Introduction to Control

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What is a robot ?

Robot = *mechatronic system with perception, decision and action skills,* capable of carrying out *different tasks in the real world, in an autonomous way.*

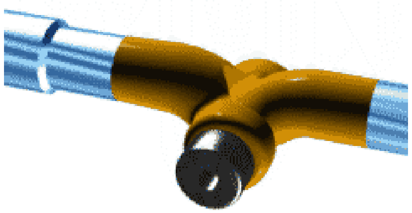
Robot = artificial machine

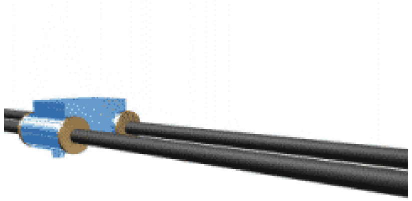
	Body	*Robot*
Perception:	*Sensors*	Sensors
Décision:	*Brain*	Computer
Action:	*Members*	Actuators

Autonomy: capacity to understand the current situation and to react in an approprious way taking into account the tasks to carry out.

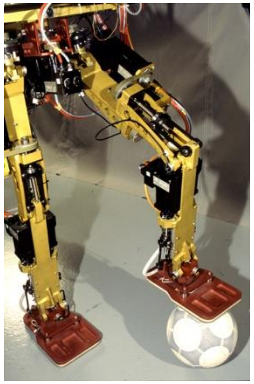
Actuators of a mobile robot

- An **actuator** is a component of a machine that is responsible for moving or controlling a mechanism or system;
- An actuator controls a **degree of freedom** (rotation, translation);





- Actuators could be complex**.**



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Outline

1. Introduction
2. Proportional control
3. PID control
4. Summary

A simple example of translation to perform(1/2)

- Robair has to move from its current position to a final position performing a translation:
  - We will control the translation speed of robair;
  - While robair is moving, we estimate its position (with odometry);
  - We will stop the translation when robair is close to its final position.

- Robair will have a constant translation speed:
  - If the translation speed is low, it will take time to reach the final position;
  - If the translation speed is high, it will take less time to reach the final but we can go too further.

A simple example of translation to perform(2/2)

- Robair has 2 objectives:
  1. Reach the final position as fast as possible;
  2. Be as close as possible of the final position.

- It is obvious that the translation speed should not be constant
  - If robair is far from the final position then its translation speed should be high;
  - If robair is close from the final position then its translation speed should be low.

- It is impossible to reach exactly the final position
  - We should add some tolerance

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Proportional control (1/2)

- Actually, my control is proportional to the difference between my current position and my final position;
- I would like to control my robot to decrease this difference

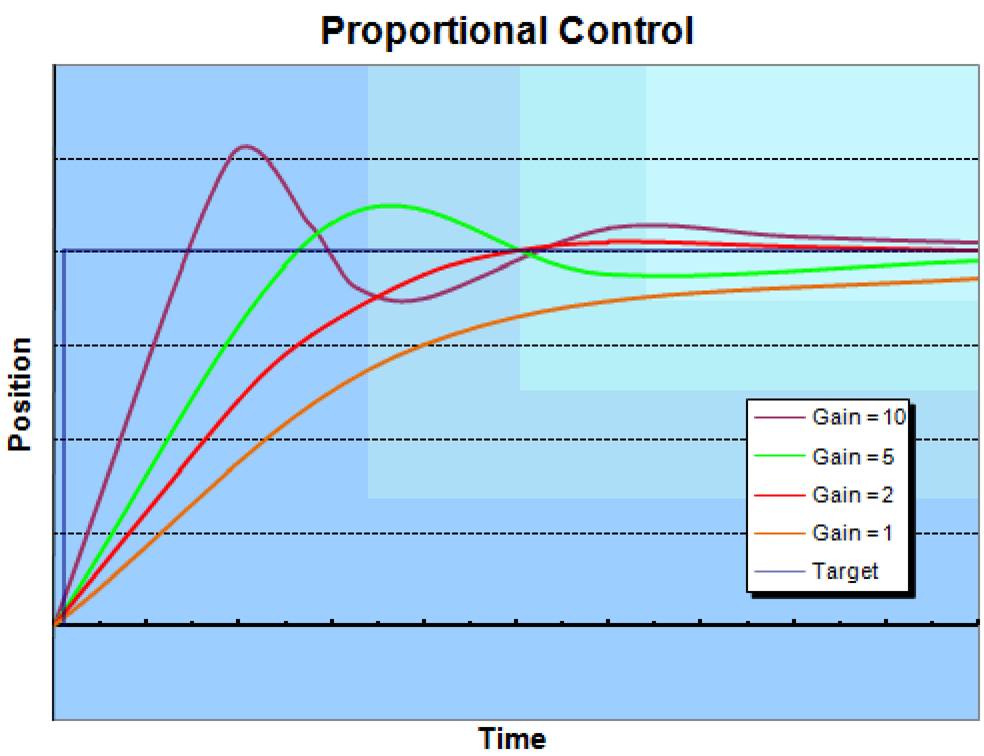
$$\boxed{m = k_p * E}$$

- where m is the output (the dof that I control), k_p is the proportional constant and E is the Error or the difference between my current position and my final position.

Proportional control (2/2)

- Finding the right value for k_p is difficult;

- For small values, the robot reaches the position without overshooting, but does so very slowly;
- With high values, the robot reaches the position faster but it overshoots the position;
- We have to find a trade off to reach the position as quickly as possible without overshooting.



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PID control(1/2)

- To improve the quality of control, most of the time, we take into account the error, but the integral of the error and the derivative of the error as well;

$$\boxed{m = k_p \ * E + k_i \ * E_i + k_d \ * E_d}$$

- E_i is the integral/sum of all the errors over time;
- Intuitively, if E_i is high, we are far to reach the final position, then we have to increase m strongly
- E_i is used to reach faster the final position but it will create overshooting and oscillations;

- E_d is the derivative of the error (ie, the difference between the 2 last errors);
- E_d is used to anticipate that we will reach soon the final position;
- E_d will compensate the oscillations created by E_i;

PID control(2/2)

- To improve the quality of control, most of the time, we take into account the error, but the integral of the error and the derivative of the error as well;

$$\boxed{m = k_p * E + k_i * E_i + k_d * E_d}$$

- Tuning k_p, k_i and k_d is difficult and is application dependent;
- When this 3 parameters are well tuned, the controller will reach its final position as quickly as possible with few and low oscillations.

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Summary(1/2)

- To control a mobile robot, we need to have a goal to reach, a DOF to control and an error to minimize;
- The error is the difference between the current position of the mobile robot and the position to reach (ie, the goal);
- To improve the robustness and effectiveness of the control, the control of a mobile robot depends on the error but on the integral/sum of the error and the derivative of the error as well;

- START with a proportional controller and tune it;
- If necessary, add integral and derivative to this controller;

Summary(2/2)

- We can control more than 1 DOF: example of robair moving to a given position combining rotation and translation
- As soon as a mobile robot moves in its environment, it has to take into account that the environment is dynamic
  1. Collision detection;
  2. Safety emergency/collision avoidance.

- Control of a mobile robot could be very complex