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Attitude and position control of a quadcopter in a networked distributed system

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Introduction

Quadcopters constitute a control challenge due to their inherent instability and coupled behavior. However, the interest for them has increased due to the multiple possibilities they offer. A linear control solution capable of stabilizing the quadcopter and controlling its position is presented by combining state space and classical control approaches. The presented results include the attitude control performance and simulations showing the behavior of the translational controllers.

System

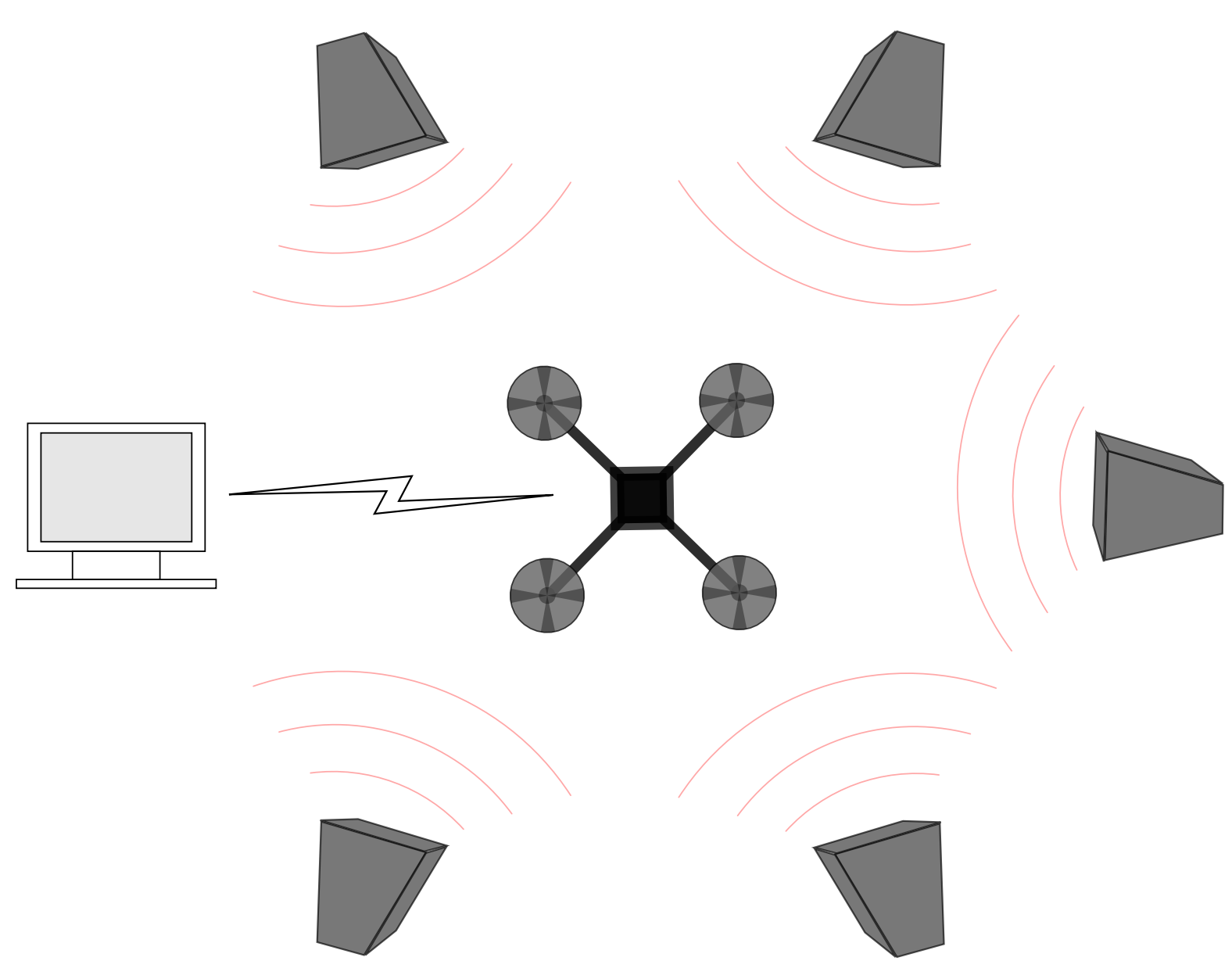


Fig. 1: The distributed system is composed by a motion tracking system connected to a computer, the quadcopter and a radio link communication between them. The network is simulated using TrueTime during the design process to ensure stability.

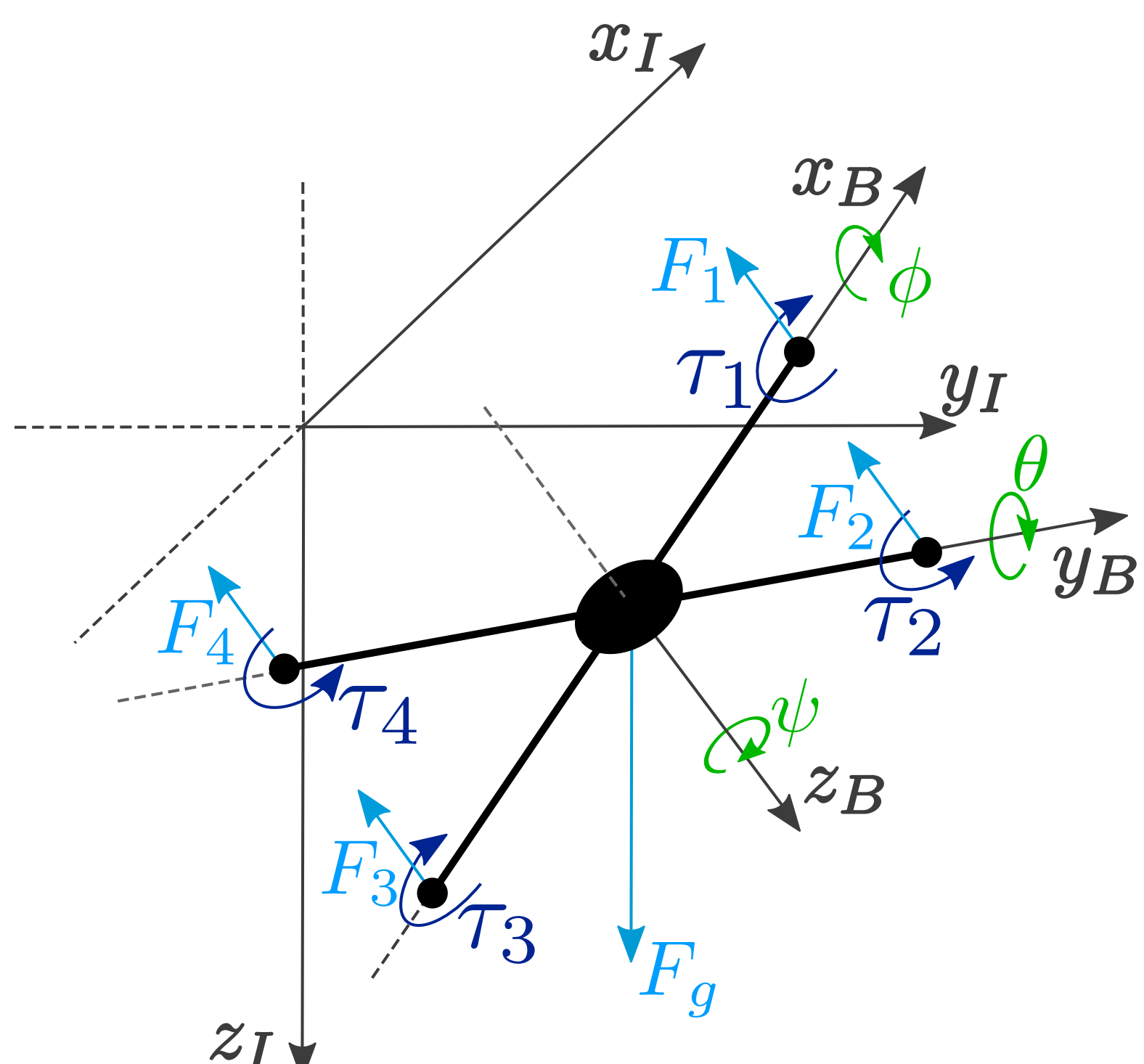


Fig. 2: Free body diagram of the quadcopter along with the inertial and body frames used for modeling.

Control Solution

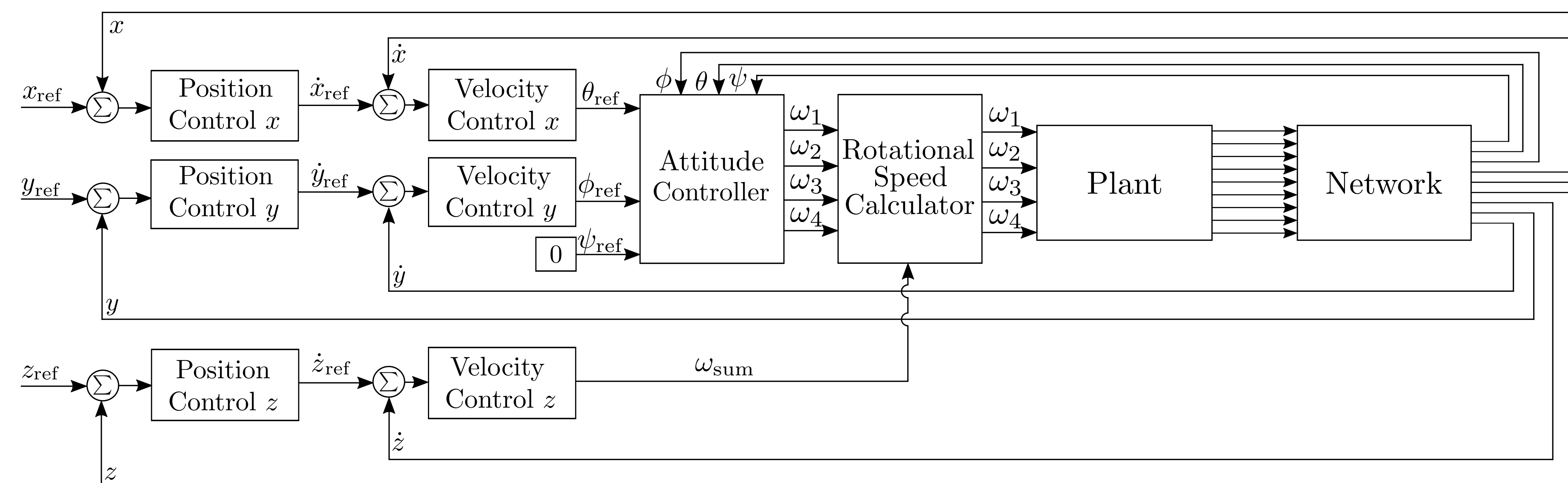


Fig. 3: Diagram of the control solution.

Attitude controller

- State feedback with integral control using LQR is designed for tracking references and handling disturbances.
- A reduced order observer is used to estimate the angular velocities.

Translational controllers

- PI controllers are used to control the velocities in order to handle input disturbances.
- The outer loops are P controllers used to control the positions.
- The bandwidths of the cascaded controllers are considered to reduce the effect of the dynamics of the inner loops in the outer loops.

Results

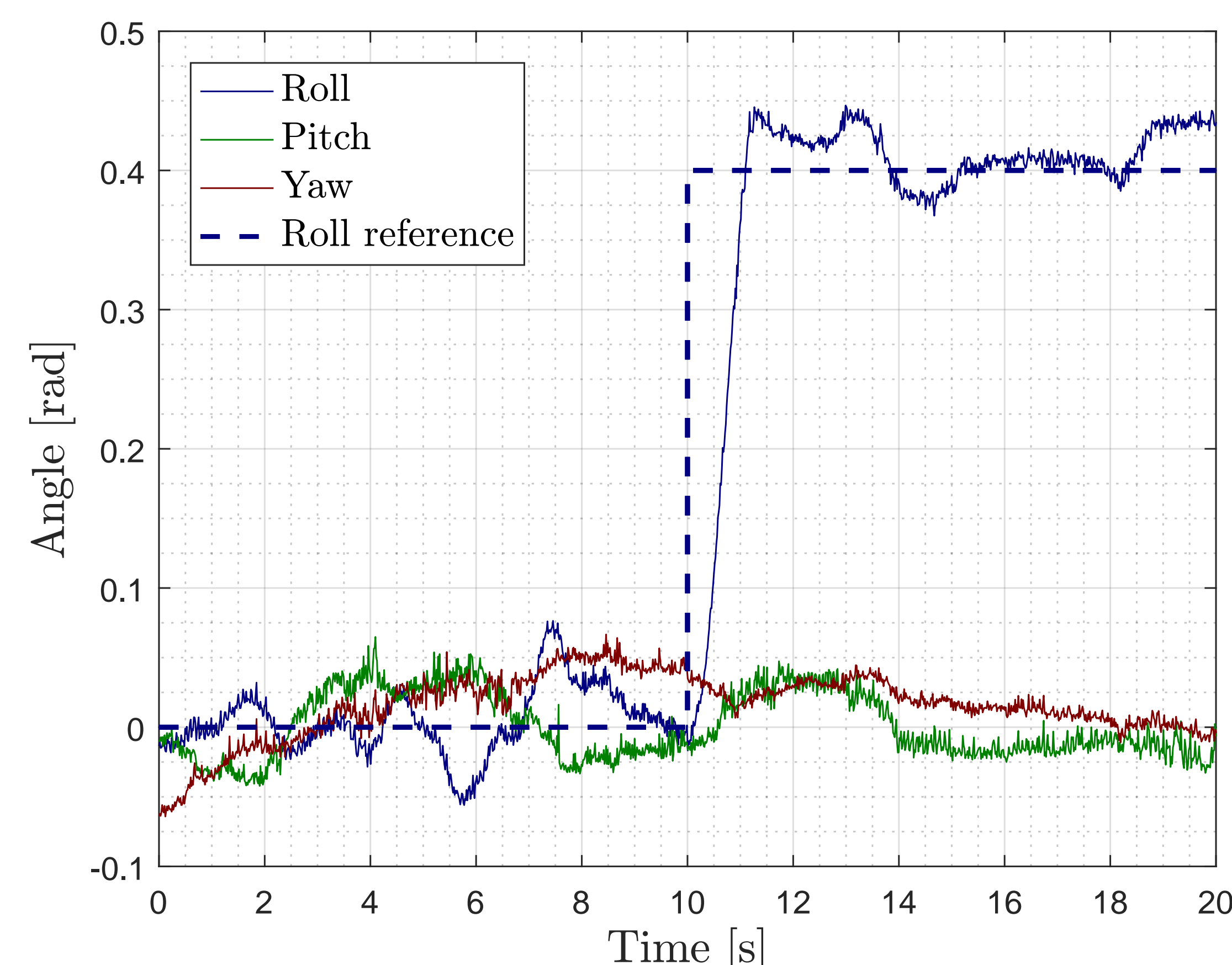


Fig. 4: Attitude control on the quadcopter. The first part of the figure shows how the angles are stabilized, then, a reference in roll of 0.4 rad is given to the controller while the other angles remain at zero.

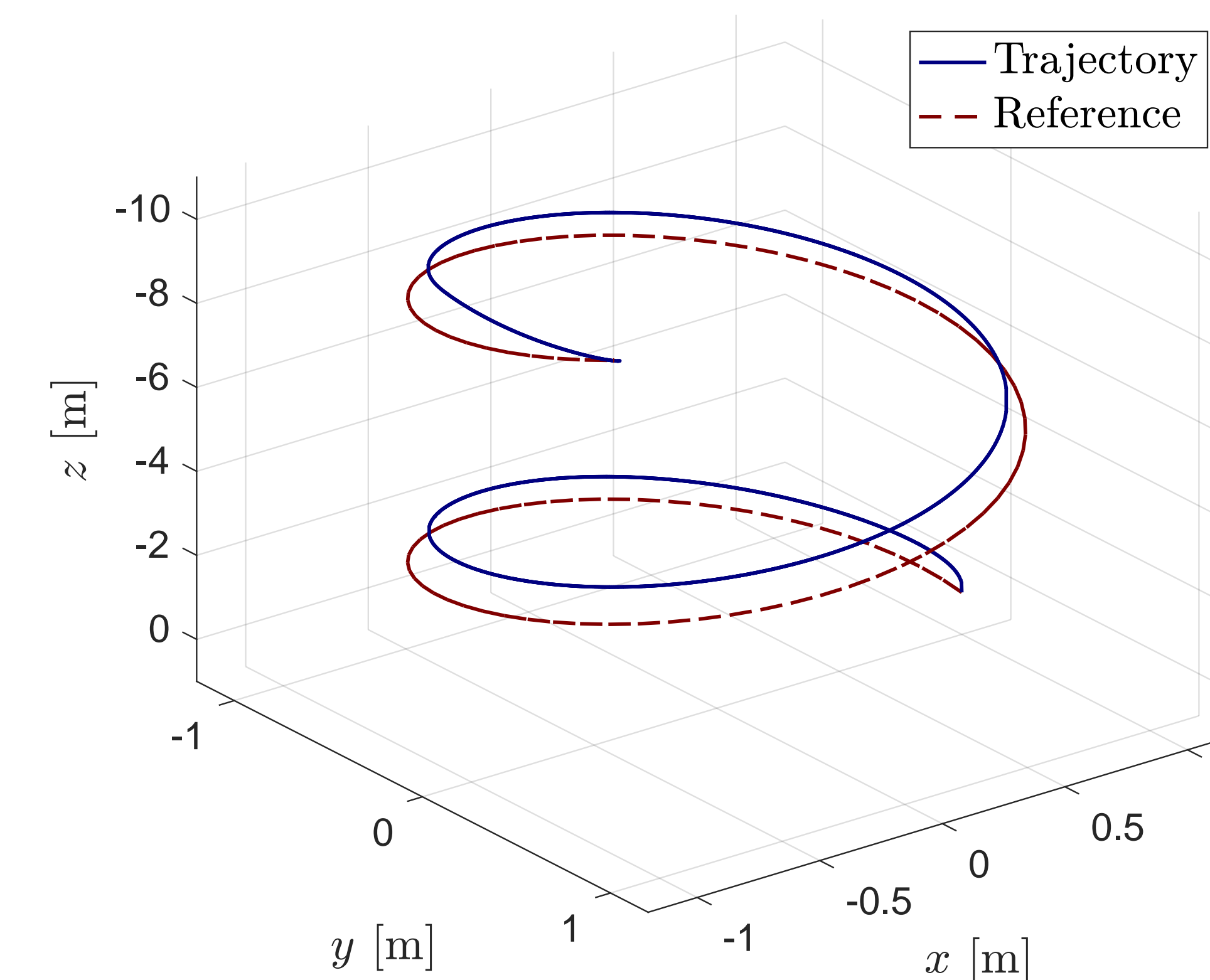


Fig. 5: The translational controllers tracking a helical trajectory. The network is included in all simulations.

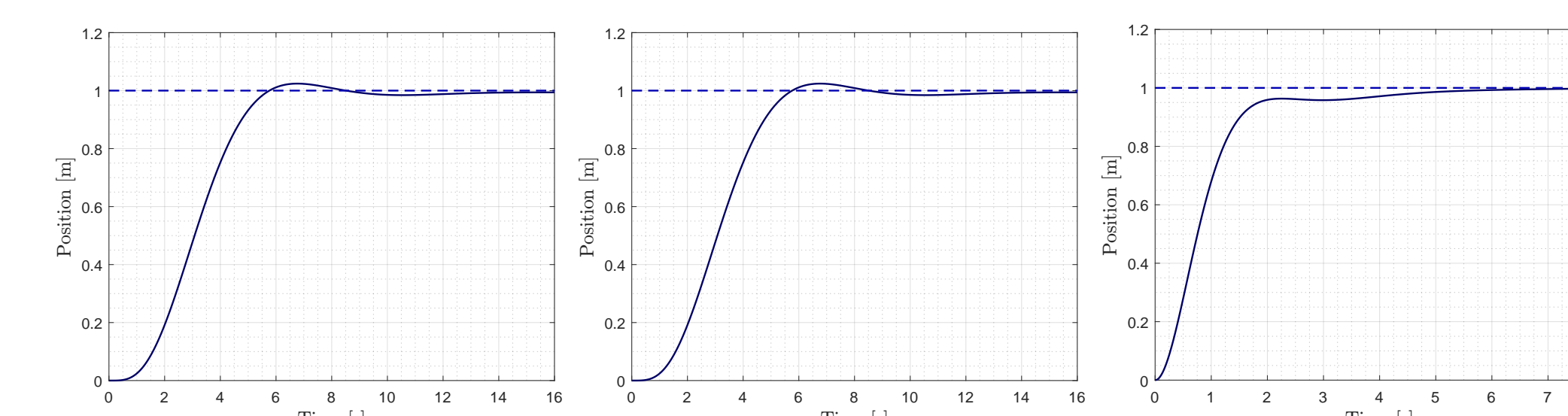


Fig. 6: Step responses of the translational position controllers in simulation.

Discussion

The network delay and sampling rate affect the controllers' performance, however, they still achieve the given references in simulation. Experimental results could not be presented for the translational controllers, as it has not been possible to successfully implement the translational controllers in due time. The design is however deemed valid, as simulations show that it should work in reality. The attitude controller is implemented and achieves the given references.

Conclusion

A linear control system has been designed, based upon a first principles model, to stabilize the quadcopter and control its position. The attitude controller has been designed in state space, while the translational control system is based on classical control methods. Network effects are included in the control design to ensure stability. Simulations show that the translational controllers have been adequately designed. The attitude controller has been implemented and tested successfully.

References

- [1] Abbas Emami-Naeini Gene F. Franklin J. David Powell. *Feedback Control of Dynamic Systems*. 7th Edition. Pearson, 2015.
- [2] D. Henriksson A. Cervin et al. "How Does Control Timing Affect Performance? Analysis and Simulation of Timing Using Jitterbug and TrueTime". In: *IEEE Control Systems Magazine* (2003).

Acknowledgements

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