

GFM Autotuning

Inputs

- Required imputed
- maxTrq maximum allow torque
- maxVel maximum positive speed
- maxPos maximum positive position
- minVel maximum negative speed
- minPos maximum negative position;
- phi_m_v speed loop phase margin (now 75°)
- MinWc minimum value of the controller bandwidth
- MaxWc maximum value of the controller bandwidth
- pOscillationTolerance allow torque oscillation tolerance, torque standard deviation will be smaller than $\text{maxTrq} * \text{pOscillationTolerance}$ (now 0.3)
- pLow_Vel_Thr threshold between low- and high-speed conditions.

Autotuning states

- State 0: Noise Level Identification
 - Description: Identify velocity noise. The motor does not move, noise is the maximum absolute value of the velocity
 - Control mode: torque
 - Transitions: to state *Timeld (default: 1.0)* seconds.
- State 1: Static friction identification
 - Description: Identify static friction (namely, the Coulomb coefficient). The torque is increased until the motor start to move.
 - Control mode: torque
 - Transitions: to state 1 for *friction_trial* times, then go to state 2.

Autotuning states

- State 2: Inertia identification
 - Description: Identify viscous friction coefficient and the motor inertia. The motor moves in positive and negative directions.
 - Control mode: torque
 - Transitions: to state 1 after *Time_identification (default: 7.0)* seconds.
- State 3: Inertia identification - stopping
 - Description: stop motor after identification.
 - Control mode: torque
 - Transitions:
 - to state 4 if the identified parameters are correct setting the bandwidth equal to the minimum value
 - to state 100 otherwise.

Autotuning states

- State 100: reset to wrong model identification
 - Description: reset the autotuner and repeat identification
 - Control mode: torque
 - Transitions: to state 0 if *estimation_trials* is less than 3, otherwise go to state 92.
- State 4: tuning at low-speed levels
 - Description: update low-speed controller parameters and switch to speed mode.
 - Control mode: torque
 - Transitions: to state 5 when the parameters have been updated

Autotuning states

- State 5: stop movements
 - Description: ensure that the motor is stopped
 - Control mode: speed
 - Transitions: to state 6 after *TrialTime* (default: 2.0) seconds, or $0.2 * TrialTime$ seconds if the speed is smaller than the noise level. Set velocity setpoint to a random value, smaller than the threshold between low and high velocity ($maxVel * low_vel_thr$)
- State 6: rise time
 - Description: compute the rise time at 95% of the setpoint value.
 - Control mode: speed
 - Transitions:
 - to state 7 when speed reach 95% of the setpoint
 - To state 9 if the speed overshoot is greater than 30%.

Autotuning states

- State 7: waiting steady state
 - Description: wait the end of the transient
 - Control mode: speed
 - Transitions:
 - to state 8 after $\min(0.4 * TrialTime, 3.0 * rise\ time)$ seconds.
 - To state 9 if the speed overshoot is greater than 30%.

Autotuning states

- State 8: computing variance
 - Description: compute torque variance and standard deviation *SIGMA*
 - Control mode: speed
 - Transitions:
 - to state 4 after $\min(0.7 * TrialTime, 5.0 * rise\ time)$ seconds If the standard deviation *SIGMA* is smaller than the threshold and the control bandwidth is smaller than the maximum value, increasing the controller bandwidth
 - To state 9 after $\min(0.7 * TrialTime, 5.0 * rise\ time)$ seconds If the standard deviation *SIGMA* is greater than the threshold and the control bandwidth is greater than the maximum value. Change to high speed tuning, set bandwidth equal to the minimum value
- State 9: tuning at high-speed levels
 - Description: update high-speed controller parameters
 - Control mode: speed
 - Transitions: to state 5 when the parameters have been updated

Autotuning states

- State 10: stop movements
 - Description: ensure that the motor is stopped
 - Control mode: speed
 - Transitions: to state 11 after *TrialTime* (default: 2.0) seconds, or $0.2 * TrialTime$ seconds if the speed is smaller than the noise level. Set velocity setpoint to a random value, greater than the threshold between low and high velocity ($maxVel * low_vel_thr$)
- State 11: rise time
 - Description: compute the rise time at 95% of the setpoint value.
 - Control mode: speed
 - Transitions: Transitions:
 - to state 12 when speed reach 95% of the setpoint
 - To state 9 if the speed overshoot is greater than 30%.

Autotuning states

- State 12: waiting steady state
 - Description: wait the end of the transient
 - Control mode: speed
 - Transitions:
 - to state 8 after $\min(0.4 * TrialTime, 3.0 * rise\ time)$ seconds.
 - To state 9 if the speed overshoot is greater than 30%.

Autotuning states

- State 13: computing variance
 - Description: compute torque variance and standard deviation *SIGMA*
 - Control mode: speed
 - Transitions:
 - to state 9 after $\min(0.7 * TrialTime, 5.0 * rise\ time)$ seconds If the standard deviation *SIGMA* is smaller than the threshold and the control bandwidth is smaller than the maximum value, increasing the controller bandwidth
 - To state 14 after $\min(0.7 * TrialTime, 5.0 * rise\ time)$ seconds If the standard deviation *SIGMA* is greater than the threshold and the control bandwidth is greater than the maximum value.
- State 9: save tuning at high-speed levels
 - Description: update high-speed controller parameters
 - Control mode: speed
 - Transitions: to state 15 when the parameters have been updated

Autotuning states

- State 15: tuning completed
 - Description: tuning completed, final state.
 - Control mode: speed
 - Transitions: NONE
- State 91: velocity tracking error
 - Description: unable to reach steady state during the tuning phase
 - Control mode: speed
 - Transitions: NONE
- State 92: parameter identification error
 - Description: unable to identify the model
 - Control mode: torque
 - Transitions: NONE

Autotuning states

- State 99: constraints violation
 - Description: constraints violation
 - Control mode: speed/torque
 - Transitions: NONE

Test in HIL

Estimated friction compared to the HIL value

COMPLETE TEST CAMPAIGN

