NAVIGATION OF MOBILE ROBOTS

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References

- J. Borenstein, H. R. Everett, L. Feng, “Where Am I?”, Technical Report, University of Michigan. (Chapter 6)

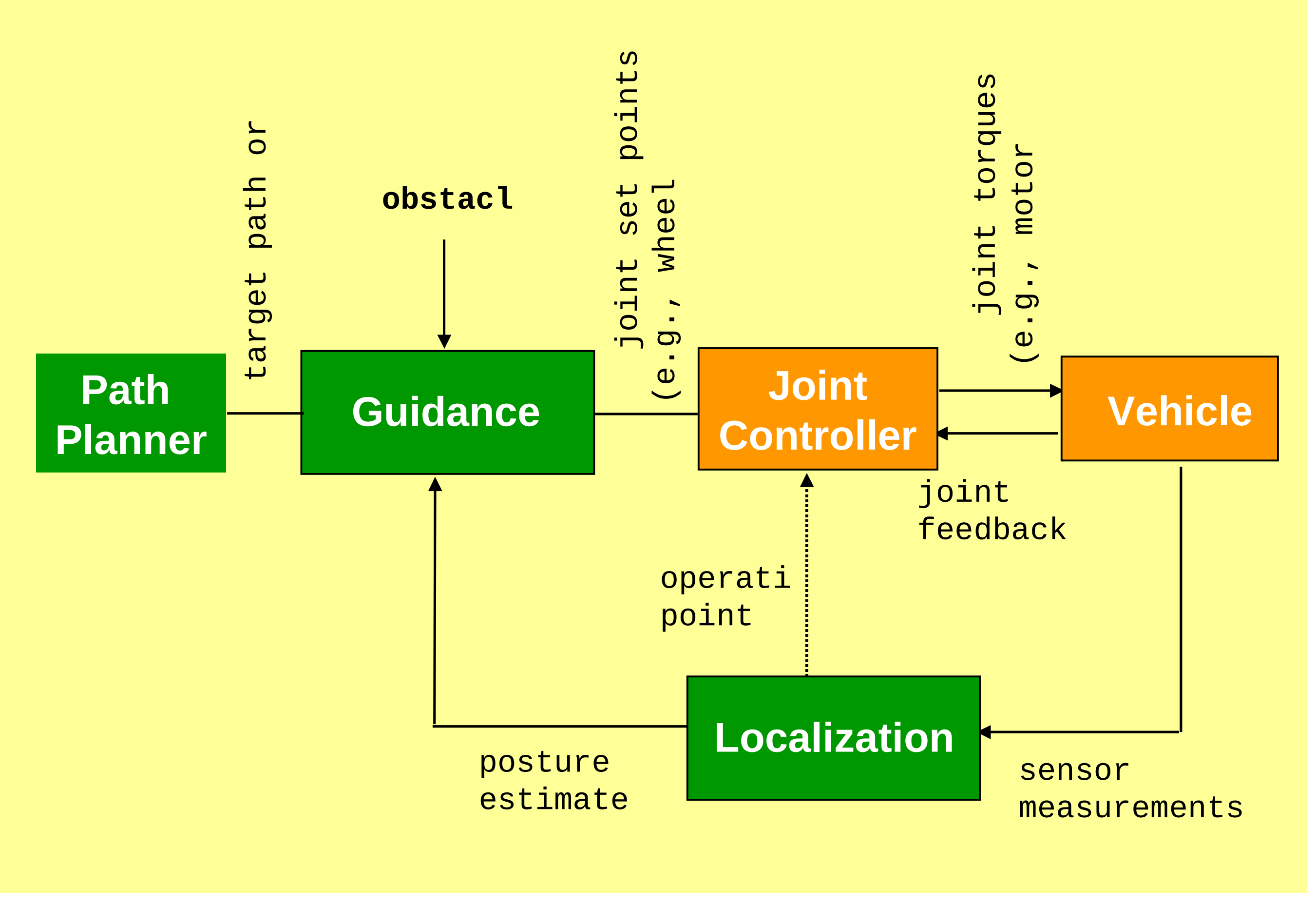
The Navigation Problem

NAVIGATION

Process used by a mobile robot to move from an initial pose to a final pose with respect to an initial frame

Key Questions:

- Where am I ?
- Where am I going ?
- How should I get there ?



- **GUIDANCE**
  - take the robot from the current posture desired posture, possibly following a determined path or trajectory, while obstacles

Some Guidance methodologies

- **State(posture)-feedback methods**:
  - **posture stabilization** (initial and final postures given; no path or trajectory pre-determined; obstacles not considered; may lead to large unexpected paths)
  - **trajectory tracking** (requires pre-planned path)
  - **virtual vehicle tracking** (requires pre-planned trajectory)
- **Potential-Field like methods**
  - **potential fields** (holonomic vehicles)
  - **generalized potential fields** (non-holonomic vehicles)
  - **modified potential fields** (non-holonomic vehicles)
- **Vector Field Histogram (VHF) like methods**
  - **nearness diagram navigation** (holonomic vehicles)
  - **freezone** (non-holonomic vehicles)

- **LOCALIZATION**
  - Determine the posture (position +
    the robot at each time instant

Some Localization methodologies

- **Relative Localization (Localization with relative measurements)**
  - Odometry

    Mobile robot localization through wheel motion evaluation
  - Inertial Navigation

    Mobile robot localization through its motion state evaluation (velocities and accelerations)

Dead-reckoning

- **Absolute Localization**
  - Active beacons

    Computes absolute location by measuring the direction of incidence (or the distance to) 3 or more active beacons. Transmitter locations must be known in inertial frame
  - Artificial and Natural Landmarks

    Landmarks are located in known environment places, or they are detected in the environment. Same method used for active beacons applies.
  - Model matching

    Information from robot sensors is compared to a map or world model. Matching sensor-based and world model maps, vehicle's absolute pose is estimated

    This can be used to update the world map over time

- **Relative Localization + Absolute Localization**

Odometry

- Uses encoders to measure the distance traveled by each wheel
  - From the robot kinematics the translation and rotation of the robot frame relative to the world frame is evaluated
- Absolute pose estimation results from the integration of relative translation and orientation between two encoder readings.
- Odometry performance is a function of the vehicle's kinematics

- **Errors in odometry**

  - Systematic Errors

    important as they lead to additive errors
    In regular terrain, they are more important than non-systematic errors
    they depend on the robot and/or sensors characteristics

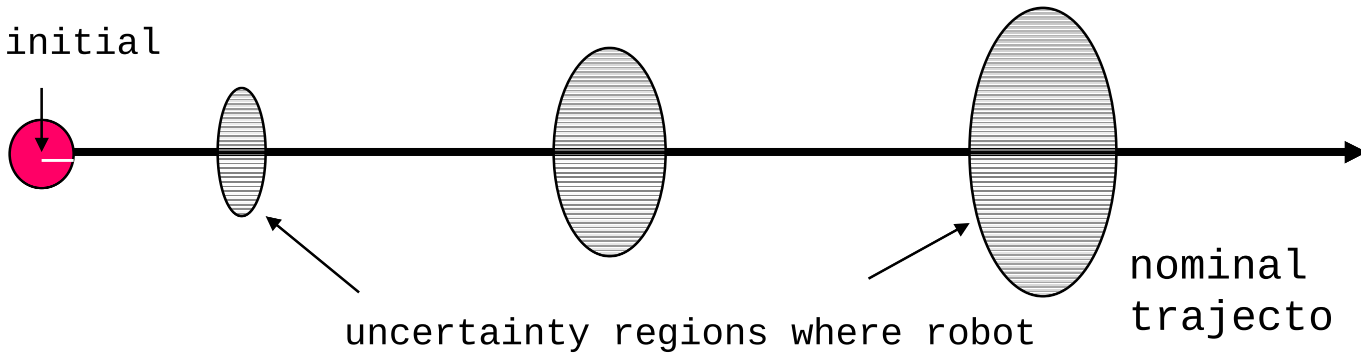
    - different wheel diameters
    - mean wheel diameter differs from the nominal
    - unaligned wheels
    - finite encoder resolution and sampling time

  - Non-systematic Errors

    in irregular terrains these may be the most important errors

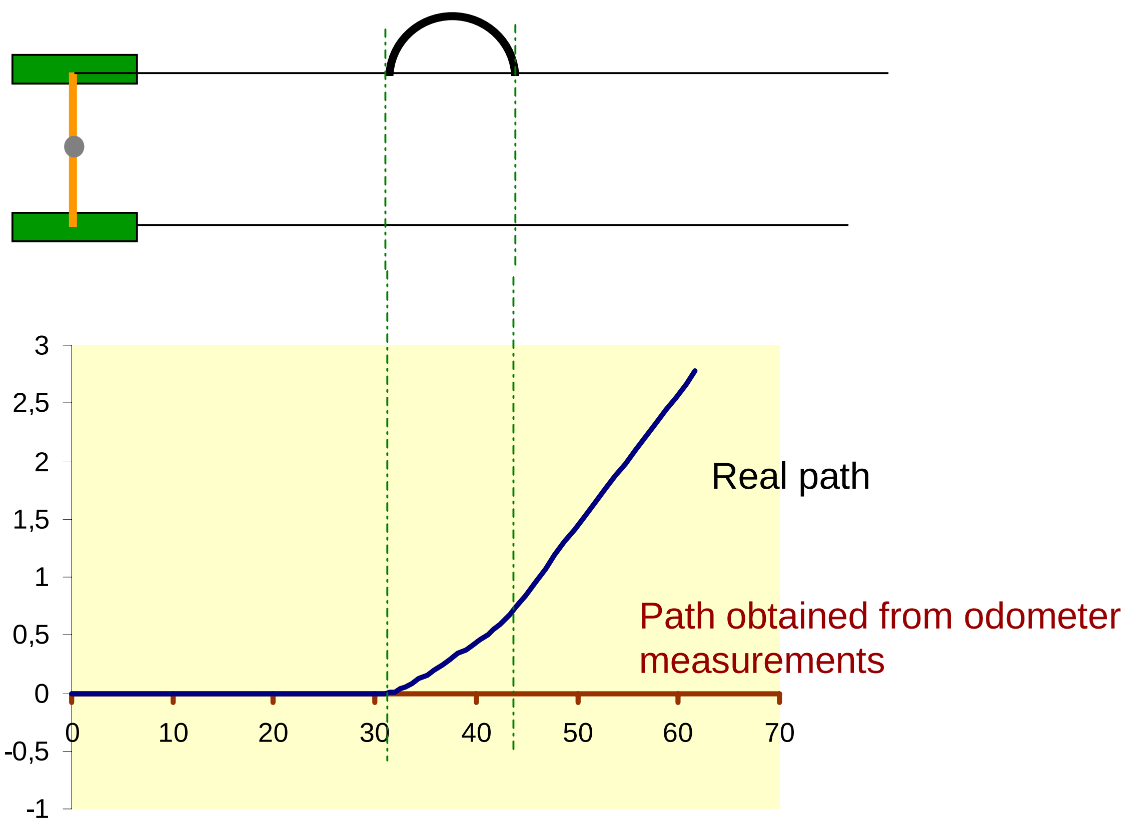
    - motion on irregular surfaces
    - Motion over unexpected obstacles
    - Wheel slippage
      - solo escorregadio
      - Large vehicle's accelerations
      - Quick rotations
      - External forces (interaction with external obstacle))
      - Internal forces (free wheels)
      - Wheel non point contact

Odometry Errors



Typical Errors for a Differential Drive Robot

- Motion command – equal velocities in both wheels
- Surface profile



See a set of Handouts on Odometry

Active Beacon Localisation Systems

- Active Beacons
  - Most common navigation aids on ships and airplanes
  - Provide very accurate positioning information with minimal processing
  - High cost in installation and maintenance

- Two different types of active beacon systems:
  - **Trilateration**
  - **Triangulation**

TRILATERATION

Determination of vehicle's pose based on distance measurements to known beacon sources

Usual configuration

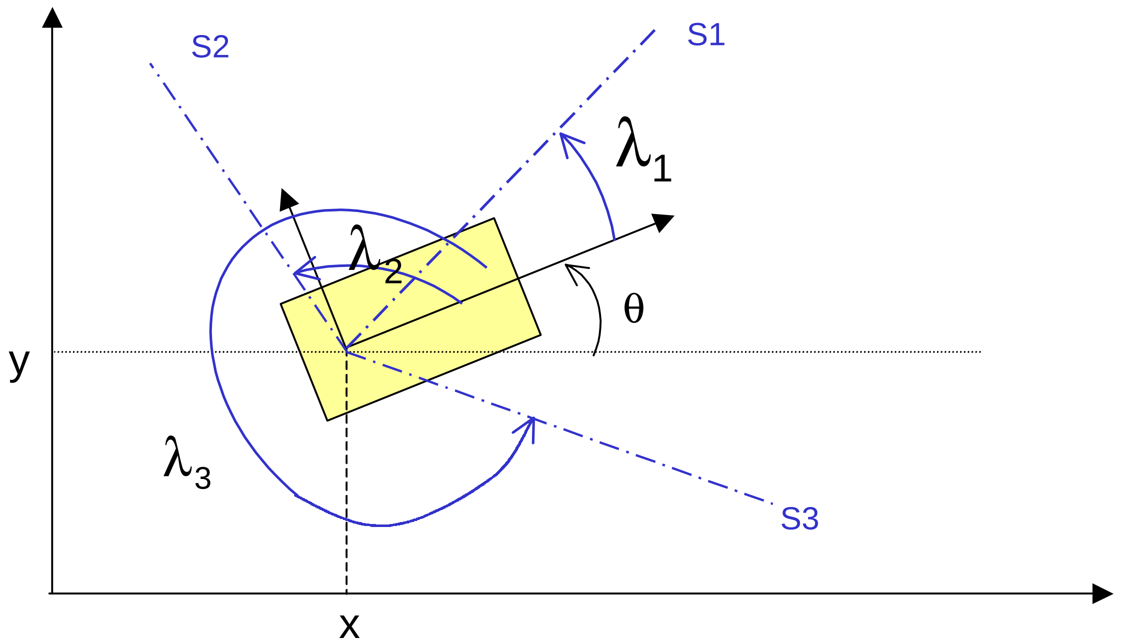
- 3 or more transmitters mounted at known locations in the environment and one receiver on board the robot
- one transmitter on-board and receivers mounted on the environment

Examples

- GPS

TRIANGULATION

- Determination of vehicle's pose (x,y,θ) based on the evaluation of the angles, λ_1, λ_2, λ_3 between the robot longitudinal axis and the direction with which three beacons installed on the environment at known positions are detected.



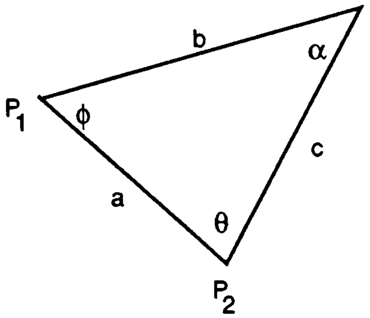
2D Triangulation

TRIANGULATION —— is a common ranging technique with its origins in ancient Greek and Egiptian civilizations

(used for ship navigation, civil engineering)

TRIANGULATION method obtains the **distance** to an object by simple geometric calculations

Result of trigonometry



Given

the length of a side of a triangle **(a)**

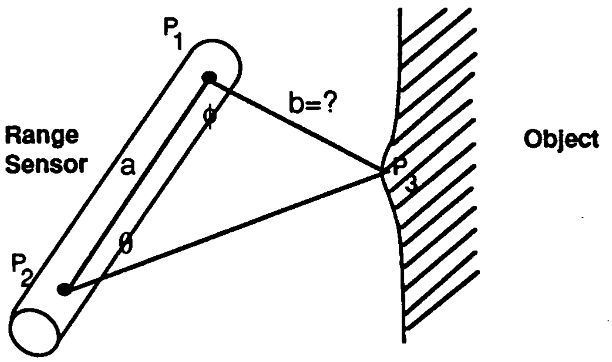
two angles of the triangle (ϕ, θ)

It is possible to determine

the length of the remaining sides **(b, c)**

the remaining angle (α)

$$b = a . \frac{\sin \theta}{\sin(\theta + \phi)}$$



Example

Stereo Vision