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

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Introduction

Quadcopters constitute a control challenge due to the unstable nature 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 a 3D simulation graph showing a trajectory followed by the quadcopter.

System

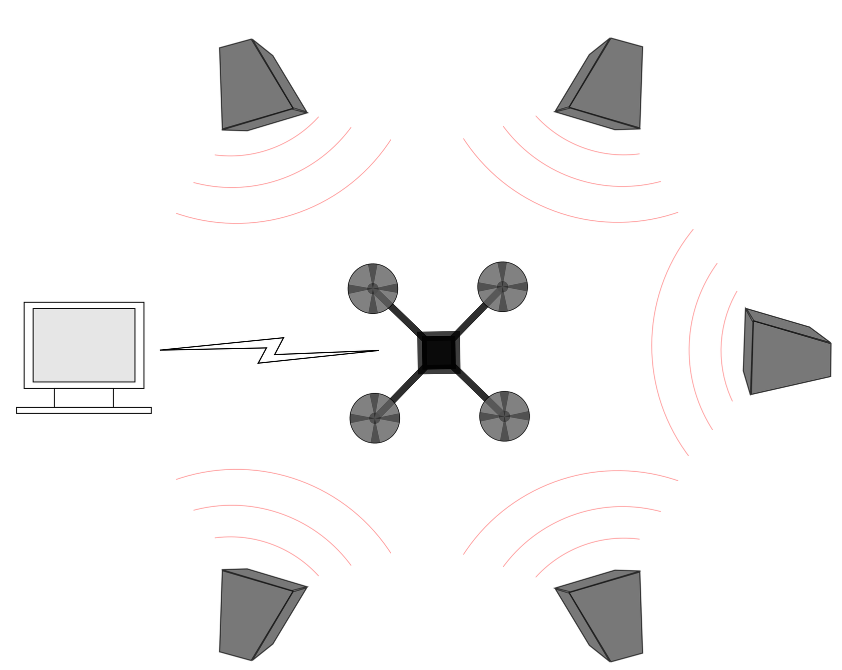

Fig. 1: The distributed system is composed by a motion tracking system connected to a computer, the quadcopter and a radio link communication between them. The network is simulated using TrueTime during the design process to ensure stability of the controllers.

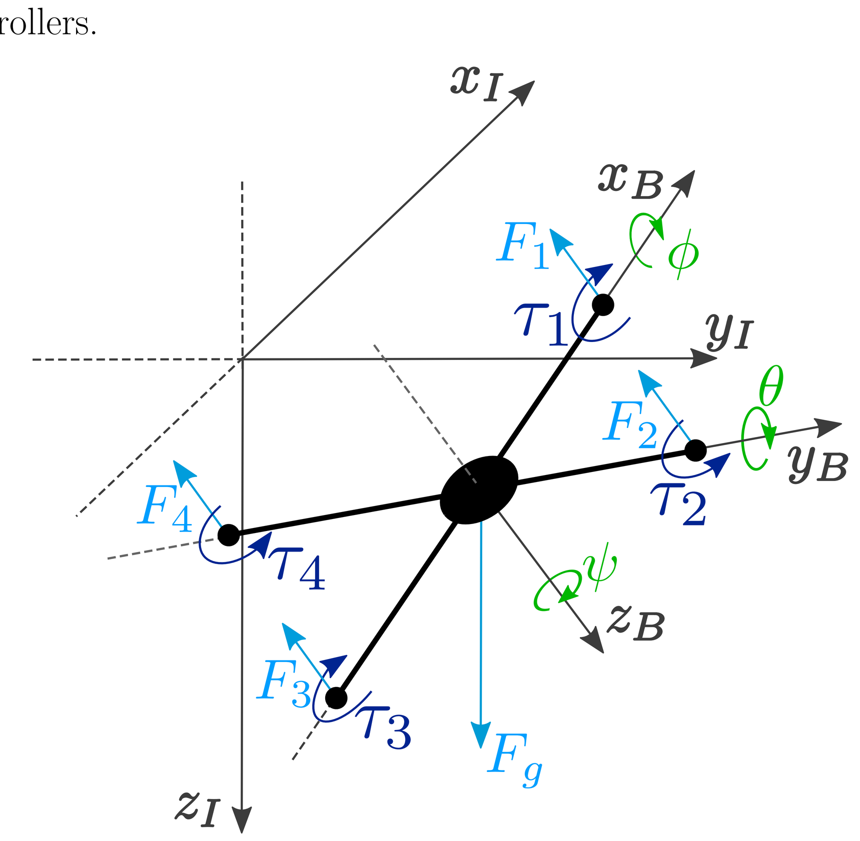

Fig. 2: Free body diagram of the quadcopter along with the inertial and body coordinate frames used for modeling.

Control Solution

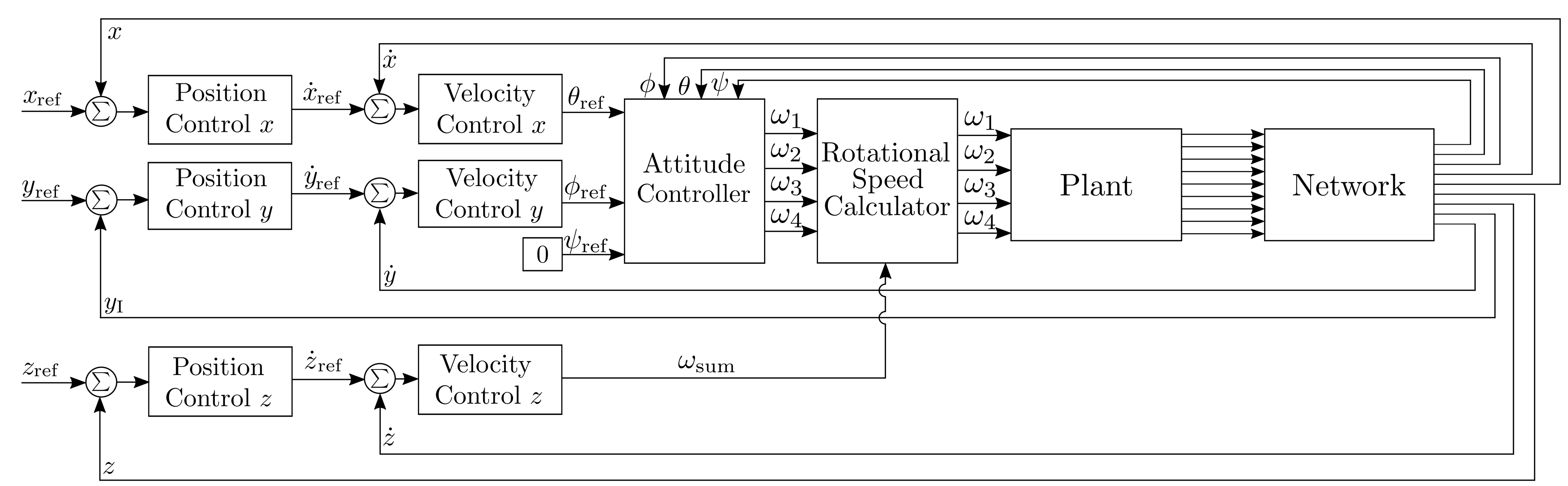

Fig. 3: Diagram of the control solution.

Attitude controller

- State feedback with integral control designed with LQR is used 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 translational velocities in order to handle input disturbances.
- The outer loops are P controllers used to control the translational positions.
- The bandwidth of the cascaded controllers are taken into account to reduce the effect of the dynamics of the inner loop in the outer loop.

Results

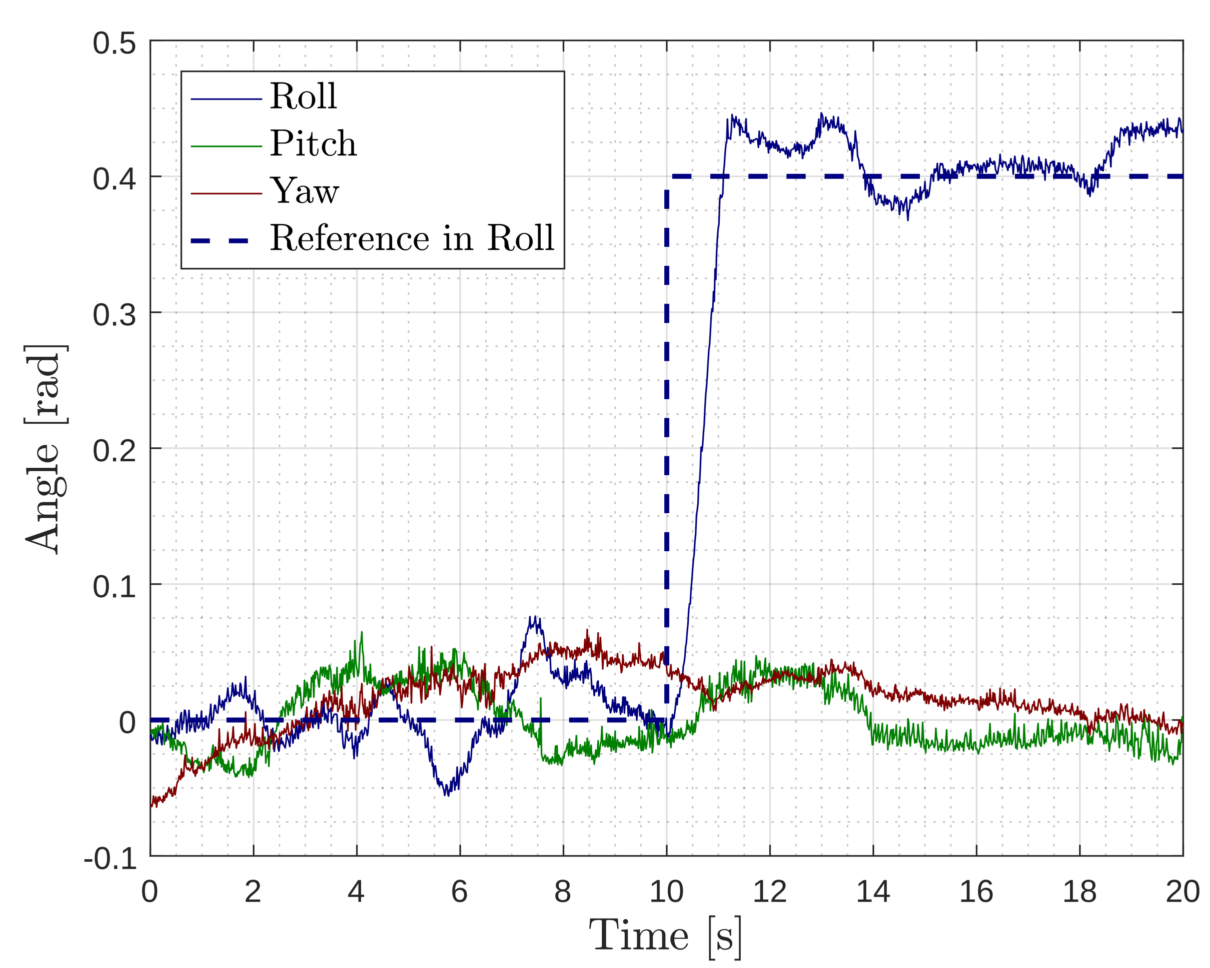

Fig. 4: Attitude control on the quadcopter. The first part of the figure shows how the angles are stabilized, then, a reference in roll of 0.4 is given to the controller while the other angles stay at 0.

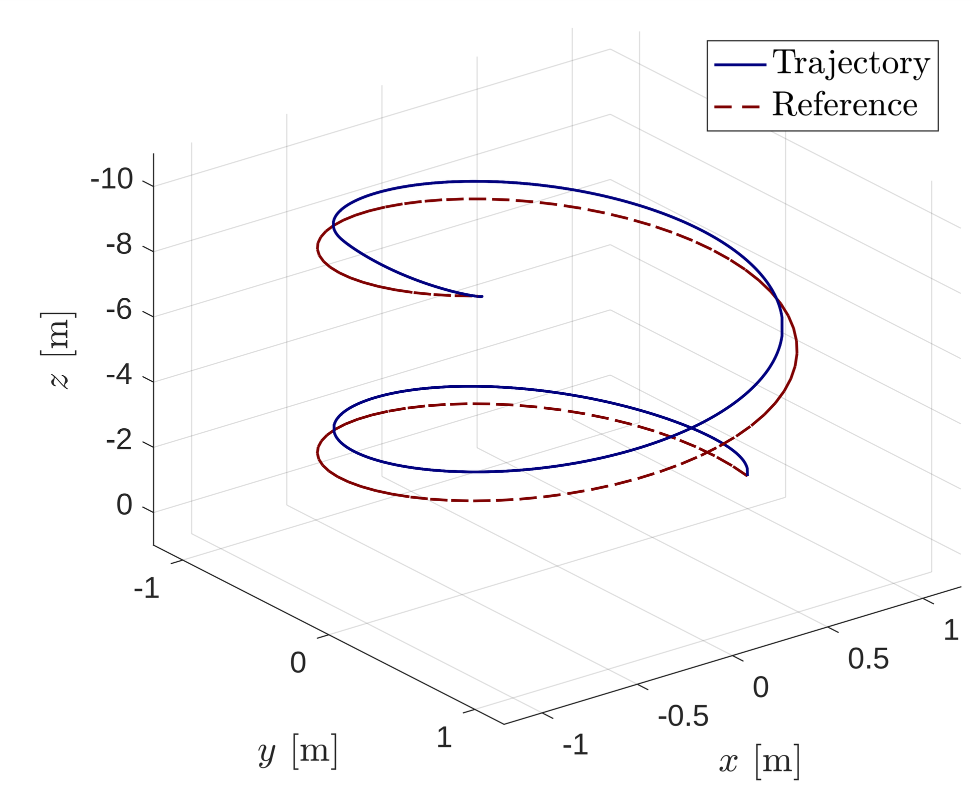

Fig. 5: The translational controllers tracking a helical trajectory. The network is included in all simulations.

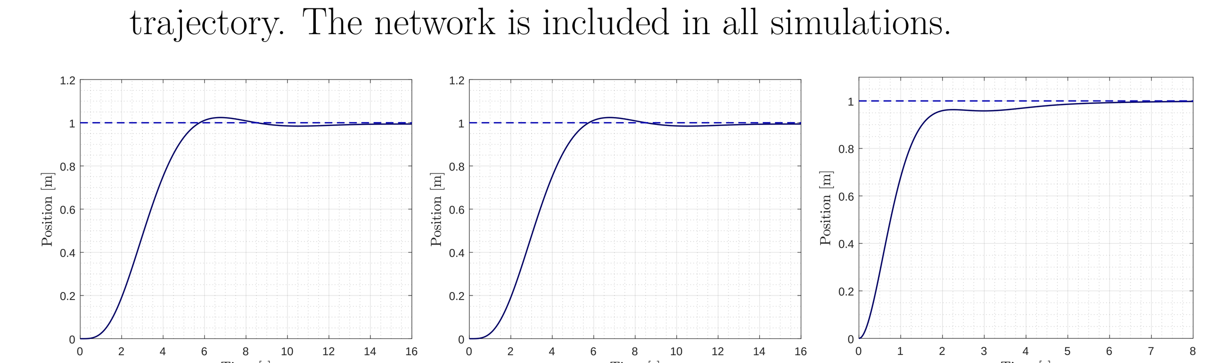

Fig. 6: Step responses of the translational position controllers in simulation.

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 implement the translational controllers with sucess in due time. The design is however deemed reasonable, as simulations show that the design should work in reality. The attitude controller is implemented and achieves the given references successfully.

Conclusion

A model has been obtained by first principle modelling. A linear control system was designed to stabilize the quadcopter and control its position. The attitude controller has been designed as state space, and the translational control system is designed as classical control. Network effects are included in the control design. The results reveals that the attitude and the simulated translational quadcopter behavior have been successfully controlled.

References

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