Attitude and Position Control of a Quadcopter in a Networked Distributed System

Alejandro Alonso García, Amalie Vistoft Petersen, Andrea Victoria Tram Løvemærke, Niels Skov Vestergaard, Noelia Villarmarzo Arruñada

Agenda

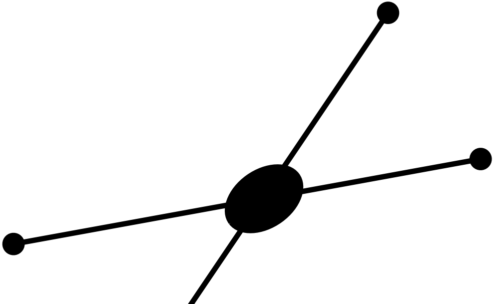
Introduction

Introduction

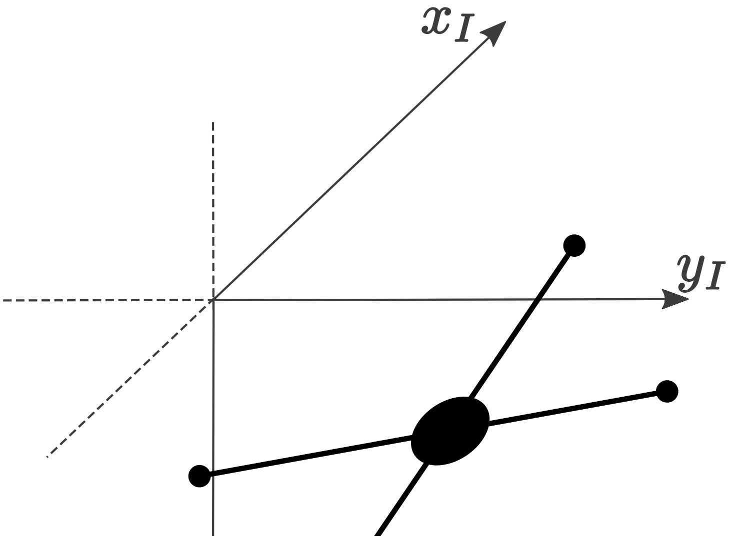
Introduction

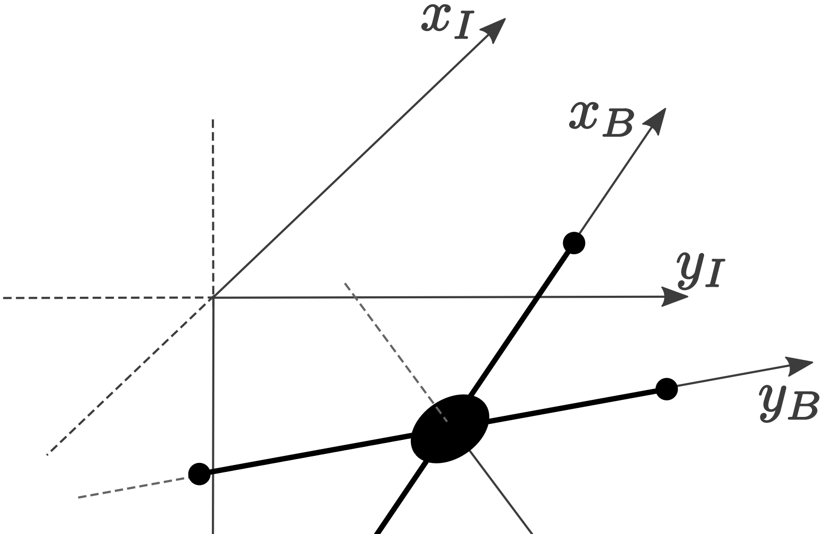
Agenda

Model
Free Body Diagram



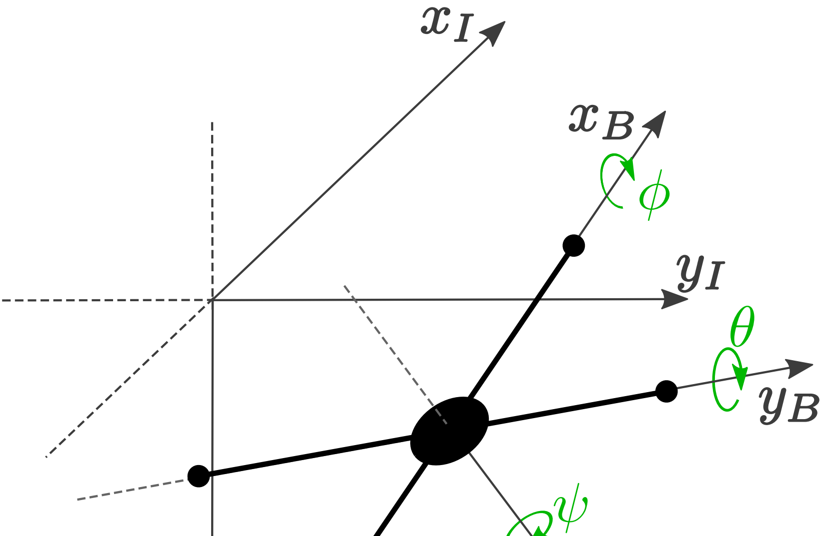
Model
Free Body Diagram



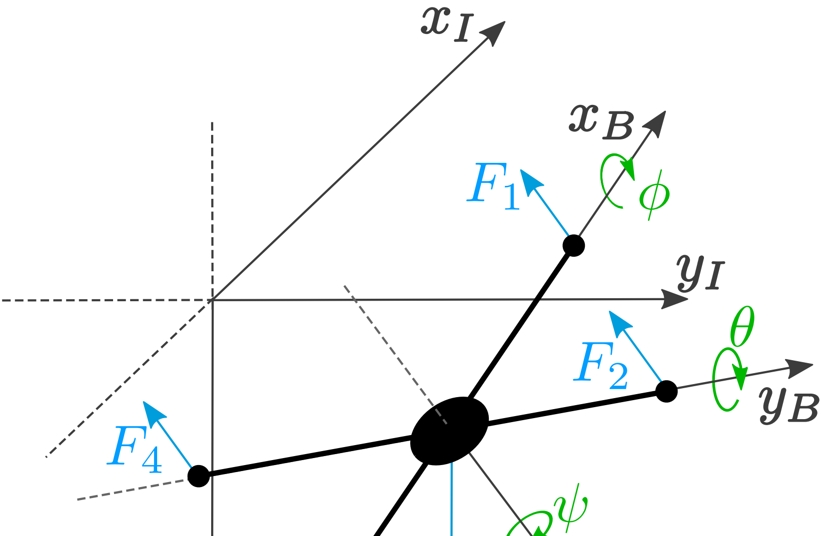


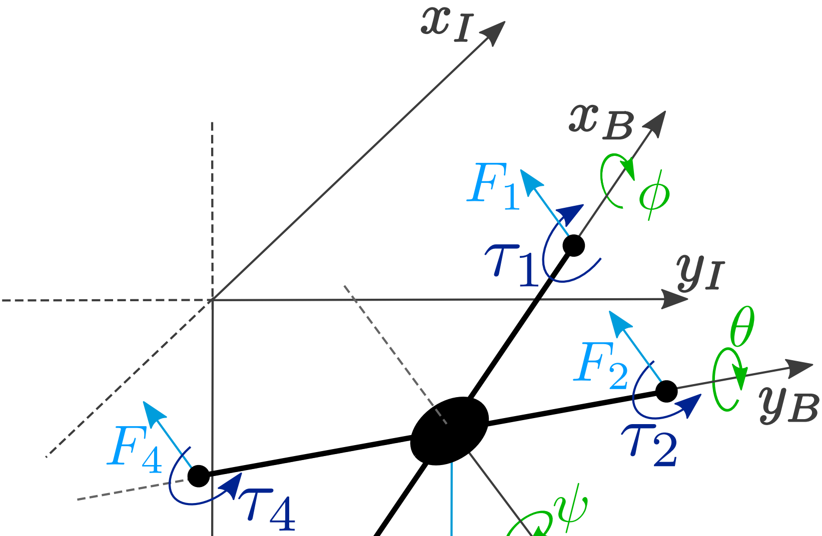
x_I
x_B
y_I
y_B

Model
Free Body Diagram



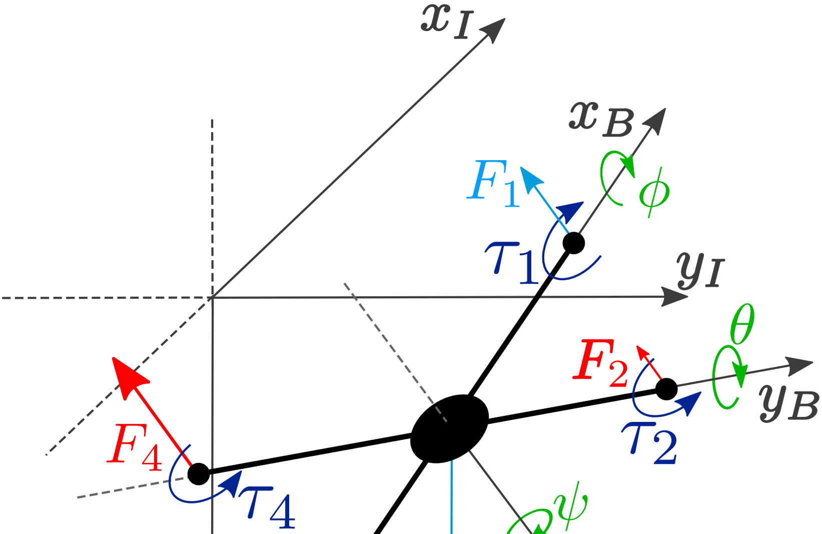
Model
Free Body Diagram

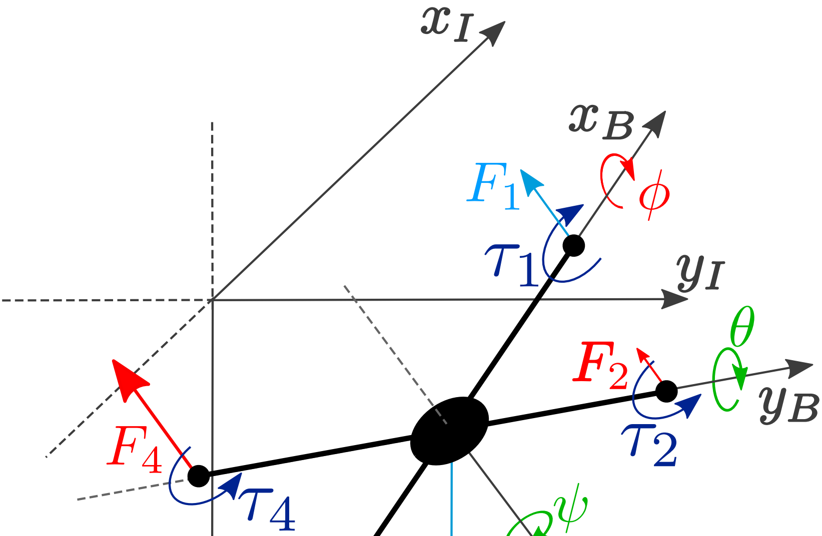



x_I
x_B
F_1
ϕ
τ_1
y_I
θ
F_2
y_B
τ_2
F_4
τ_4
ψ

Model

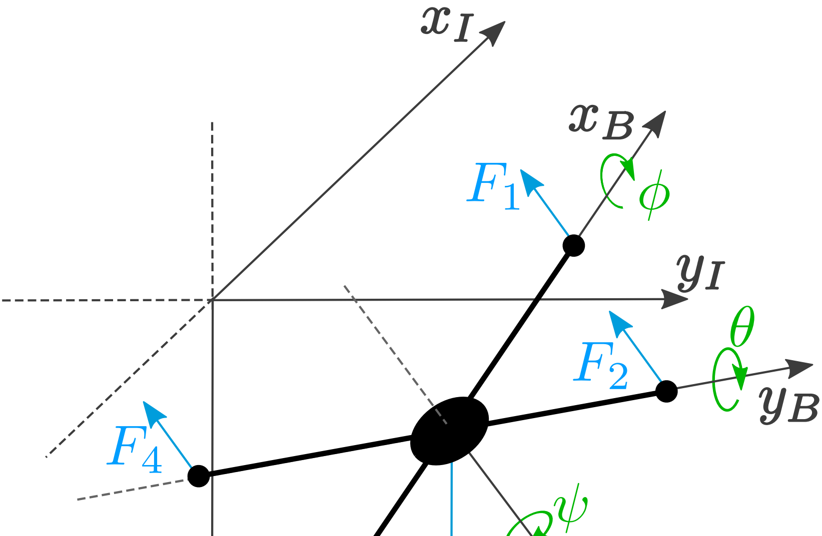
Free Body Diagram





x_I
x_B
F_1
ϕ
τ_1
y_I
θ
F_2
y_B
τ_2
F_4
τ_4
ψ

Model
Free Body Diagram



Translational Model

Something with rotation

Translational Model

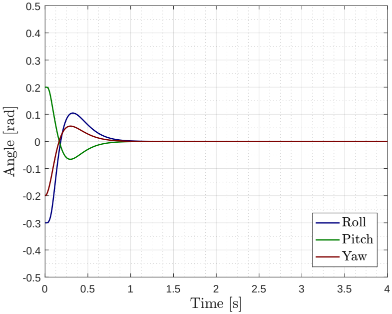
equations

Linearization of the Model

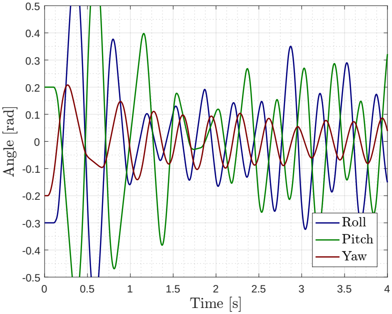
Network

talk about protocol

- Delay
- Missed packets



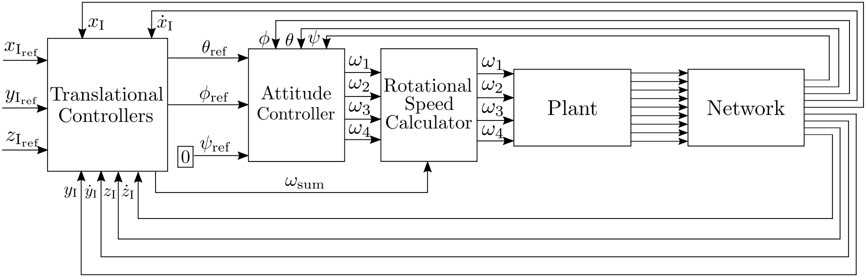
Control design only taking the model into account

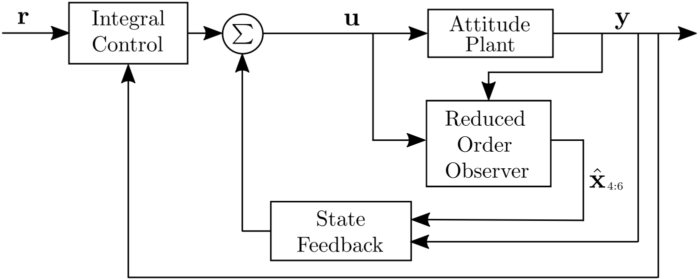


Same controller with the effect of the network

Agenda

Control Solution



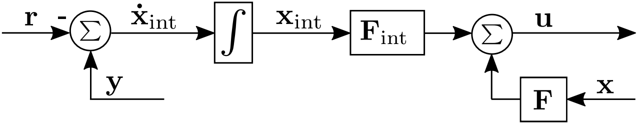


r
Integral Control
Σ
u
Attitude Plant
y
Reduced Order Observer
$\hat{\mathbf{x}}_{4:6}$
State Feedback

Control Solution
Attitude Controller

- System Representation

- State Feedback with Integral Control



extended

- LQR

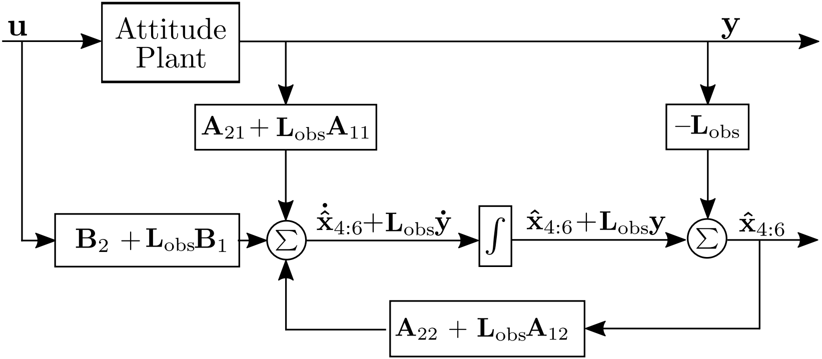
$$J = \int_0^{\infty} \mathbf{x}^T \mathbf{Q} \mathbf{x} + \mathbf{u}^T \mathbf{R} \mathbf{u} \; dt$$

- Bryson's Rule

$$Q_{ii} = \frac{1}{\text{maximum acceptable value of } [x_i^2]}$$

$$R_{ii} = \frac{1}{\text{maximum acceptable value of } [u_i^2]}$$

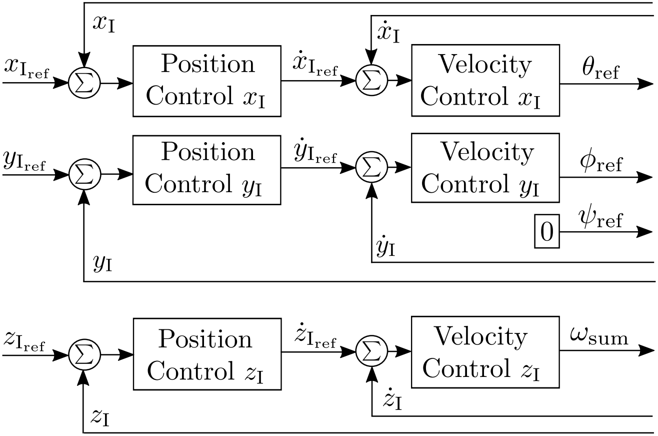
- Reduced Order Observer



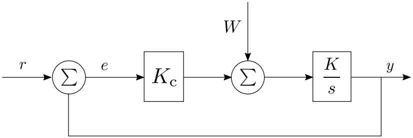
$$\mathbf{A}_{22} + \mathbf{L}_{\mathrm{obs}}\mathbf{A}_{12}$$

Agenda

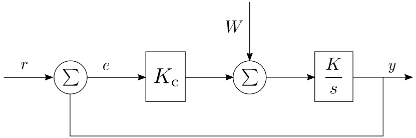
Control Solution
Translational Controller



Control Solution
Translational Controller

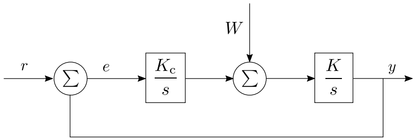


Control Solution
Translational Controller



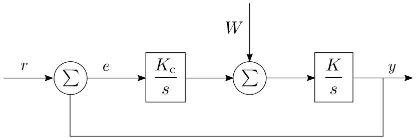
$$\frac{y}{W} = \frac{\frac{K}{s}}{1 + K_c \frac{K}{s}} = \frac{K}{s + K_c K} \Rightarrow \lim_{s \to 0} \frac{K}{s + K_c K} = \frac{1}{K_c}$$

Control Solution
Translational Controller



$$\frac{y}{W} = \frac{\frac{K}{s}}{1 + K_c \frac{K}{s}} = \frac{K}{s + K_c K} \Rightarrow \lim_{s \to 0} \frac{K}{s + K_c K} = \frac{1}{K_c}$$

Control Solution
Translational Controller



$$\frac{y}{W} = \frac{\frac{K}{s}}{1 + \frac{K_c}{s}\frac{K}{s}} = \frac{Ks}{s^2 + K_c K} \Rightarrow \lim_{s \to 0} \frac{Ks}{s^2 + K_c K} = 0$$

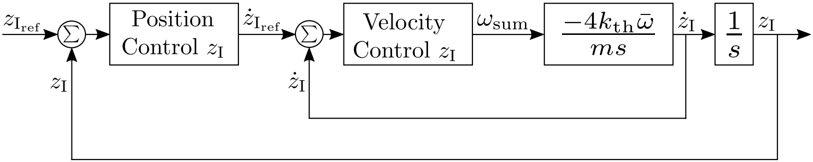
Control Solution
Translational Controller

$$\frac{\dot{x}_{\mathrm{I}}}{\theta} = \frac{-k_{\mathrm{th}} 4\overline{\omega}}{ms} \qquad \frac{\dot{y}_{\mathrm{I}}}{\phi} = \frac{k_{\mathrm{th}} 4\overline{\omega}}{ms} \qquad \frac{\dot{z}_{\mathrm{I}}}{\omega_{\mathrm{sum}}} = \frac{-2k_{\mathrm{th}}\overline{\omega}}{ms}$$

Control Solution

Translational Controller

$$\frac{\dot{x}_{\mathrm{I}}}{\theta} = \frac{-k_{\mathrm{th}}4\overline{\omega}}{ms} \qquad \frac{\dot{y}_{\mathrm{I}}}{\phi} = \frac{k_{\mathrm{th}}4\overline{\omega}}{ms} \qquad \frac{\dot{z}_{\mathrm{I}}}{\omega_{\mathrm{sum}}} = \frac{-2k_{\mathrm{th}}\overline{\omega}}{ms}$$

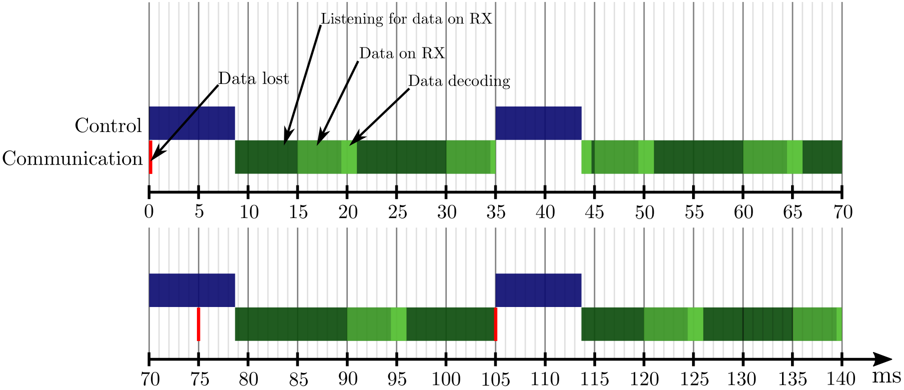


put three root locus

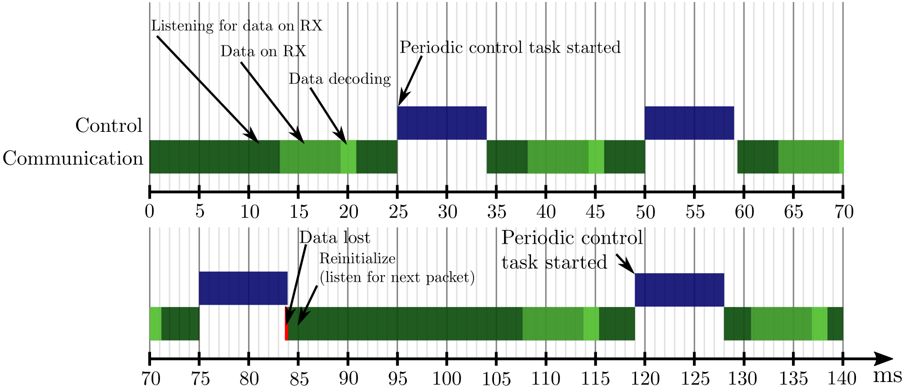
consideration of bandwidth equations for velocity controllers
equations for position controllers

Implementation

FreeRTOS, tasks

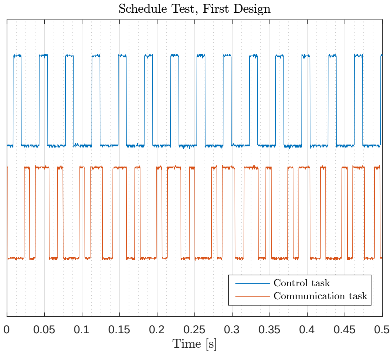


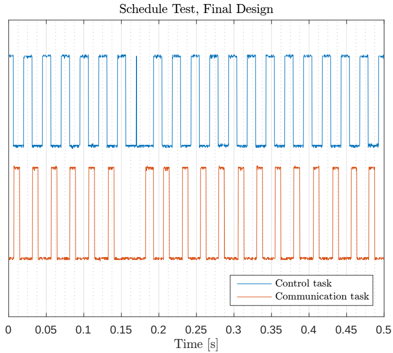
Listening for data on RX
Data on RX
Data lost
Data decoding
Control
Communication
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
70 75 80 85 90 95 100 105 110 115 120 125 130 135 140
ms



Listening for data on RX
Data on RX
Data decoding
Periodic control task started
Control
Communication
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Data lost
Reinitialize
(listen for next packet)
Periodic control
task started
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
ms

Implementation
Schedule





Agenda

Results

Attitude Controller Simulations

Results
Translational Controllers Simulations

Results
Attitude Controller Functional Tests

Conclusion

- Similar to SEMCON
-
-

Attitude and Position Control of a Quadcopter in a Networked Distributed System