Guidance Laws for Setpoint Publisher

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Let r be a reference signal sent to a system and let r_{sp} be the desired setpoint. Sudden changes in magnitude in r may destabilize the commanded system. Hence, a guidance law is required to smooth r in time. In the following section, we'll present guidance laws for a discrete setpoint publisher application. While the laws may be based in continous-time algorithms, discrete time versions will be derived. Let T_{s} be the rate at which the setpoints are published, and let k be the discrete-time step, such that $r_k = r(kT_{\mathrm{s}})$.

1st order guidance law

Let the guidance law be given by

$$\dot{r} = K(r_{\mathrm{sp}} - r) = -Kr + Kr_{\mathrm{sp}}, \tag{1}$$

where $K > 0$ is a tunable parameter. Using exact discretization, the discretized version of the previous equation is given by

$$r_k = e^{-KT_{\mathrm{s}}} r_{k-1} + (1 - e^{-KT_{\mathrm{s}}}) r_{\mathrm{sp}}. \tag{2}$$

Let $K_{\mathrm{f}} \triangleq KT_{\mathrm{s}}$, such that

$$r_k = e^{-K_{\mathrm{f}}} r_{k-1} + (1 - e^{-K_{\mathrm{f}}}) r_{\mathrm{sp}}. \tag{3}$$

The guidance law becomes more aggressive as K_{f} increases in magnitude.

2nd order guidance law

Let the guidance law be given by

$$\ddot{r} = -\omega_{\mathrm{n}}^2 r - 2\zeta\omega_{\mathrm{n}}\dot{r} + \omega_{\mathrm{n}}^2 r_{\mathrm{sp}}, \tag{4}$$

where $\omega_n, \zeta > 0$ are tunable parameters. Using exact discretization, the discretized version of the previous equation is given by

$$r_k = -a_1 r_{k-1} - a_2 r_{k-2} + b r_{\mathrm{sp}}, \tag{5}$$

where,

$$b = 1 + a_1 + a_2, \tag{6}$$
$$a_1 = -2R\cos\theta, \tag{7}$$
$$a_2 = R^2, \tag{8}$$
$$R = e^{-T_{\mathrm{s}}\zeta\omega_{\mathrm{n}}}, \tag{9}$$
$$\theta = T_{\mathrm{s}}\omega_{\mathrm{n}}\sqrt{|1-\zeta^2|}. \tag{10}$$

Let $\omega_{\mathrm{f}} \triangleq \omega_{\mathrm{n}} T_{\mathrm{s}}$, such that

$$R = e^{-\zeta\omega_{\mathrm{f}}}, \tag{11}$$
$$\theta = \omega_{\mathrm{f}}\sqrt{|1-\zeta^2|}. \tag{12}$$

A value of $\zeta > 1$ usually results in a smoother response. The guidance law becomes more aggressive as ω_{f} increases in magnitude.

Maximum velocity constraint for 1st and 2nd order laws

Suppose $\dot{r}$ is constrained such that $|\dot{r}| < \dot{r}_{\mathrm{max}}$. A rate limiter can be implemented in the 1st and 2nd order laws to weakly impose this constraint, such that, in the case where $|r_k - r_{k-1}| > \dot{r}_{\mathrm{max}} T_{\mathrm{s}}$,

$$r_k = r_{k-1} + \mathrm{sign}(r_k - r_{k-1}) \dot{r}_{\mathrm{max}} T_{\mathrm{s}}. \tag{13}$$