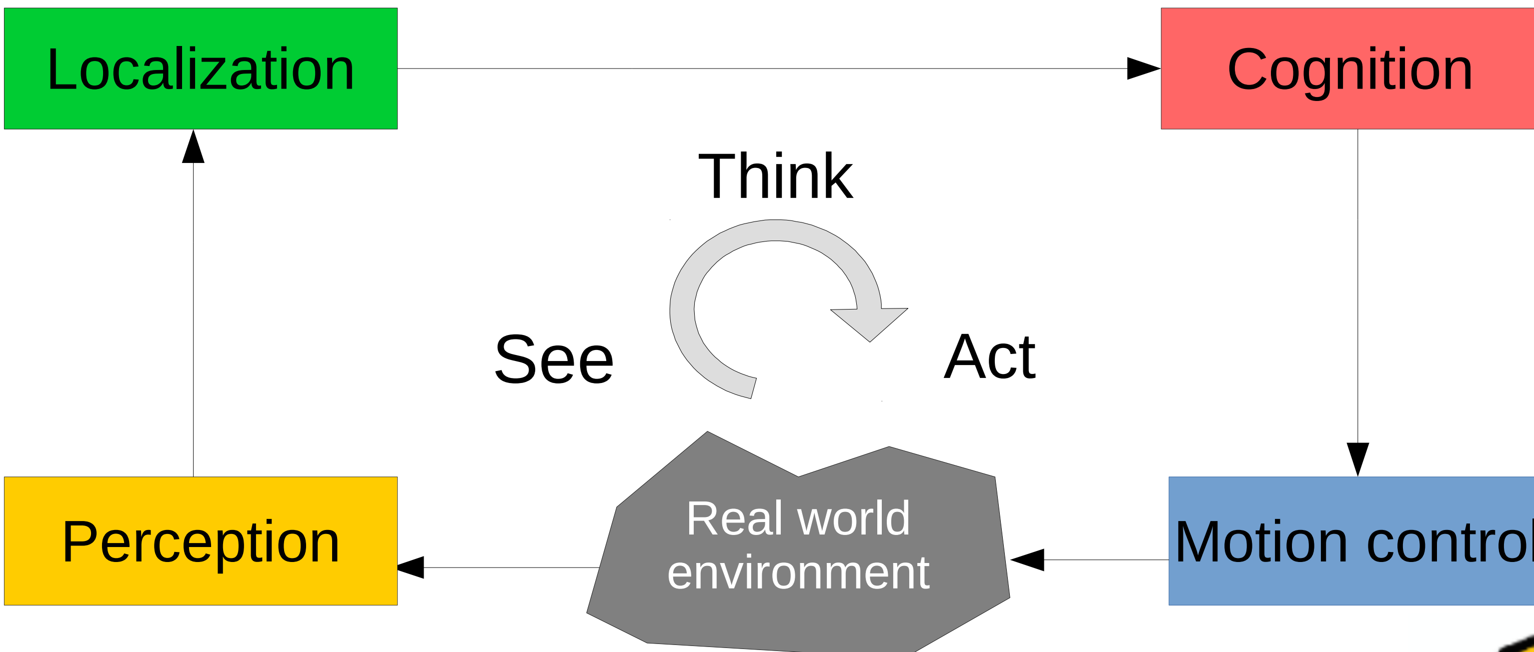
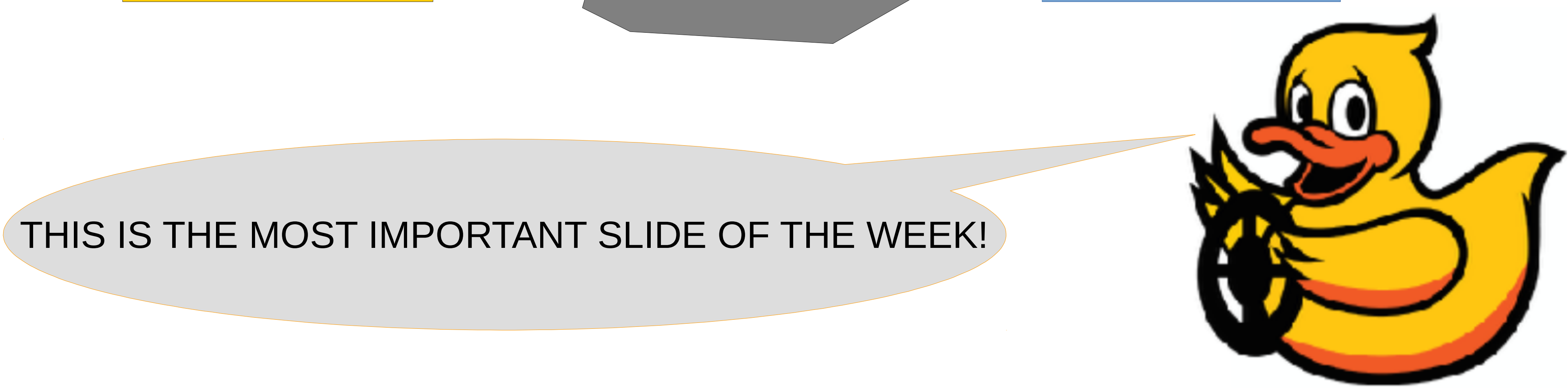
Autonomous mobile robot

See – think – act





Autonomous Mobile Robots – R. Siegwart, I. Nourbakhsh, D. Scaramuzza

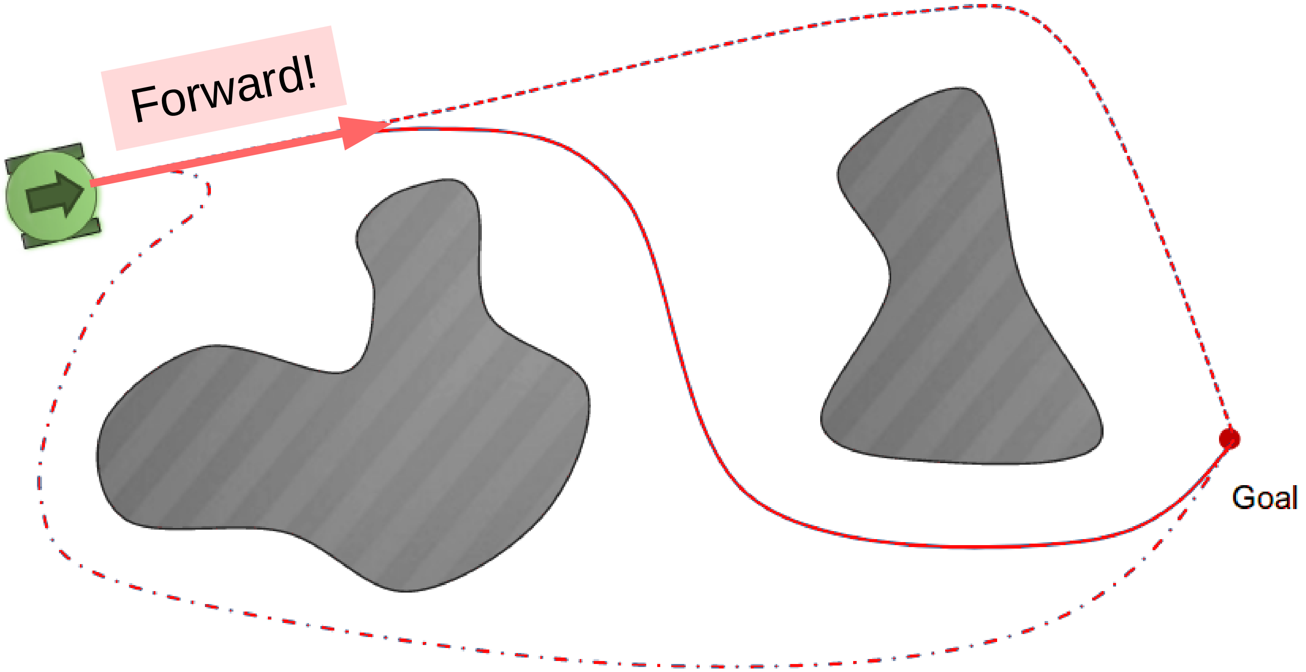
Cognition

Position

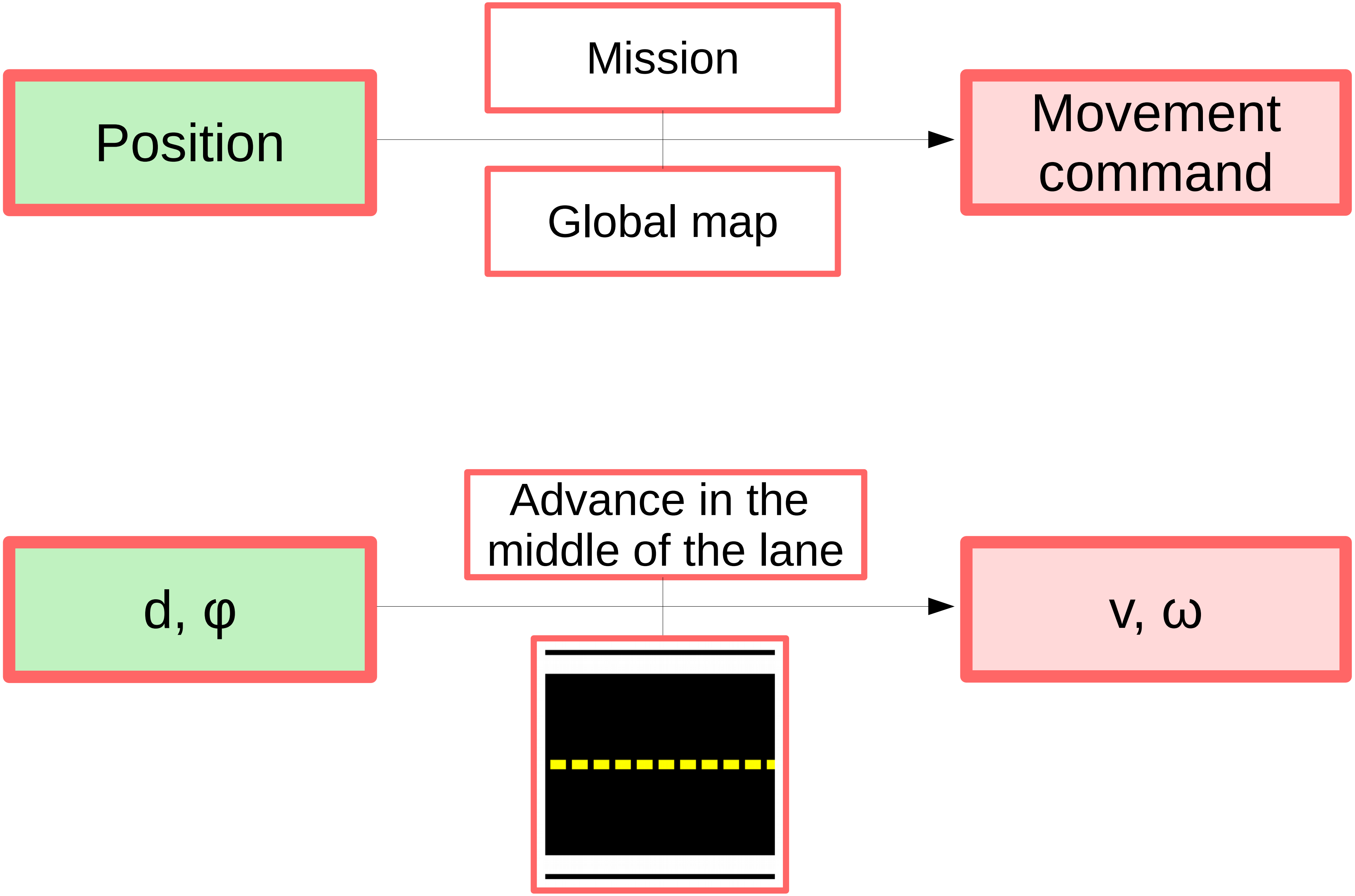
Mission

Global map

Movement command



Cognition


Mission
Position
Movement command
Global map
Advance in the middle of the lane
d, φ
v, ω

Cognition

- Goal

  Advance in the middle of the name

- How?

  Velocity v has to be constant

  Angular velocity ω is used to correct

  - φ
  - d

Cognition

- Angular velocity ω is used to correct
  - φ
  - d

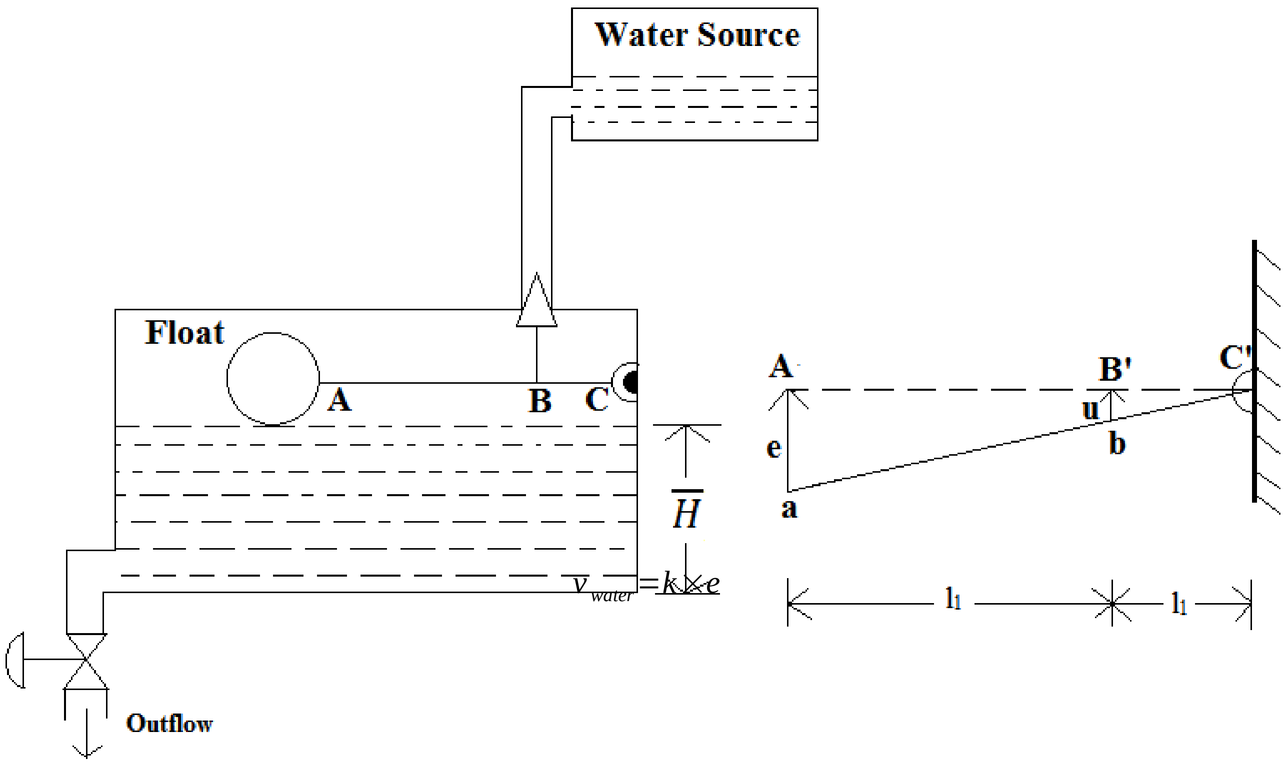
If $\varphi = 0$ (looking forward) and $d > 0$ (too much on the left), what should I do?

If $d = 0$ (right at the center) and $\varphi < 0$ (looking on the right), what should I do?

If $d = 0$, $\varphi_1 < 0$ and $\varphi_2 < \varphi_1$, would $\omega_1 > \omega_2$?

Proportional control

Proportional control



The water flow *F* is in liters/second. It is the time derivative of the volume *V* of water in the tank :

$$F(t) = V'(t)$$

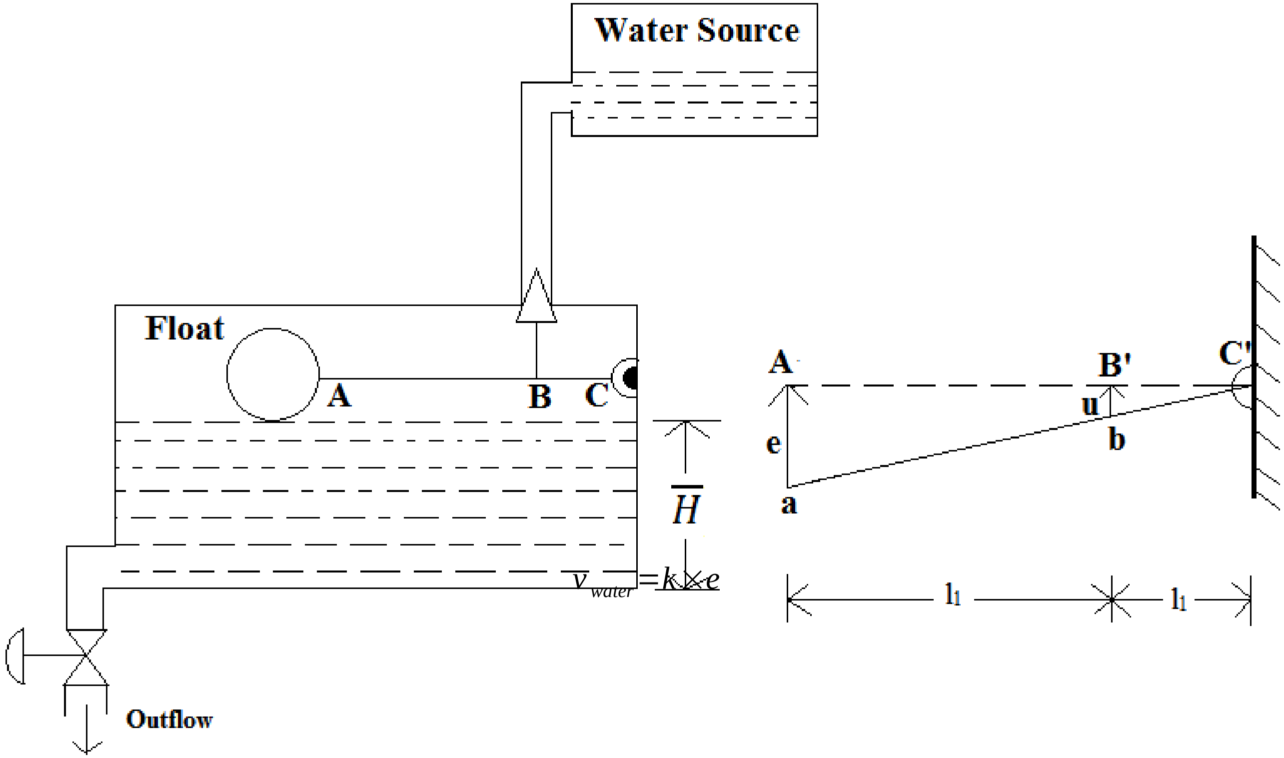
The floater position *a* is in m, and it is the height of the cuboid formed by the water. As width and depth are constant, *a* is proportional to *V*:

$$a(t) = V(t)/c$$

Therefore,

$$F(t) = c \times a'(t)$$

Proportional control



$$F(t) = c \times a'(t)$$

The toilet boil uses a proportional control system:

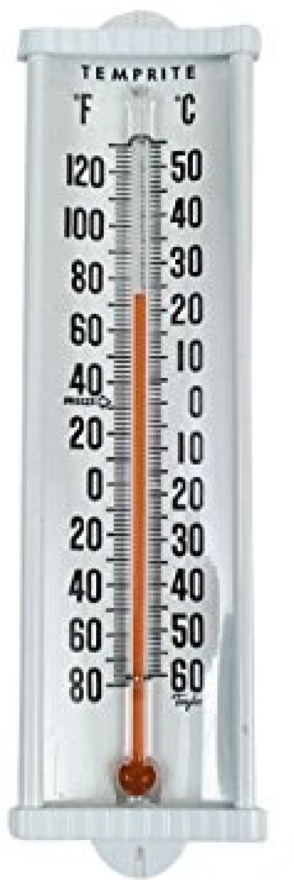
A is the <u>desired</u> position for the floater (tank is full).
The <u>error</u> *e* is the difference:

$$e(t) = A - a(t)$$

And the toilet lets in a flow proportional to *e* with a constant *k_flow:*

$$F(t) = - k\_flow \times e$$

Another example: temperature control in your car



Objective: keep the car temperature T at T_0 = 25°C

Adjusting the heater power

Objective: keep the temperature *T(t)* at 25°C

We can prove that the power W of the heater/air conditionner is proportional to T'(t):

W = c x T'(t)

How much power should we use to keep the car at T0 = 25?

$$W = k_{heater} \times (T_0 - T)$$

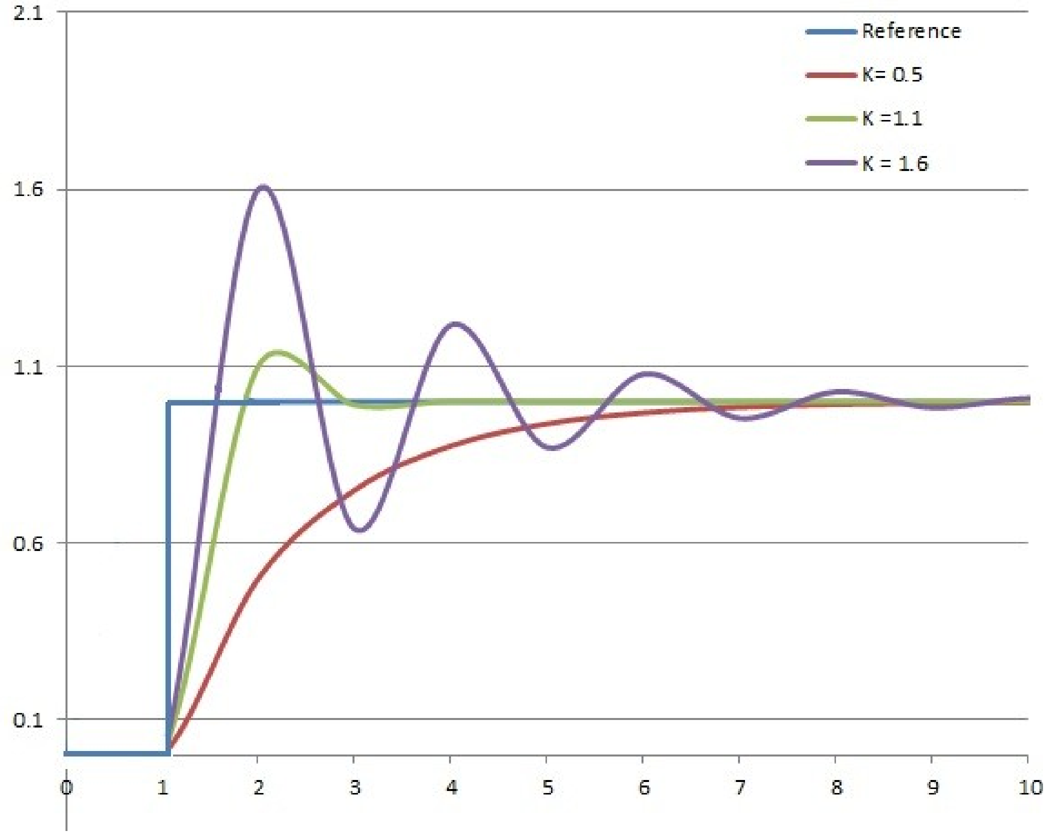
Error *e*

Influence of k_heater

$$W = k_{heater} \times (T_0 - T)$$

The people who made this example are crazy!
Canadians, probably.

T_0



https://en.wikipedia.org/wiki/PID_controller#/media/File:PID_varyingP.jpg

Influence of k_heater

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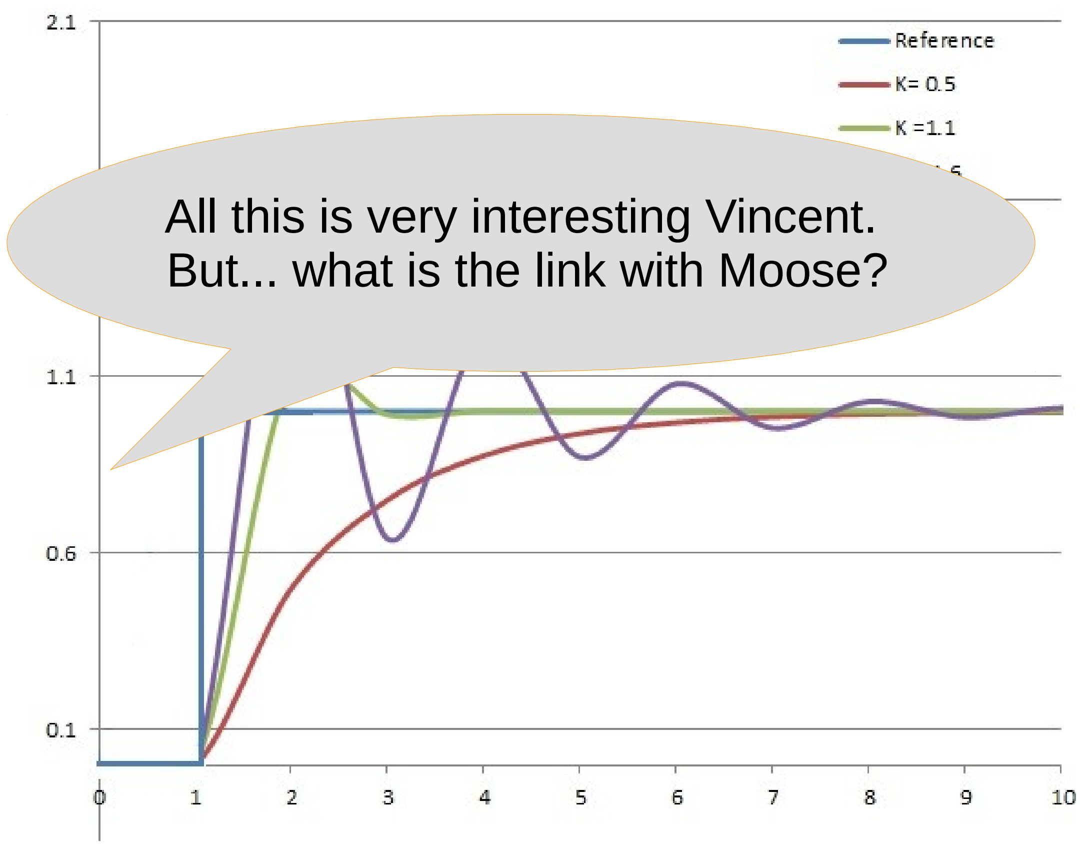

All this is very interesting Vincent.
But... what is the link with Moose?

https://en.wikipedia.org/wiki/PID_controller#/media/File:PID_varyingP.jpg

Let's summarize.

To use proportional control to keep variable *a(t)* to desired value a_0 we need:

- To be able to control the derivative *a'(t)*
- To be able to measure the error between *a(t)* and a_0

Then, we use:

$$a'(t) = k_a \times (a_0 - a(t))$$

We have to choose k_a correctly, so that we change fast enough but not too much.

ω and φ

- We know that $\omega(t) = \varphi'(t)$, and we can control $\omega(t)$.
- We can measure $\varphi(t)$ and we know $\varphi_0 = 0$

Therefore, we will use:

$$\omega_\varphi(t) = k_\varphi \times (0 - \varphi) = -k_\varphi \times \varphi = k_\theta \times \varphi$$

φ(t) and d

- We know that

$$d'(t) = v_d(t) = v(t) \times \sin(\varphi(t))$$

We set v(t) as constant.

We use an approximation: sin(x) ≈ x when x is small.

Thinking that φ(t) is small, we have:

$$d'(t) = v(t) \times \varphi(t)$$

So we would like :

$$\varphi_d(t) = k_D \times (0 - d) = -k_D \times d$$

$\varphi(t)$ and d

- We know that

$$d'(t) = v_d(t) = v(t) \times \sin(\varphi(t))$$

We set v(t) as constant.

We use an appr … hen x is small.

Thinking

But, Vincent, we cannot control $\varphi(t)$!

$$d'(t) = v(t) \times \varphi(t)$$

So we would like :

$$\varphi_d(t) = k_D \times (0 - d) = -k_D \times d$$

But... we cannot control φ(t)

But... we cannot control φ(t)

Yes we can!

$$\omega_d(t) = k_{\varphi,d} \times (\varphi_d - \varphi)$$

$$\varphi_d(t) = k_D \times (0 - d) = -k_D \times d$$

$$\omega_d(t) = k_{\varphi,d} \times (-k_D - d) = k_d \times d$$

So, what do we have

$$\omega_d(t) = k_{\varphi,d} \times (-k_D - d) = k_d \times d$$

$$\omega_\varphi(t) = k_\varphi \times (0 - \varphi) = -k_\varphi \times \varphi = k_\theta \times \varphi$$

$$\omega = k_d \times d + k_\theta \times \varphi$$

That's it?

$$\omega = k_d \times d + k_\theta \times \varphi$$

Yes, that's it!
But now, we have to find k_d and k_θ.

Calibrating k_d and k_θ

$$\omega = k_d \times d + k_\theta \times \varphi$$

Let's try it!