Group Project: Design Phase

CSE 499

System Physics

Determining Robot Angle:

Using the accelerometer:

- Let
  - Accel = results from the accelerometer based on axis (x, y, z)
  - Phi = distance from -z axis angle (in degrees) (default 0)
  - RAD2DEG = 360/pi
  - pi = 3.14159
- accelAngle = $tan^{-1}\frac{accel\,Y}{accel\,Z} \bullet RAD2DEG$

Using the tilt sensors:

- Let
  - Gyro = results from the tilt sensor on the x-axis
  - Psi = angle produced by gyroscope (default 0)
  - dt = change in time from last update = current time - previous time (in ms)
- gyroAngle = gyro X * dt / 1000

Final Formula

- Let
  - Alpha = 0.95 so gyroscope has larger impact on system
- newAngle = $Alpha \cdot accelAngle + (1 - Alpha) \cdot gyroAngle$
- newAngle = $\alpha \cdot \theta_g + (1 - \alpha) \cdot \theta_a$

Inverted Pendulum: [1]

- Let
  - (measurements are approximated until proper measurements made)
  - M = mass of base = 0.4 kg
  - m = mass at pendulum end = 0.3 kg
  - l = pendulum length = 0.2 m
  - b = coefficient of friction = 0.1 $N/(m \cdot s)$
  - I = pendulum inertia = 0.006 $kg \cdot m^2$
  - U = Force
  - Theta = pendulum angle
  - Phi = deviation from 0 degrees/radians
  - g = gravitational acceleration = $9.8\ m/s^2$
- ODEs

- $(I + ml^2)\Phi'' - mgl\Phi = mlx''$
- $(M + m)x'' + bx' - ml\Phi'' = u$

- Laplace Transforms
  - $q = (M + m)(I + ml^2) - (ml)^2$
  - $\frac{\Phi(s)}{U(s)} = \frac{\frac{ml}{q}s}{s^3 + \frac{b(I+ml^2)}{q}s^2 - \frac{(M+m)mgl}{q}s - \frac{bmgl}{q}}$

Sampling

ADC Elements:

- Accelerometer Sensor
  - Helps determine the direction of the robot
  - 400 kHz max frequency
  - Sample Period
    - $T \leq \frac{1}{2f_{max}} = 1.25\, ms$
- Tilt Sensor
  - Helps determine the orientation of the robot
  - No sampling restrictions
- Ultrasonic Sensor
  - Help determine if the robot is about to collide with an object
  - 10 microsecond delay required
  - distance = (long *)(duration / 15.2)

Control System Specifications

- Gain: Kp = 19, Ki = 10, Kd = 5 (trial and error from MATLAB)
- Damping Ratio: .916% (from MATLAB)
- Time Constants: 1.2824 s
  - $\tau \leq \frac{1}{\zeta\omega_N} = \frac{1}{.916 \cdot 1.4} = 1.2824$
- Natural Frequency: 1.4 rad/s (from MATLAB)

Citations

[1] University of Michigan, "Inverted Pendulum: System Modeling," *Control Tutorials for MATLAB and Simulink - Inverted Pendulum: System Modeling*. [Online]. Available: https://ctms.engin.umich.edu/CTMS/index.php?example=InvertedPendulum&section=SystemModeling. [Accessed: 13-Mar-2022].