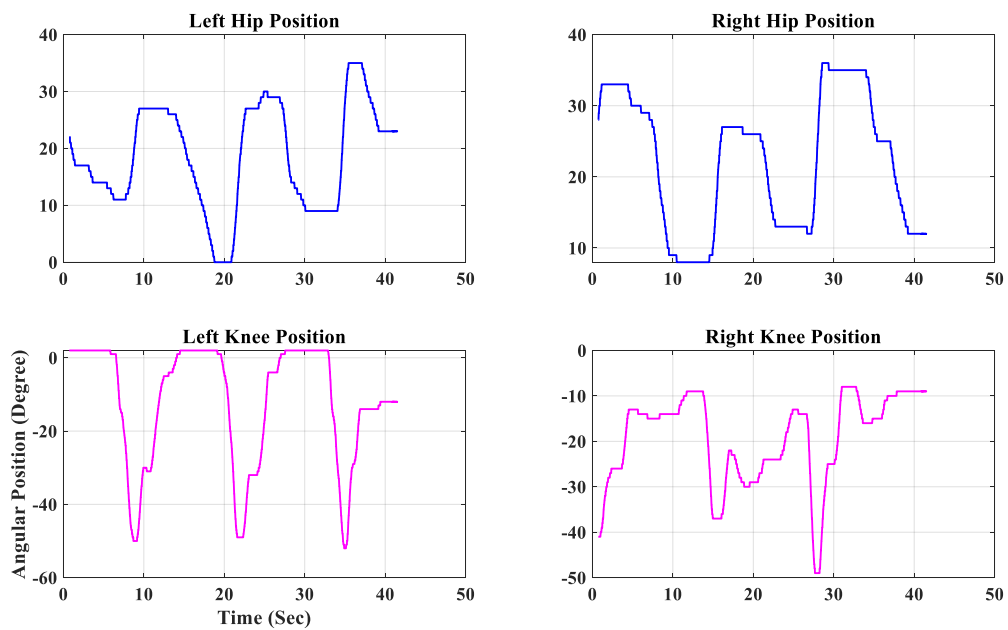


Fig.10. Angular Positions of Each Joint for the LLE with the User.

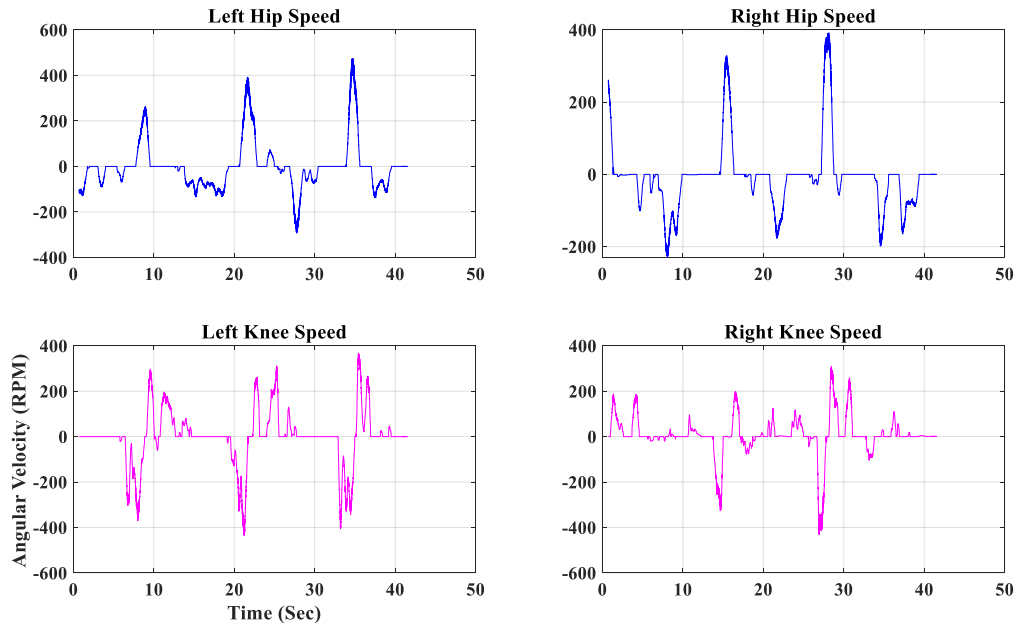


Fig.11. Angular Velocities of Each Joint for the LLE with the User.

Fig. 10 shows the angular position of each joint of the LLE while the user walks with it in unengaged mode. Additionally, the associated angular velocities for these positions are presented in Fig. 11.