Advanced Autonomous Systems – 2021
Project 0

This short project is composed by problems which are useful as a training session, for preparing you for projects during subsequent weeks in AAS.

Problem 1

Given the following approximate model of a pendulum,

$$\ddot{\theta}(t) = -A \cdot \sin(\theta(t)) - B \cdot \dot{\theta}(t) + C \cdot u(t)$$

$$A = 110 \cdot \frac{rad}{s^2}, \quad B = 2.2 \cdot \frac{1}{s}, \quad C = 1.1 \cdot \frac{rad}{s^2 \cdot volt}$$

where $\theta(t)$ is the angular position (expressed in radians) of the pendulum, and $u(t)$ is the voltage (expressed in volts) controlling the pendulum's electric motor.

a) Obtain a valid state space representation for this system, in continuous time.
b) Obtain an approximate discrete time model (using Euler's approximation), for a sample time dt=1ms.
c) Implement a program (in plain Matlab language), for simulating the model proposed in (b).

Test your program simulating the following cases:

c.1) The pendulum is released, at time =0, having the following initial conditions: angular velocity =0 and angle = 110 degrees. The voltage of the electric motor is assumed to be constantly 0 volts (no torque being applied by the motor).

c.2) Similar to (c.1) but having the electric motor controlled with a constant voltage = 3 volts.

In both cases, perform the simulation for an interval of time from 0 to t=7 seconds.
Plot the results (position and angular velocity) in a figure.

d) Using the model implemented in item c, implement a simulation in Simulink.

Problem 2

Given the following simplified 3DoF kinematic model (of a car-like wheeled platform),

$$\dot{x}(t) = v(t) \cdot \cos(\theta(t))$$
$$\dot{y}(t) = v(t) \cdot \sin(\theta(t))$$
$$\dot{\theta}(t) = \tan(\alpha(t)) \cdot {}^{v(t)}\!/\!_{L}$$

a) Obtain an approximate discrete-time version of the model, assuming small discrete steps, e.g. of dt=0.01 seconds (10ms). Consider the case of a vehicle that has ***L=2.5m***.

b) Implement a program for simulating the system in (a). Run it under different steering actions (sequences of steering angles $\alpha(k)$) and assume constant speed, $v(k) = 3.5$ m/s, $\forall k$.

c.1) See what happen if you keep the steering angle set at a constant value.
c.2) Try to generate a path having an 8-shape (define a proper sequence of control actions to achieve it).

c.4) Apply a small modification on the model (e.g. a small change in parameter L) and see how the result is affected, for a long-term simulation (for cases c.1 and c.2). Plot, jointly, both models' trajectories using different colors, to appreciate the different responses.

Note: The main purpose of this task is to give the students some initial training, before the actual projects are released. This task is intended to be solved during week 1.