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

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Introduction

The quadcopter constitutes a control challenge due to its 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 control its position is presented by combining state space controllers and classical control. The presented results include the attitude control performance and a 3D simulation graph showing a trajectory followed by the quadcopter.

Model

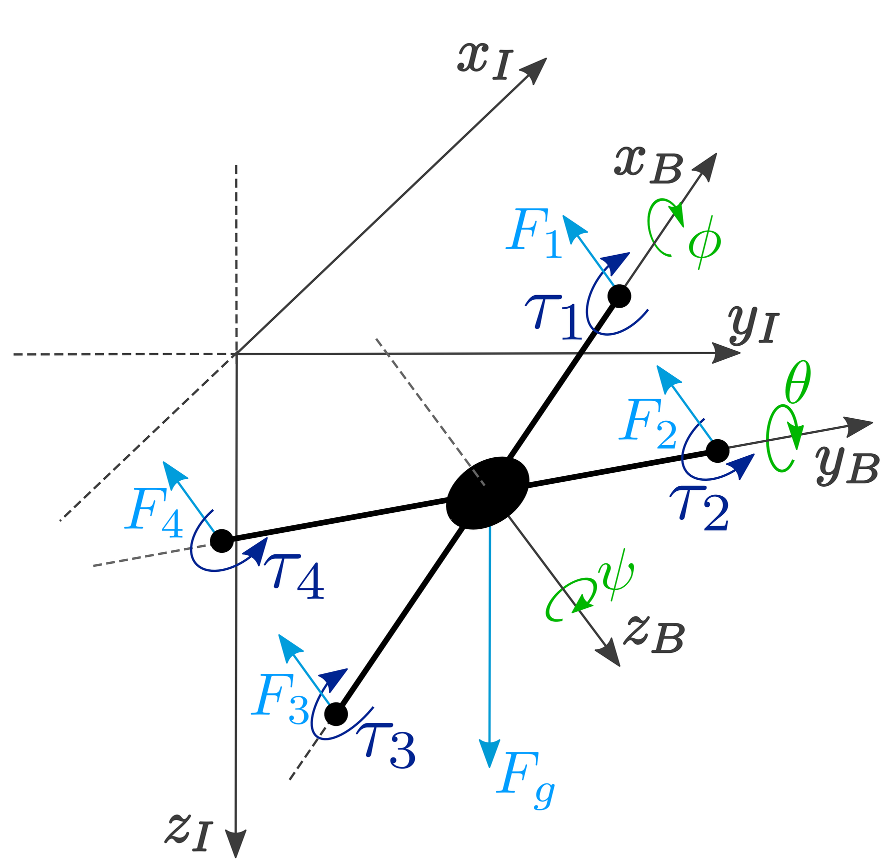


Figure: Free body diagram of the quadcopter along with the inertial and body coordinate systems.

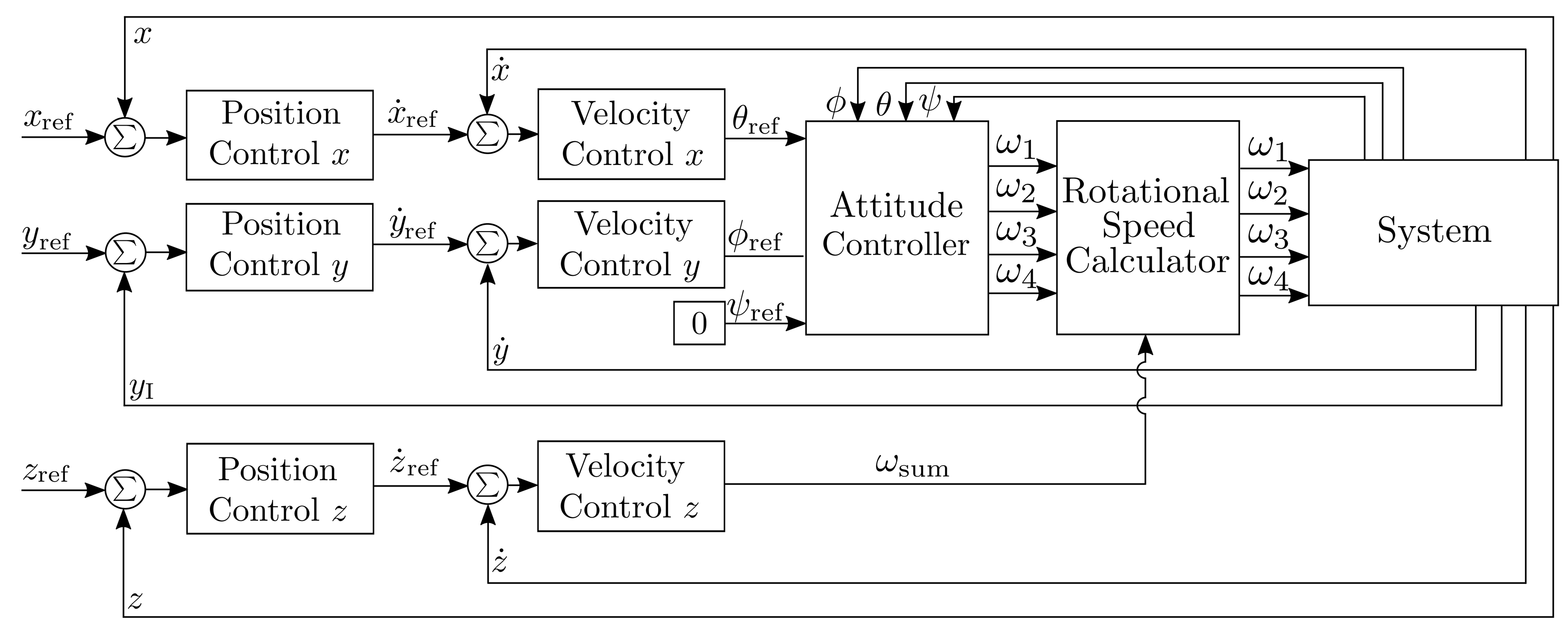
- Attitude model equations

$$J_x\ddot{\phi} = k_{\text{th}}(\omega_4^2 - \omega_2^2)L$$
$$J_y\ddot{\theta} = k_{\text{th}}(\omega_1^2 - \omega_3^2)L$$
$$J_z\ddot{\psi} = k_{\text{d}}(\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2)$$

- Translational model equations

$$m\ddot{x}_{\text{I}} = -k_{\text{th}}({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \times (\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi)$$
$$m\ddot{y}_{\text{I}} = -k_{\text{th}}({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \times (\cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi)$$
$$m\ddot{z}_{\text{I}} = F_g - k_{\text{th}}\,({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \times \cos\phi\cos\theta$$

Control Solution



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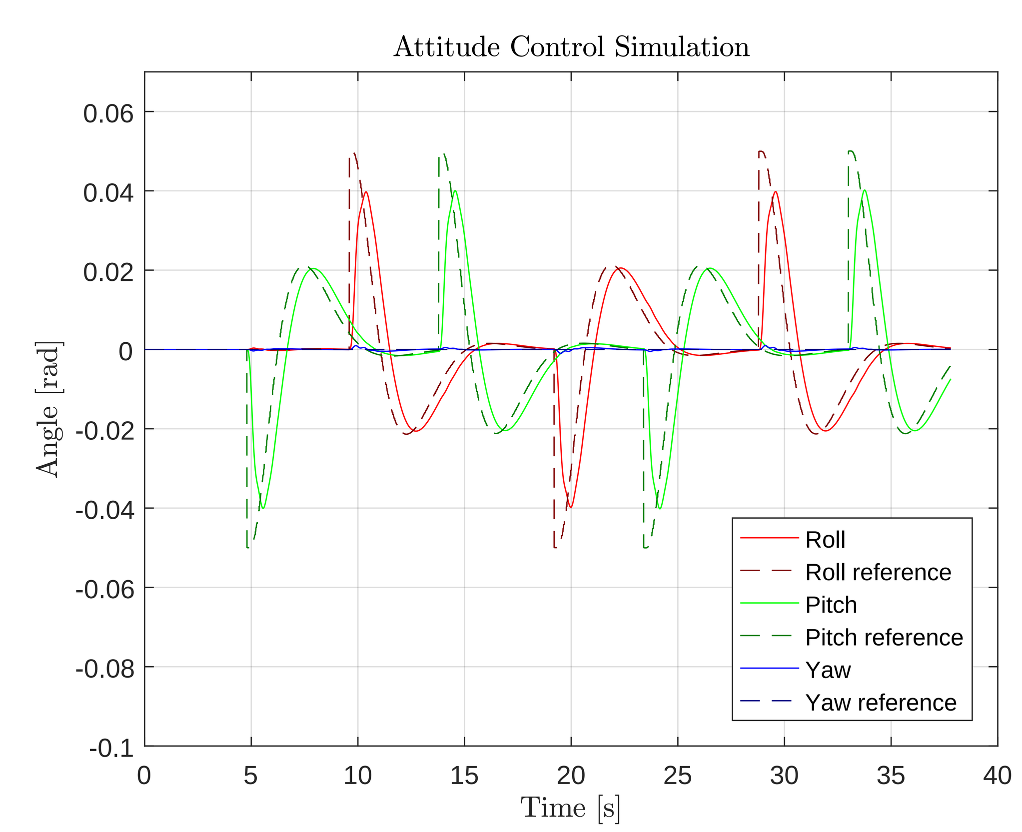
- Attitude controller
  State feedback with integral control, to be able to track references and handle disturbances, is used along with a reduced order observer, estimating angular velocities.
- Translational controller
  PI controller are used to control the translational velocities.
  Bandwidth of the cascaded controllers need to be taken into account in order to reduce the effect.

Results



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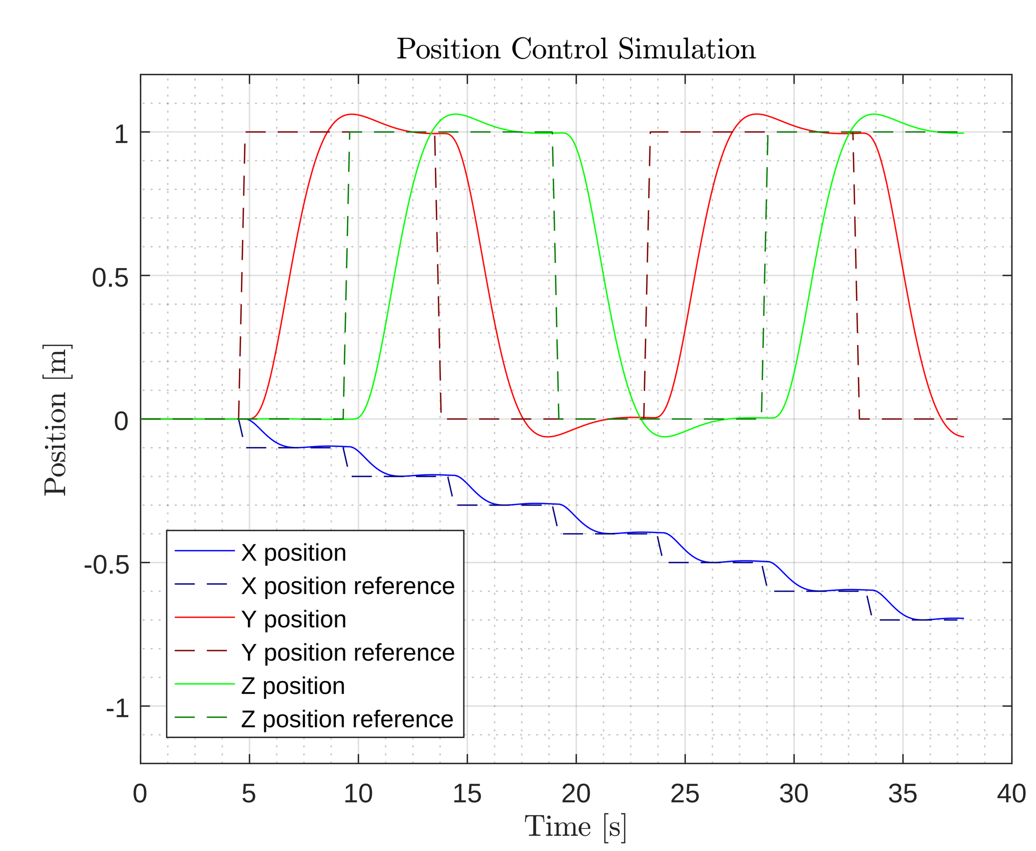

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Discussion

The results obtained in the simulations show both the attitude and position response of the quadcopter.
It is seen that the controllers achieve the desired reference even though the network delay and the sampling rate affect the performance. The main network effect is the designed bandwidth of the controllers. This occurs due to the limited frequency in which the sensor data is obtained from the motion tracking system through the wireless connection.

Conclusion

The control system has been split into an attitude and a translational controller. The former has been designed using a state space approach, including state feedback with integral control and a reduced order observer. The translational control system has been designed with a classical control approach and result in three cascade loops, including proportional and PI controllers. The results obtained from the design show that both the attitude and the translational behavior of the quadcopter has been successfully controlled.

References

CONTROL BOOK.

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