Gain-Scheduled PI Control on Continuous Time Invariant Linearized Model of a Non-Linear Quadcopter (Unmanned Aerial Vehicle) System

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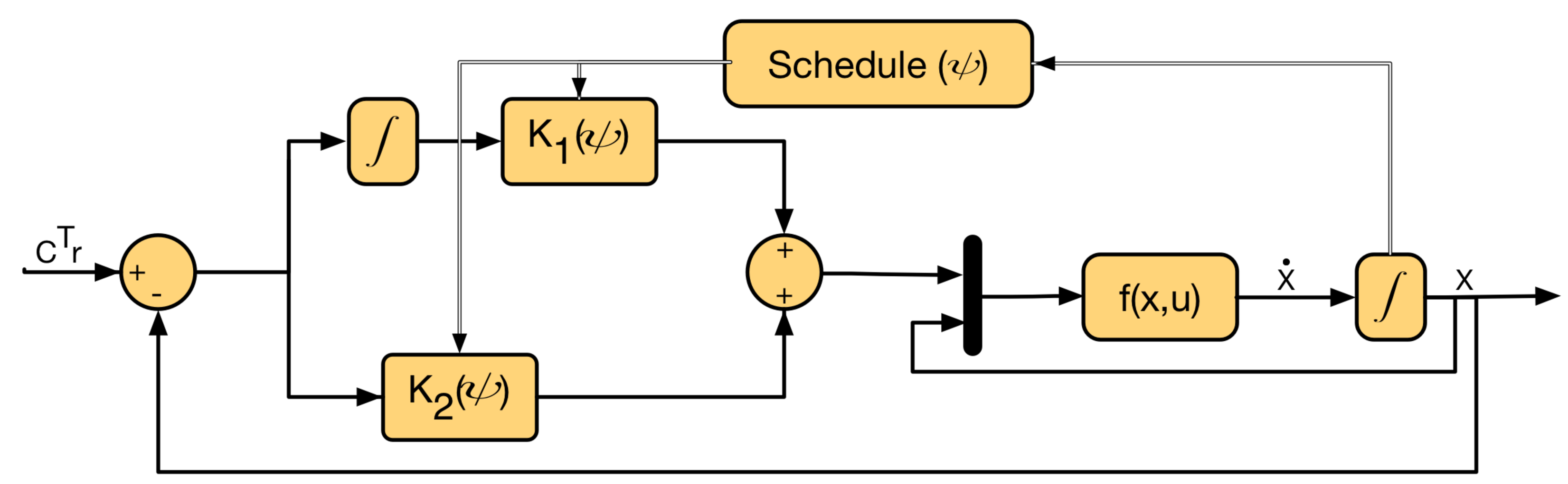
Motivation

Unmanned Aerial Vehicle
- Application: used for surveillance
- Under-actuated system
- Non-Linear Model
- Accurate trajectory tracking
- High maneuverability

Model used: Quadcopter-(AscTec-Pelican)

Quadcopter: UAV with four rotors

Schematic Diagram



Result

- Scheduling variable is the yaw angle.
- Adaptive gain matrix using linear quadratic regulator.
- Linear nature is preserved over the entire range by rebooting its parameters as the system evolves.
- Equilibrium is a hovering condition.

Design

Linear Model

$$\dot{x} = A(x-x_{ss}) + B(u-u_{ss})$$
$$y = Cx$$
$$x_{ss} = (x1_{ss}, y1_{ss}, z1_{ss}, 0, 0, \psi_{ss}, 0, 0, 0, 0, 0, 0)^T$$
$$u_{ss} = (g, 0, 0, 0)^T$$

Jacobian Matices

$$A = \begin{bmatrix} 0_{6\times6} & I_6 \\ \Psi & \Delta \end{bmatrix} \quad B = \begin{bmatrix} 0_{8\times4} \\ I_4 \end{bmatrix}$$

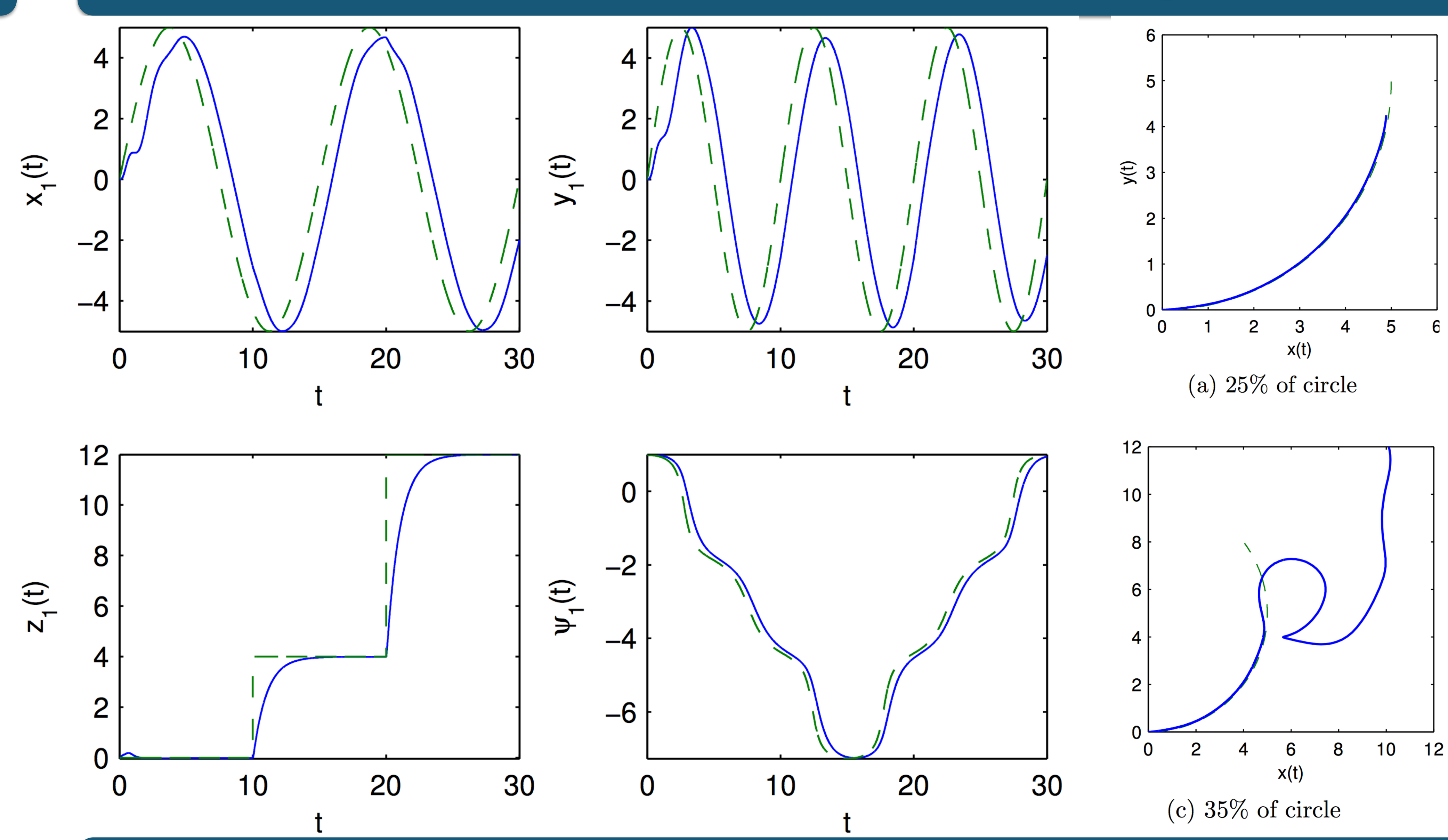
$$\Psi(\psi_{1ss}) = \begin{bmatrix} 0 & 0 & 0 & g\cos\psi_{1ss} & g\sin\psi_{1ss} & 0 \\ 0 & 0 & 0 & g\sin\psi_{1ss} & -g\cos\psi_{1ss} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} -k_1/m & 0 & 0 & 0 & 0 & 0 \\ 0 & -k_2/m & 0 & 0 & 0 & 0 \\ 0 & 0 & -k_3/m & 0 & 0 & 0 \\ 0 & 0 & 0 & -k_4 l/I_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -k_5 l/I_2 & 0 \\ 0 & 0 & 0 & 0 & 0 & -k_5/I_3 \end{bmatrix}$$

LQR Gain K

$$u = -k_1(x - C^T r) - k_2\sigma$$
$$\dot{\sigma} = Cx - r$$

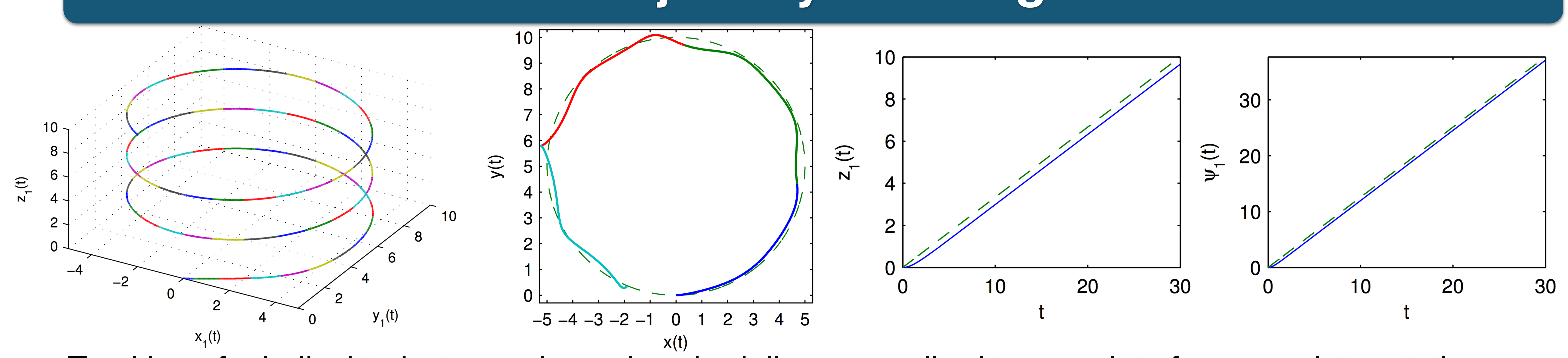
Set Point Tracking



(a) 25% of circle (b) 30% of circle (c) 35% of circle

Attempt to track the circular trajectory with varying yaw angle under fixed gain control. The tolerance for a set operating point is pi/6.

Trajectory Tracking



Tracking of a helical trajectory using gain scheduling, prescribed to complete four complete rotations.

RC Quadcopter

Fabrication of a quadcopter using Arducopter 2.8 flight controller.
- Communication is established using MAVLink protocol on a open source SIK firmware having a baud rate of 5700 with the ground station (APM-Planner).
- This allows us to interact in real time and receive streaming data from the camera installed and status of other components on board.
- 6 Channel Mode-2 RC flying is deployed.
- The quadcopter has the ability to fly in the guided mode (autonomously) by clicking on the waypoints on the map.

Quaternion Model

Motivation
- Covariance matrix has singularity in the Euler form
- The unity norm constraint, which is quadratic in form, is particularly problematic if the attitude parameters are to be included in an optimization, as most standard optimization algorithms cannot encode such constraints.
- Euler angles are less accurate than unit quaternion when used to integrate incremental changes in attitude.

Future work

Fractional order controller is being designed and simulated on the bases of quaternion error model.