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

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Group 733 - Alejandro Alonso García, Amalie V. Petersen, Andrea Victoria Tram Løvemærke, Niels Skov Vestergaard, Noelia Villarmarzo Arruñada

School of Information and Communication Technology - Department of Control and Automation
Email: [aalons16] [apet13] [alavem13] [nveste12] [nvilla16] @student.aau.dk

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Introduction

This task is solved by implementing a linear control design. The system is split into an attitude and translational model. These are controlled individually by state space and classical controllers respectively. The prototype gets its attitude and position from a motion tracking system based on infrared cameras, keeping the control in a micro processor on the quadcopter. This layout constitutes a distributed system, where network issues, such as delays and packet losses, are taken into account.

Model

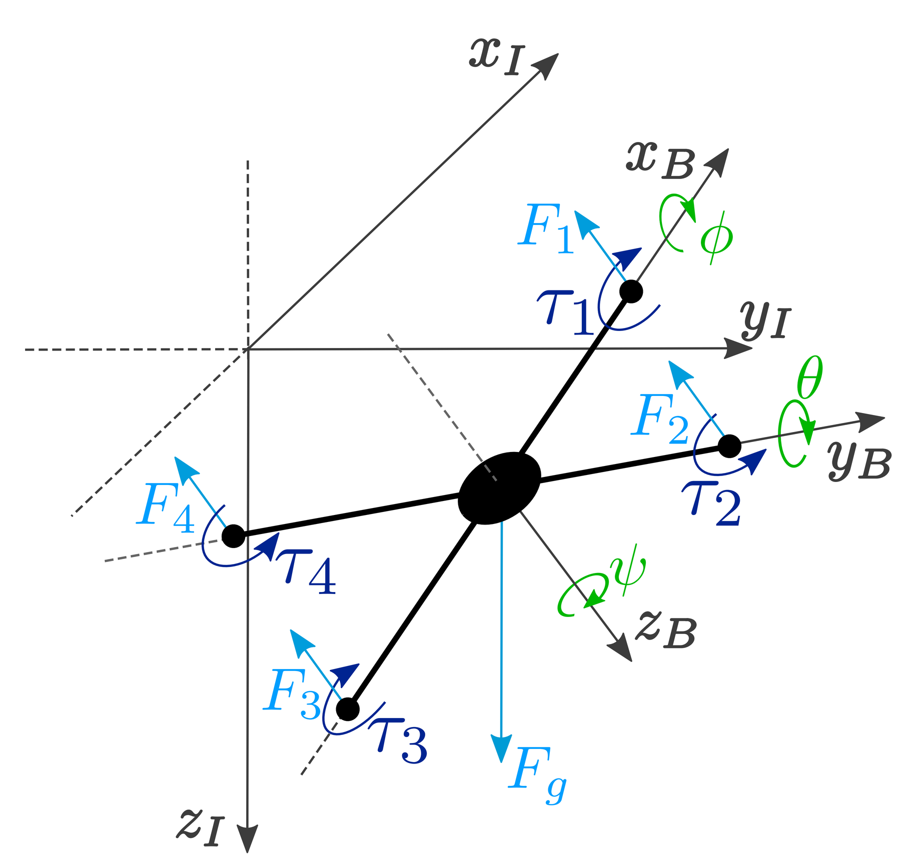


Figure: Free body diagram of the quadcopter along with the inertial and body coordinate systems.

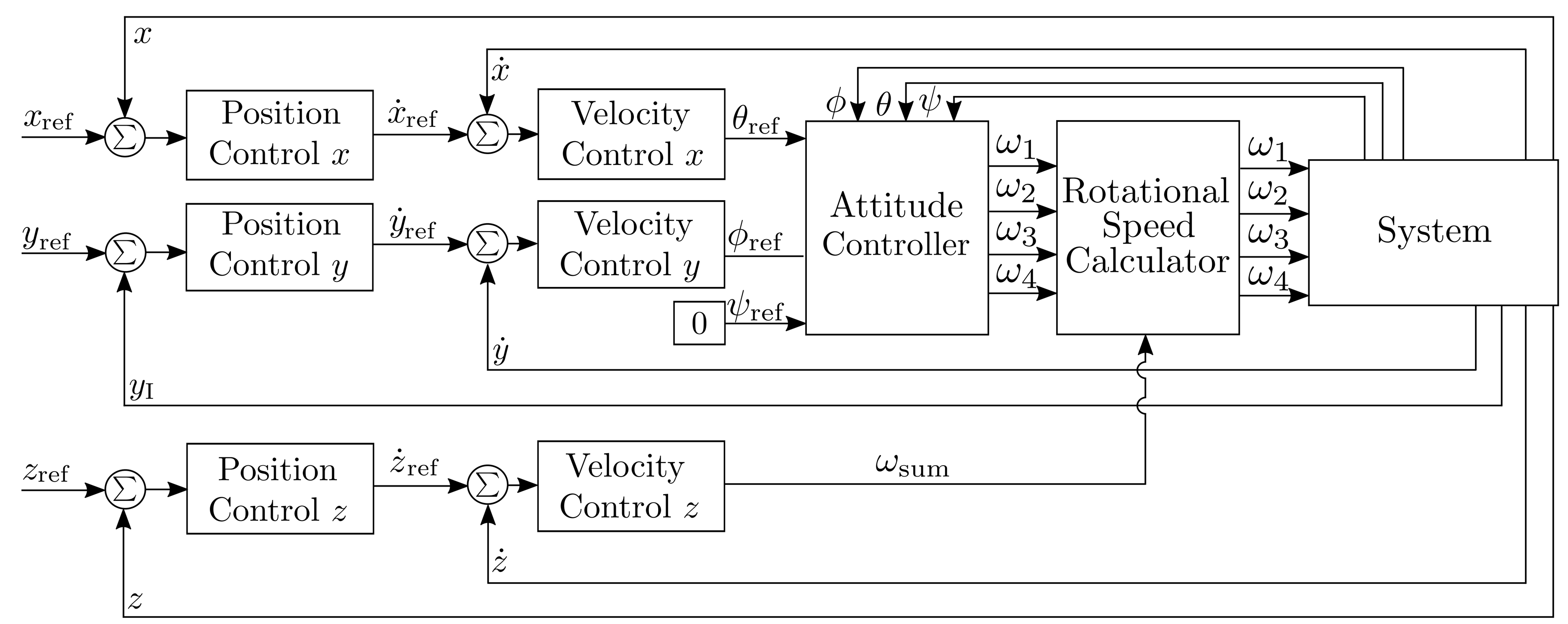
- Attitude model equations

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

- 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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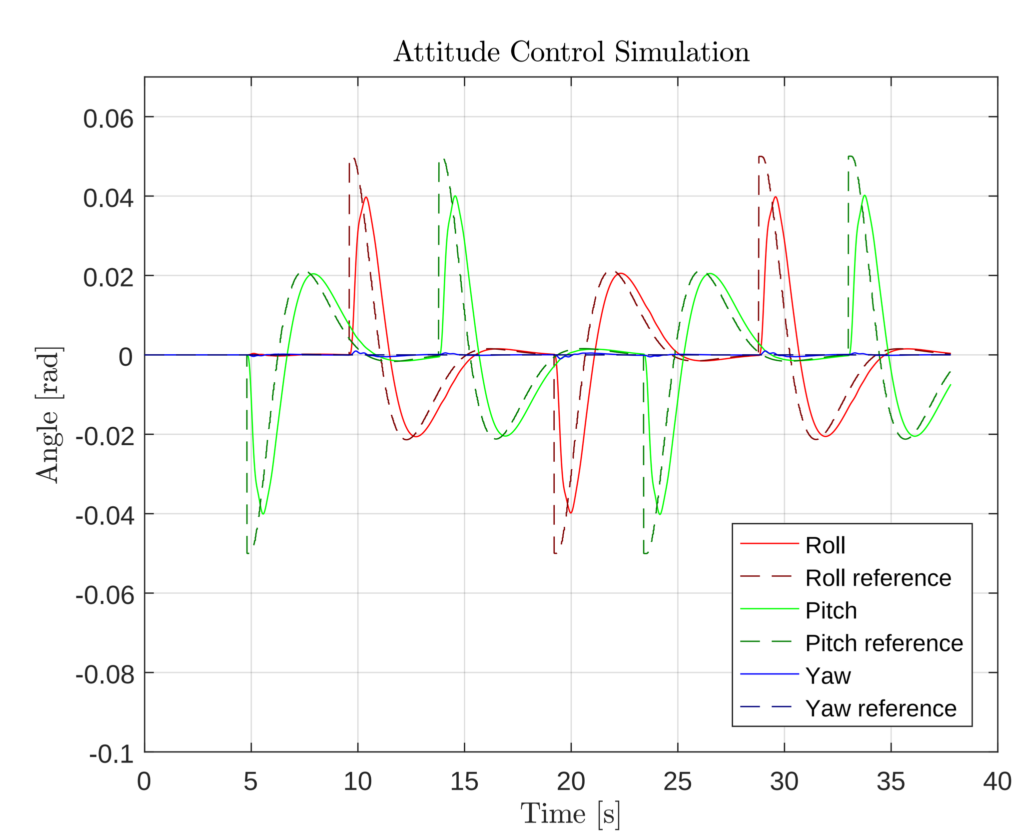
- Attitude controller
  State feedback with integral control, to be able to track references and handle disturbances, is used along with a reduced order observer.

- 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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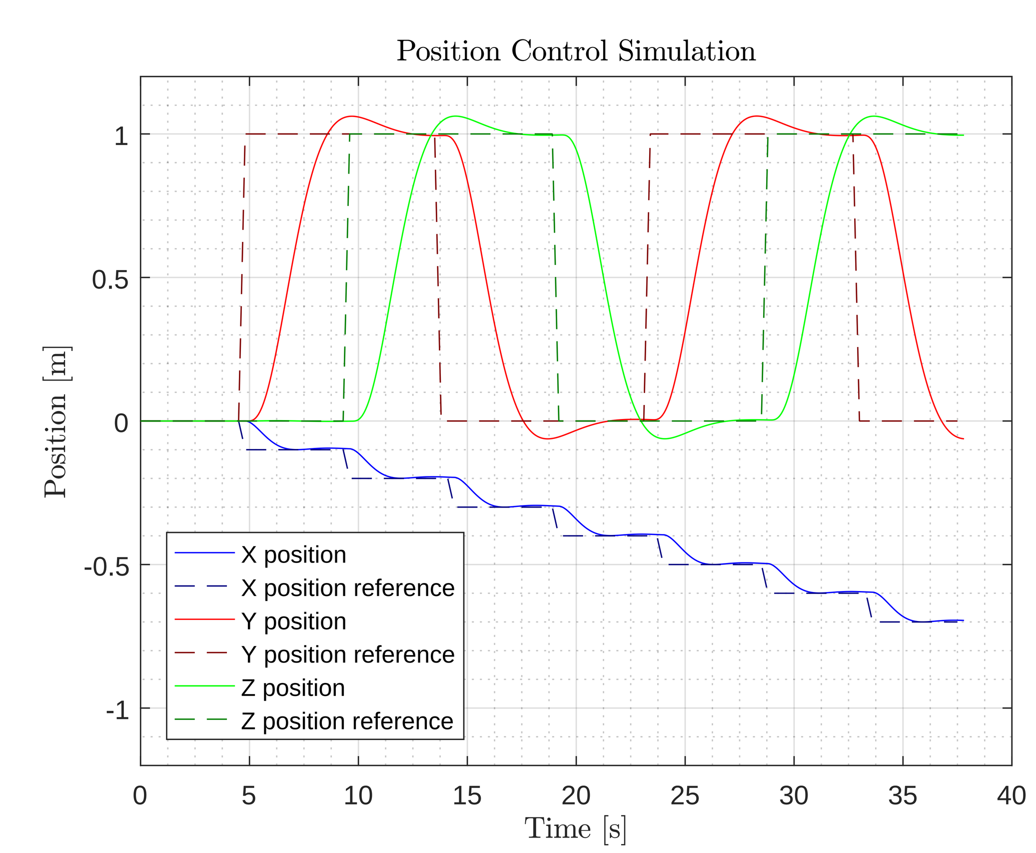

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Discussion

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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