Depth control of a float

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Surface drifting buoys

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Shepherd

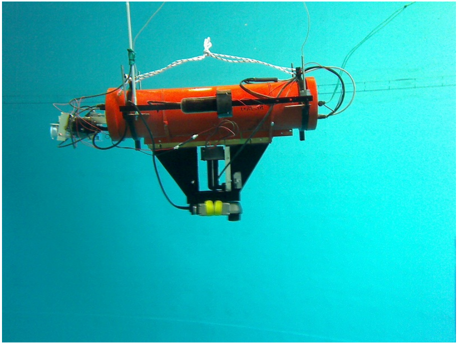
www.ensta-bretagne.fr/jaulin/shepherd.html

Control

Three examples

- The crank
- The car
- The traffic jam

Depth control

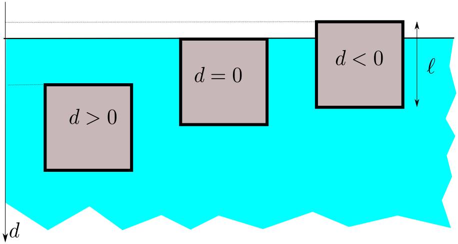


PID control is fine, since the relative degree is $\rho = 2$. With a ballast $\rho = 3$

For the buoy, we need to include the model inside the controller

1. To be precise
2. To have a low consumption

We consider an underwater buoy, a cube of width ℓ, immersed in the water of density $\rho_0(z)$.



Underwater buoy controlled by a ballast

The total force applied to the buoy is

$$f = \underbrace{mg}_{f_g\downarrow} - \underbrace{\rho_0(z)\, g \ell_z^2 \cdot \max(0, \ell_z + \min(d, 0))}_{f_a\uparrow} - \underbrace{\frac{1}{2}\rho_0(z)\, v \cdot \mid v \mid \ell_z^2 c_x}_{f_d\updownarrow}$$

A ballast allows us to control the density of the buoy which is $(1 + \beta b)\,\rho_b(z)$, where $\beta = 0.1$.

Since the mass of the buoy is $m=(1+\beta b)\,\rho_b(z)\,\ell_z^3$. The second Newton law tells us that

$$m\dot{v}=mg-\rho_0 g\ell_z^2\cdot\max(0,\ell_z+\min(d,0))-\frac{1}{2}\rho_0(z)\,v\cdot\mid v\mid\ell_z^2 c_x.$$

The state equations are thus

$$\left\{\begin{array}{lcl}\dot{d} & = & v\\ \dot{v} & = & g-\frac{\rho_0(z)g\ell_z^2\cdot\max(0,\ell_z+\min(d,0))+\frac{1}{2}\rho_0(z)v\cdot|v|\ell_z^2 c_x}{(1+\beta b)\rho_b(z)\ell_z^3}\\ \dot{b} & = & u\end{array}\right.$$

When no saturation exists, we have

$$\begin{cases} \dot{d} & = & v \\ \dot{v} & = & g - \frac{\rho_0(z)}{\rho_b(z)} \cdot \frac{g\ell_z + \frac{1}{2} v \cdot |v| c_x}{(1+\beta b)\ell_z} \\ \dot{b} & = & u \end{cases}$$

We have

$$\begin{aligned} \dot{y} &= \dot{d} = v \\ \ddot{y} &= g - \frac{\rho_0(z)}{\rho_b(z)} \cdot \frac{g\ell_z + \frac{1}{2} v \cdot |v| c_x}{(1+\beta b)\ell_z} \end{aligned}$$

In our particular case, since here, $\ddot{y}$ is monotonic with respect to b, we do not need to compute the third derivative $\dddot{y}$.

The sliding surface is

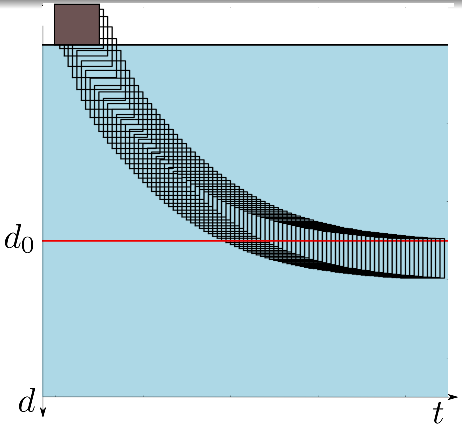
$$s(\mathbf{x},t) = \underbrace{\ddot{y}_d - \ddot{y}}_{\ddot{e}} + \alpha_1 \underbrace{(\dot{y}_d - \dot{y})}_{\dot{e}} + \alpha_0 \underbrace{(y_d - y)}_{e} = 0,$$

If may take $\alpha_1 = 2, \alpha_0 = 1$ to have the stability, we get:

$$\ddot{d}_0 - \left(g - \frac{\rho_0(z)}{\rho_b(z)} \cdot \frac{g\ell_z + \frac{1}{2} v \cdot \mid v \mid c_x}{(1+\beta b)\ell_z} \right) + 2\left(\dot{d}_0 - v\right) + (d_0 - d) = 0.$$

We choose

$$u = \operatorname{sign}\left(\ddot{d}_0 - \left(g - \frac{\rho_0(z)}{\rho_b(z)} \cdot \frac{g\ell_z + \frac{1}{2} v \cdot |v| c_x}{(1+\beta b)\ell_z}\right) + 2\left(\dot{d}_0 - v\right) + d_0 - d\right).$$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Perspectives


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