Dynamic modeling and caracterization of a hexapod crawling robot

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Abstract. Traversing rough terrains is one of the domains where multi-legged crawling robots benefit from their relatively more complex kinematics in comparison to wheeled robots. The complexity of crawling robots is usually related not only to mechanical parts but also to servomotors and necessary electronics to efficiently control such a robotic system. In this work we tested and validated the forward and inverse kinematics model of a hexapod, allowing us to have a reliable simulation of the complete platform. The servomotor used was characterized and simulated. The relationship between the speed and the supply voltage measured was determined. The electromechanical motor model was verified integrating the motor speed according to Euler.

Problem Statement

Multi-legged robots have a great potential to traverse rough terrains at the cost of relatively more complex robot design and locomotion control in comparison to wheeled robots. The Phantom AX with servo motors Dynamixel AX12 shown in Fig. 1 has 6 legs, each one with 3 degrees of freedom (DoF). In this work, we theoretically analyze and test the leg motion taking into account both a kinematic and a dynamic model.

Fig. 1: Phantom AX robot.

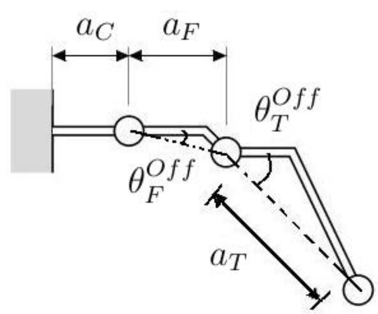

Fig. 2: DH parameters of one leg.

The kinematic model of the 18-DoF robot was theoretically based on Denavit-Hartenberg (DH) notation. The DH parameters shown in Fig. 2 were initially meassured, then optimized to improve the confidence of the simulation. Forward kinematics model was tested first for one leg and then extended to the entire frame of the robot. Inverse Kinematics was solved as well according to [1]. The working space of the robot was determined allowing us to make trajectory-planning with obstacles/collision avoidance in future work [2]. Finally, we show results on the characterization of the dynamic model of one servomotor. The latter is fundamental to construct a full dynamic model of the entire robot.

Results

To test the Forward Kinematic Model, we compared the foottip positions of the robot's leg with the simulation of the kinematic model. In Fig. 3 we show the simulation of a single leg. In Fig. 4 we show the simulation of the complete body.

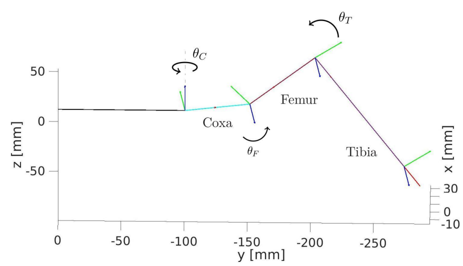

Fig. 3: One leg simulation.

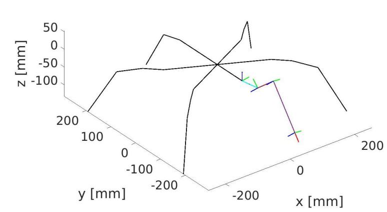

Fig. 4: Complete body simulation.

To improve the DH parameters we implemented a minimization of our measurements using the simulation. The results of the comparison between the initial simulation and the optimized simulation are shown in Table 1.

θ_c	θ_F	θ_T	$\|\|X_s, Y_s\|\|$ $[mm]$	$\|\|X_{Op}, Y_{Op}\|\|$ $[mm]$	$\|\|Z_s\|\|$ $[mm]$	$\|\|Z_{Op}\|\|$ $[mm]$
$25°$	$0°$	$75°$	10	0	10	4
$0°$	$0°$	$75°$	11	1	10	4
$-40°$	$10°$	$40°$	3	2	18	1
$-20°$	$90°$	$-60°$	4	8	1	5
$20°$	$60°$	$70°$	20	1	4	1

Table 1: Comparison of the optimized D-H parameters.

where the joint angles θ are associated with the coxa, femur and tibia respectively. The subscript 's' stands for the initial simulation results and 'Op' stands for the simulation implemented with the optimized DH parameters. The norm implies the error between the real measurements and the simulated ones.

Then with the new parameters we corroborate the model of the inverse kinematics, comparing reals positions with the simulated ones. On the other hand in Fig. 5 we show the work space on the XY plane and in Fig. 6 we show the

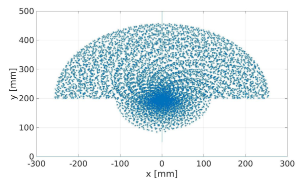

Fig. 5: Workspace: Plane XY.

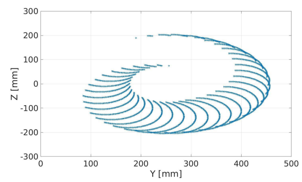

Fig. 6: Workspace: Plane YZ.

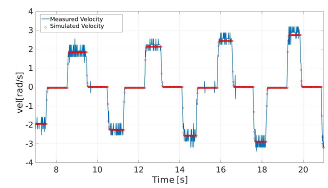

Fig. 7: Simulation of the velocity motors ($\vec{g} = 0$).

work space on the plane YZ, both computed by simulations using the kinematic model [2]. We implemented the electromechanical model of a servo motor of [3]. Then we took velocity measurements of the motor and compared them with the simulation. Fig. 7 shows the simulation of the motor velocity for the case were the torque of the gravity its not taken into account.

Conclusions and future work

In this work, the forward kinematics model of Phantom Ax robot was presented. We were able to verify the model for the entire platform. The parameters of D-H were optimized, improving the confidence of the simulation. The inverse kinematics in the real robot was validated. The work space was determined using the kinematic model, which is essential for planning the trajectories of the robot and avoiding possible obstacles/collisions. The servomotor Dynamixel AX12A was characterized and simulated. The relationship between the speed and the supply voltage measured in PWM was determined. The proposed model was verified by performing an adjustment by the Euler integration method of the speeds measured in the engine. From these last results we will model the dynamics of a complete leg to continue with the extension of the whole platform. Our final goal is to achieve the detection of different terrains with only the reading of the motor torques.

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