Benchmarking Mobile Robots' Motion

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Outline

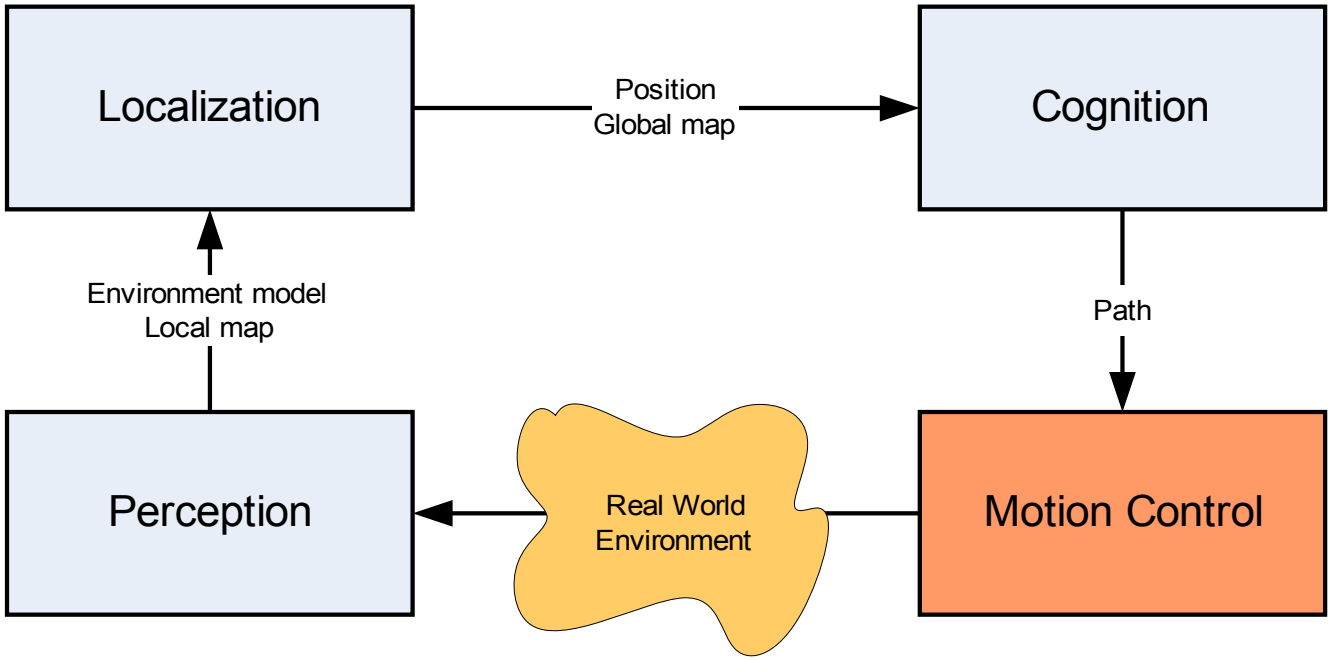
- Why benchmarking motion control strategies?
- The mobile robot Motion control problem
- Common Motion control algorithms
- How to compare motion control algorithms?
- Some benchmarks
- Ways of testing and assessing those benchmarks…
- Future directions…

Why benchmarking motion control strategies?

- Motion control is a key aspect of mobile robots' performance
- There are several well known methods to control the motion of mobile robots
- Every time a new motion control algorithm is proposed, some comparisons with traditional algorithms are usually made, but…
- **There are no set of benchmarks globally accepted to assess the performance of motion control algorithms**

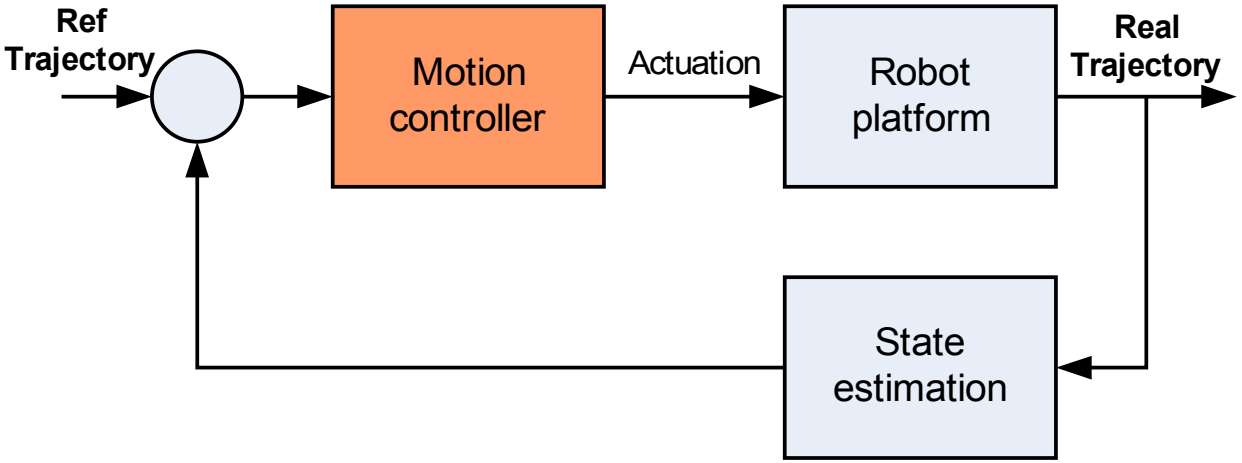
What is a Mobile Robot?

- A **Mobile Robot** is an automatic machine that is capable of **movement** in a given environment.



The mobile robot Motion control problem (1)

- Path-following (control laws that force a vehicle to move along a geometric path)
- Trajectory tracking (control laws that force a vehicle to reach and follow a time parameterized reference)

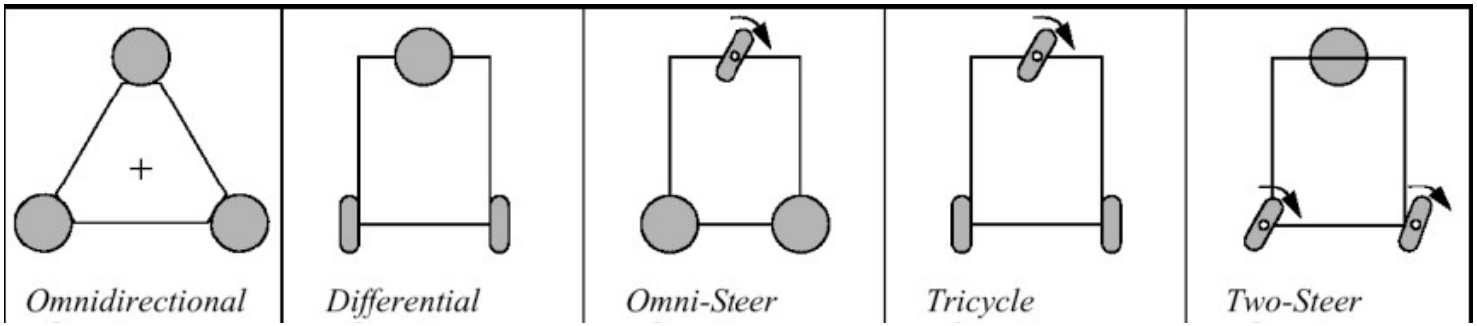


The goal is to minimize any error between the robot's state and a desired state!

The mobile robot Motion control problem (2)

- Motion space: 2D, 2.5D, 3D
- Mechanical platform:
  - Kinematics constraints
  - Dynamics constraints
- Fully actuated vs. underactuated vehicles
- Programming: motion primitives

- We can only compare things that are comparable!...



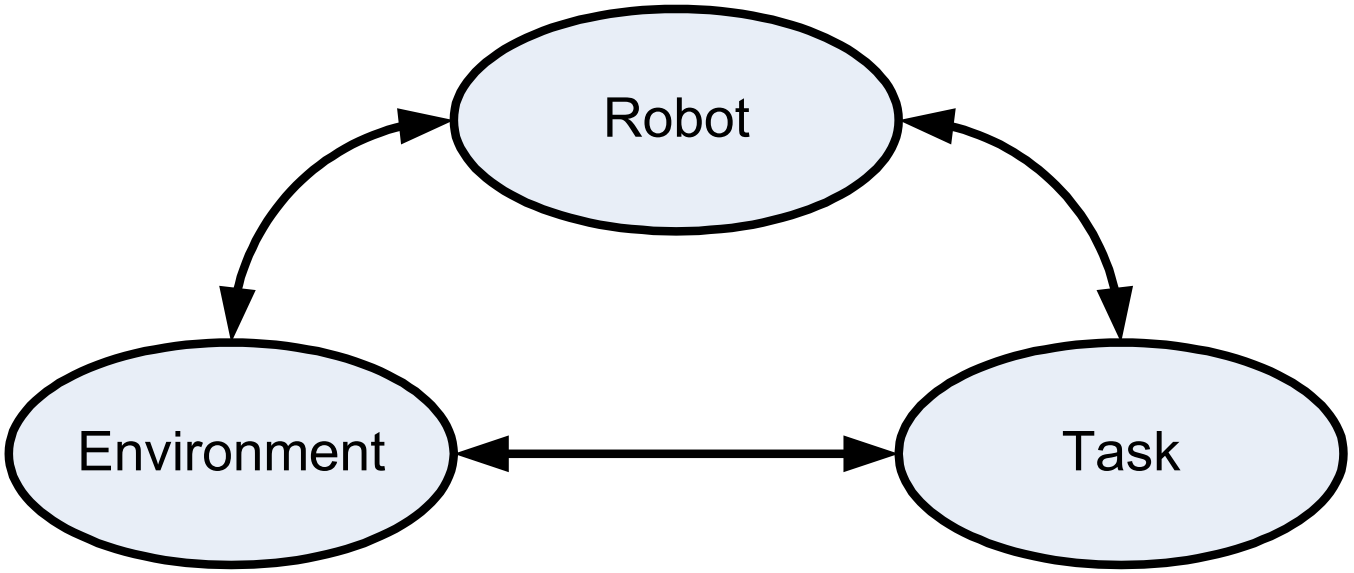
How to compare motion control algorithms?

- Metrics to assess the performance of a trajectory tracking control algorithm?

- The final results will depend from the controller, but also from external disturbances leading to state estimation errors
  - e.g. wheels slippage -> odometry errors (1)
  - Define the sensors employed

(1. Addressed by Borenstein with the UMBmark test)

Benchmarking in robotics



- Define the environment
- Define the task (reference trajectory)
- Use comparable robots

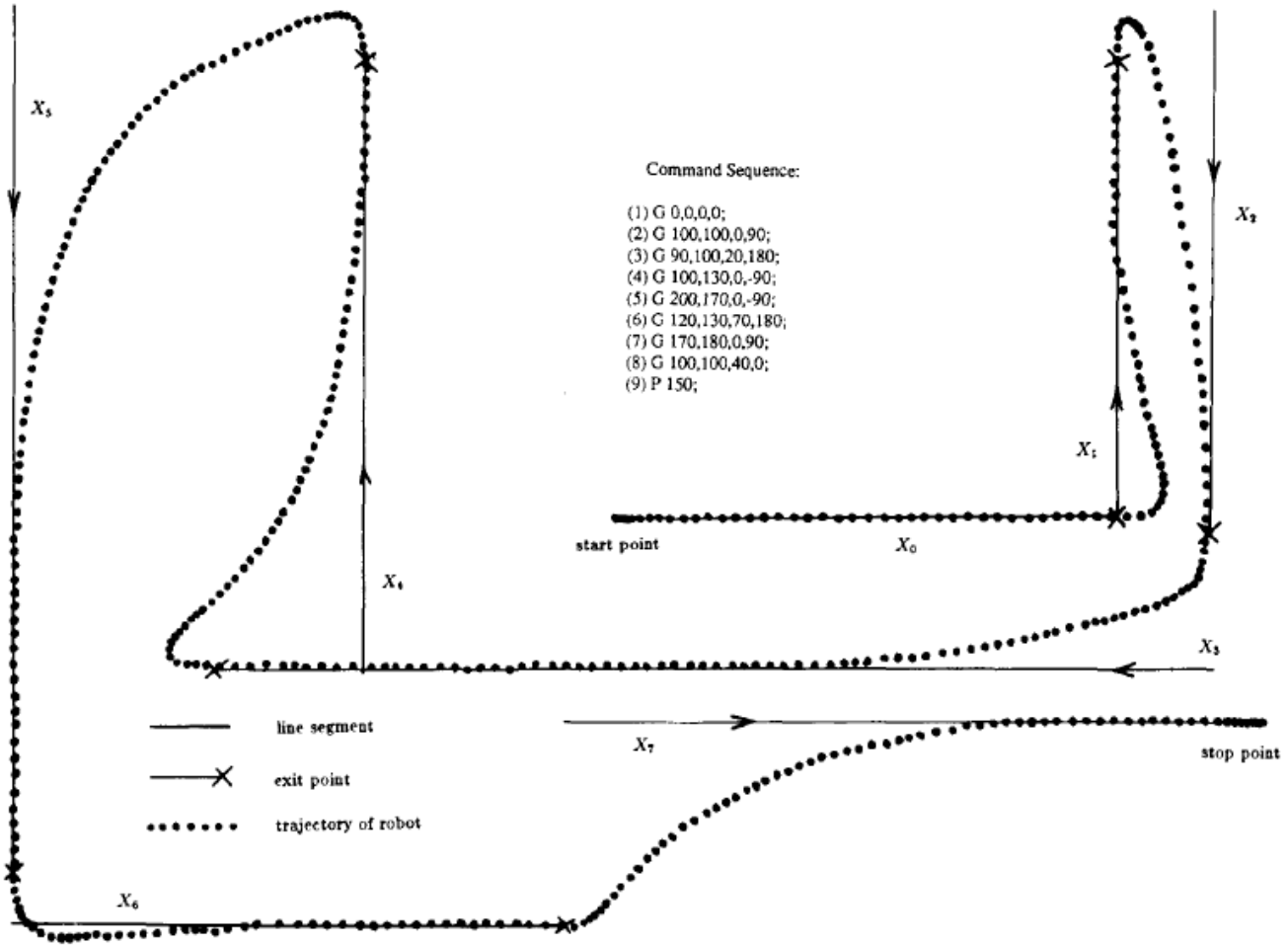
Desirable characteristics for a benchmark

- **Integrity** (should be a trustable measure)
- **Confirm the reality** (should be valid in a real environment)
- **Quantifiable** (should provide an objective evaluation)
- **Generality** (should be valid for different types of robots)
- **Portability** (should be easily portable)
- **Scientific** (should evaluate scientific parameters)
- **Updatable**
- **Robot-Independent**

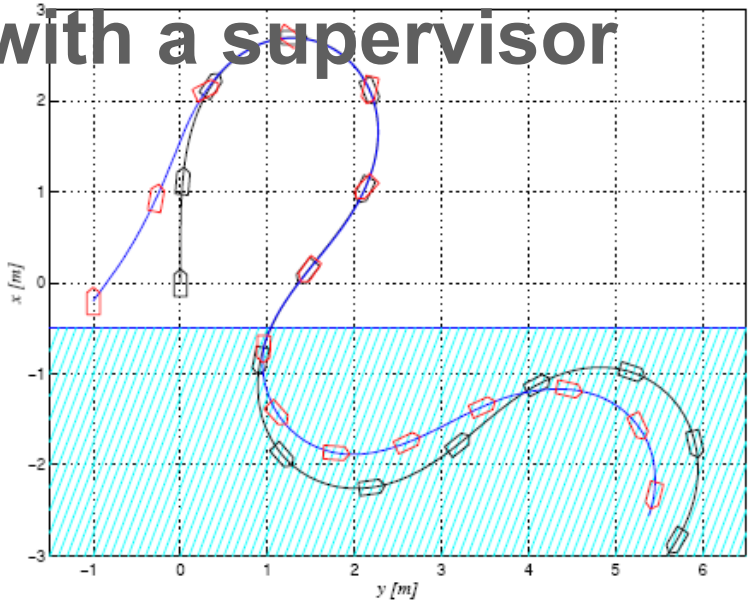
Some potential metrics for benchmarks

- **Std error** through a given path (the most common "benchmark" in this case). Usually, only a visual representation of real vs. desired paths are presented.
- Time to fulfill a given path (or set of paths). This is a **race like benchmark** – the fastest robot has the "best controller" (it is important to use the same or similar electromechanical platforms)
- Energy consumption
- ...

Motion using a sequence of segments as a reference (Kanayama T-RA 1988)

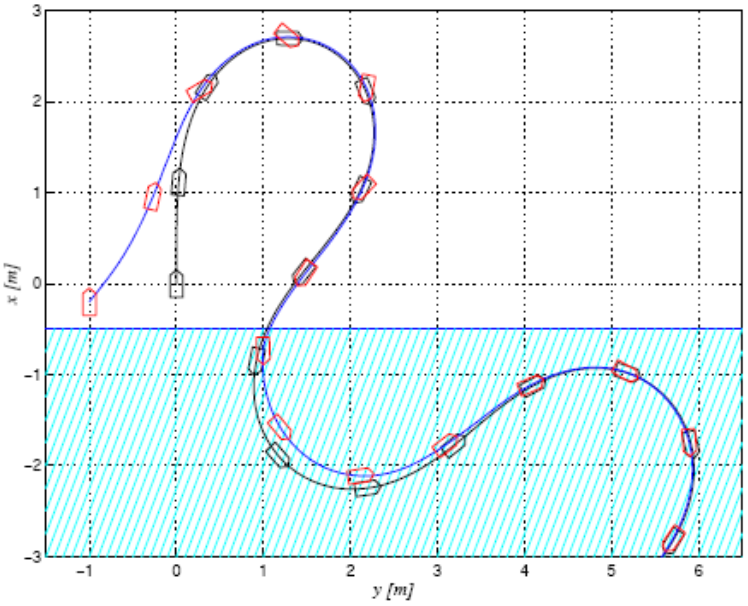


Trajectory controller with a supervisor



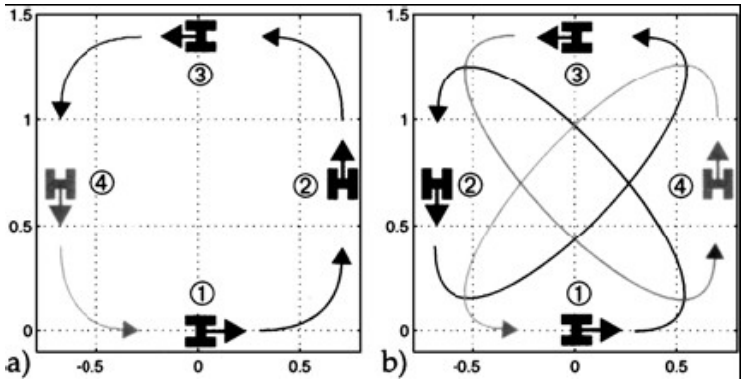
(a)

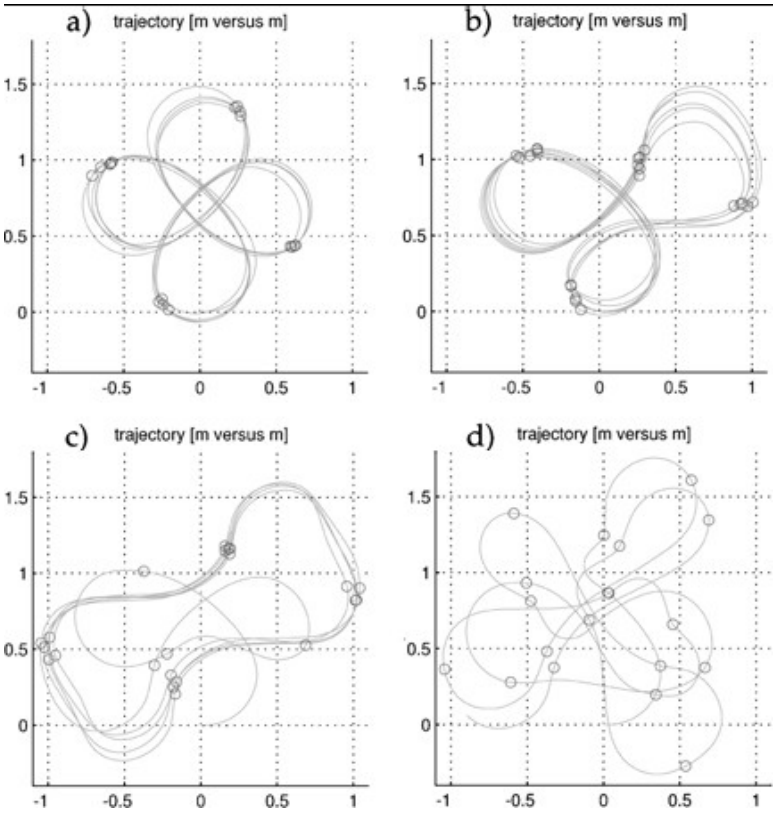
Hovercraft trajectory with a estimator-based supervisory controller for trajectory-tracking



(from Aguiar & Hespanha, IEEE-TAC, 2004)

Switching targets (dynamic analysis)





Switching times

a) 6s; b) 5s; c) 4s; d) 3s

(from Webers & Zimmer, Aut.Rob., 2002)

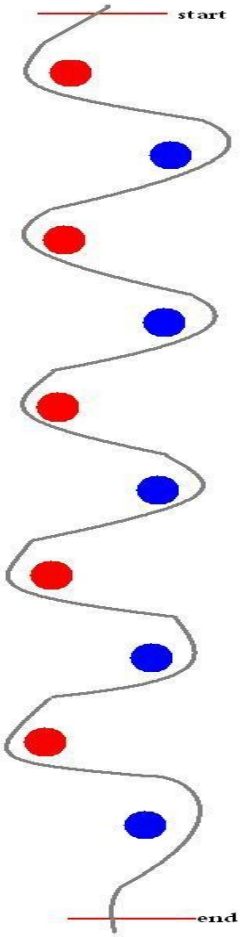
Testing scenarios for motion control

- A set of **standard testing scenarios** to compare different motion control algorithms

Assessing the results

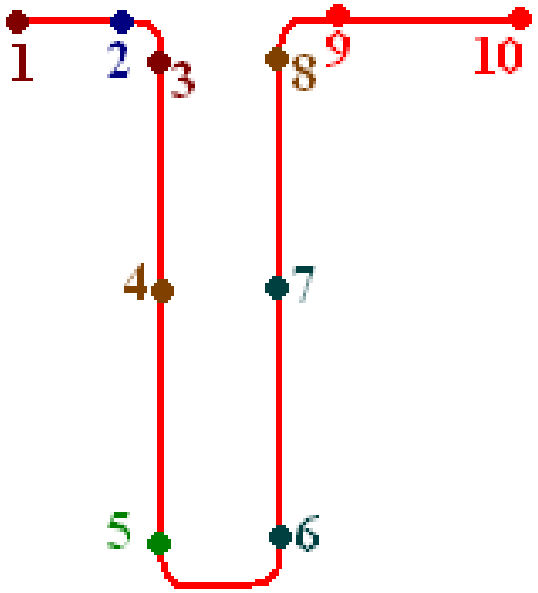
- Use an accurate time indexed position measurement/tracking system (e.g. A ceiling camera able to track visual marks placed on the robot – it can be a coloured LED).

Slalom test



- Inspired by slalom skiing
- Can be adapted to any robot
- Can be used with proprioceptive sensors only or also with exteroceptive sensors

Crinkle test



- A composition of segments and arcs defined by way points indexed in time

Future works…

- These ideas are being refined and will be tested in a set of different platforms
- Several well known motion control algorithms (e.g. Kanayama, Yang,...) will be tested against the proposed benchmarks

- Your comments and ideas are welcome ☺