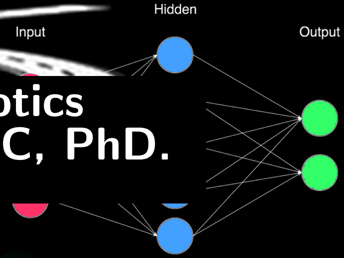
$$Q(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha\left[r_{t+1} + \lambda \max_a Q(s_{t+1}, a) - Q(s_t, a_t)\right]$$

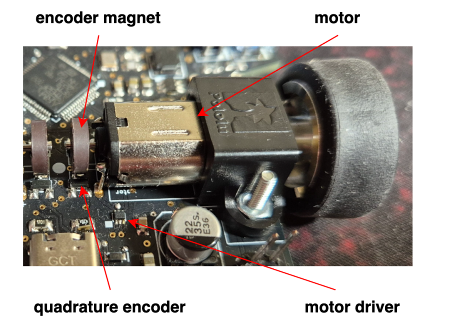
(The New Action Value = The Old Value) + The Learning Rate × (The New Information − the Old Information)

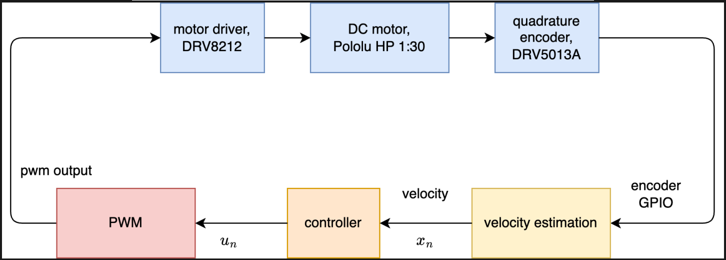
Algorithms for robotics

Michal CHOVANEC, PhD.



motor velocity controller





motor parameters

- motor maximum input range $u_{max} = 1.0$
- motor constant $k = 139.084$
- motor time constant $\tau = 8.276[ms]$

$$\alpha = -\frac{1}{\tau}$$

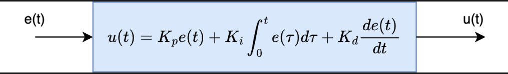
$$\beta = k\frac{1}{\tau}$$

$$\frac{d\omega(t)}{dt} = \alpha\omega(t) + \beta u(t)$$

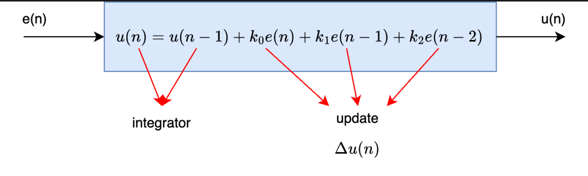
$$\frac{d\omega(t)}{dt} = -120.83\omega(t) + 16805.7u(t)$$

PID control

- textbook continuous controller



- discrete controller



$$k_0 = K_p + K_i \Delta t + \frac{K_d}{\Delta t}$$

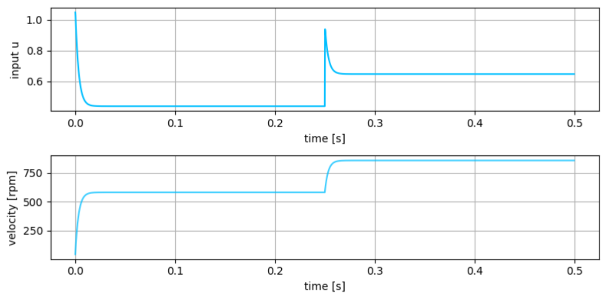
$$k_1 = -K_p - 2\frac{K_d}{\Delta t}$$

$$k_2 = \frac{K_d}{\Delta t}$$

PID control - P only

- target value : **1000rpm**
- P-only control causes **steady state error**

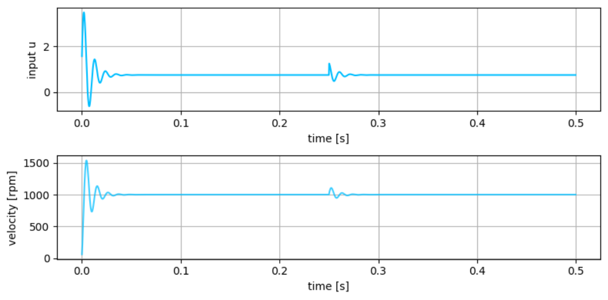
$$u(n) = u(n-1) + k_p e(n) - k_p e(n-1)$$
$$k_p = 0.01$$



PID control - PI

- target value : **1000rpm**
- PI control **removes steady state error**
- too high I term causes **oscilations and overshot**

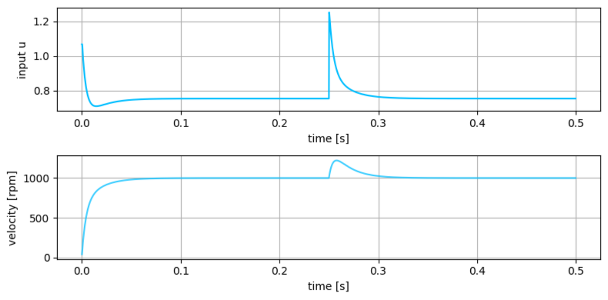
$$
\begin{aligned}
u(n) &= u(n-1) + (k_p + k_i \Delta t)e(n) - k_p e(n-1) \\
k_p &= 0.01 \\
k_i &= 0.005
\end{aligned}
$$



PID control - PI

- target value : **1000rpm**
- correct tunned PI controller for 1st order system
- **no overshot, no steady state error**

$$u(n) = u(n-1) + (k_p + k_i \Delta t)e(n) - k_p e(n-1)$$
$$k_p = 0.01$$
$$k_i = 0.0002$$



complete generic discrete PID

1. calculate u-change candidate :

$$\Delta\hat{u}(n) = k_0 e(n) + k_1 e(n) + k_2 e(n)$$

2. clip maximum allowed u-change, to avoid u-kick :

$$\Delta u(n) = clip(\Delta\hat{u}(n), -du_{min}, du_{max})$$

3. clip maximum allowed u value, to avoid saturation / windup :

$$u(n) = clip(u(n-1) + \Delta u(n), -u_{min}, u_{max})$$

complete generic discrete PID

```python
def __init__(self, kp, ki, kd, antiwindup = 10**10, du_max=10**10):
    self.k0 = kp + ki + kd
    self.k1 = -kp -2.0*kd
    self.k2 = kd

    self.e0 = 0.0
    self.e1 = 0.0
    self.e2 = 0.0


    self.antiwindup = antiwindup
    self.du_max     = du_max
```

```python
def forward(self, xr, x, u_prev):
    # error compute
    self.e2 = self.e1
    self.e1 = self.e0
    self.e0 = xr - x

    du = self.k0*self.e0 + self.k1*self.e1 + self.k2*self.e2

    #kick clipping, maximum output value change limitation
    du  = numpy.clip(du, -self.du_max , self.du_max)

    #entiwindup, maximum output value limitation
    u   = numpy.clip(u_prev + du,  -self.antiwindup, self.antiwindup)

    return u
```

PID control - issues

- mostly hand tuned parameters
- only single input, single output systems
- no implicit noise filtering