Reply

Orientation Control System: Enhancing Aerial Maneuvers for Quadruped Robots

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Dear Ms. Vera Popovic,

Thank you for giving us the chance to submit a revised draft version of the manuscript titled "Orientation Control System: Enhancing Aerial Maneuvers for Quadruped Robots" to the MDPI journal *Sensors*. We are grateful for the time and the effort you and the reviewers have dedicated to providing insightful comments on the original manuscript. We have incorporated changes to reflect most of the provided suggestions: they are highlighted in red within the manuscript. For removing the highlights, please comment line 73 and uncomment line 74 in the file named `mdpi2022roscia.tex`.

Here is a point-by-point response to the reviewers' comments and concerns.

Comments for Reviewer 1

- **Comment 1:** *Extend the text of the manuscript (e.g. introduction or conclusion) with specific results in the world and Europe, - Improve the quality of the paper by presenting the results of publications by researchers and experts who are involved in this field and registered in world databases (wos). These are e.g: Measurement of industrial robot pose repeatability, Investigation of snake robot locomotion possibilities in a pipe, thanks.*
  Response: Thank you for this advice. However, in the case of our study, it seems slightly out of range because we tackle of the angular dynamics of the main body of a quadruped robot, that is observable.

- **Comment 2:** *Figure 4 should be contrasting and readable*
  Response: Thank you for pointing this out. We have incorporated your suggestion in the revised manuscript.

- **Comment 3:** *Conclusions and future work should be extended to contain practical applications based on research described in this paper - expand references.*
  Response: We are glad you made such an important hint to improve the quality of the manuscript. Possible applications of the presented OCS include but are not limited to efficiently adjust the posture of quadruped robots walking or jumping on uneven terrains. As proved in the third simulation (back-flip), our approach improves the capabilities of quadrupeds in space application enabling fast locomotion by means of leaps, ensuring a reactive control action on the robot angular momentum. Furthermore, the method presented in Section 3 for designing the OCS does not depend on the specific platform, thus it can be replicated for reorienting mechanical structures with different morphology, e.g, monopods or bipeds. A construction worker's backpack can contain two flywheels with incident rotation axes: in the event of a fall from scaffolding, they can be used to reorient the human body to avoid impact of the head with the ground with the same controller proposed in this work.

- **Comment 4:** *Number all mathematical equations*

Response: Thank you for bringing this to our attention. We applied the comment into the document.

- **Comment 5:** *For article type, 20 references are not enough. Please add more references (>20) during your revisions.*
  Response: We really appreciate your suggestion, which helped us to improve the manuscript. We included other relevant works in the literature review, e.g. [An, 2022], [Tang, 2022], and [Kurtz, 2022].

- **Comment 6:** *Standardization of literature input (into one style)*
  Response: Agree. We have corrected the literature input.

Comments for Reviewer 2

- **Comment 1:** *'All the simulations are performed in Gazebo'. The paper must have more details related with the simulation, including a snapshot of the simulated robot in its environment.*
  Response: Thank you for the insightful comment. We summarized the details of the simulation in 1, which is incorporated to the manuscript too. Moreover, inspired by your suggestion, we attached a sequence of snapshots for the third simulation (back-flip), showing the robot in the Gazebo environment.

Table 1. Physics related parameters used for simulate the robot dynamics in Gazebo

Parameter	Value
Step size	0.001 s
Real time update rate	250
Physics engine	Open Dynamics Engine (ODE)
Solver	Quick (Projected Gauss-Seidel method)
Iterations	50
Successive Over Relaxation parameter	1.3
Rescaling Moment of Inertia	no
Friction model	Pyramid

- **Comment 2:** *The authors should give more details regarding the next sentence, being crucial for the paper outputs: "The robot full dynamics is modeled with Pinocchio". Currently Gazebo supports 4 physics engines: ode, bullet, simbody and dart, being the default physics engine ode. Since the simulator models the robot dynamics, why use Pinocchio software?*
  Response: We acknowledge that we could have made a better explanation here. We rephrased "The robot full dynamics is modeled with Pinocchio. The references for the joints of the legs are computed off-line using Crocoddyl and tracked with a proportional-derivative joint controller." with "References for the joints of the legs are computed off-line using Crocoddyl, an optimal control library for robots based on Differential Dynamic Programming (DDP) algorithms. It uses Pinocchio for fast computation of robots dynamics and their analytical derivatives. References $\boldsymbol{q}_{ref}$, $\dot{\boldsymbol{q}}_{ref}$ and $\boldsymbol{\tau}_{ref}$ for joint positions, velocities and torques are then executed on-line with a proportional-derivative joint controller:

$$\boldsymbol{\tau}_j = \boldsymbol{K}_{p,j}(\boldsymbol{q}_{ref} - \boldsymbol{q}) + \boldsymbol{K}_{d,j}(\dot{\boldsymbol{q}}_{ref} - \dot{\boldsymbol{q}}) + \boldsymbol{\tau}_{ref}"$$

- **Comment 3:** *Section 2 should be expanded with more citations, an describing more related works.*
  Response: Thank you for the suggestion. Reviewer 1 pointed out the same advise, then you could refer to the response to Comment 5 of the the previous section.
- **Comment 4:** *Ide for robot code development*

Response: We coded the controller using Python v3.8, with the IDE Pycharm v3.2 (https://www.jetbrains.com/pycharm/). The manuscript lacks about this information because we believe that, in our work, the use of a specific IDE is not relevant.

In addition to the above observations, all orthographic and grammatical errors mentioned have been corrected.
We look forward to hear regarding our submission and to respond to any further questions and comments.
Sincerely,