Enclosure methods for safe localisation

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State Equation

System defined by state equation

$$\begin{cases} \dot{x} = f(x,u) & (\textit{evolution}) \quad (1) \\ y = g(x,u) & (\textit{observation}) \quad (2) \end{cases}$$

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Application

- Dynamic knowledge of the system
- Control the system
- Simulate the system

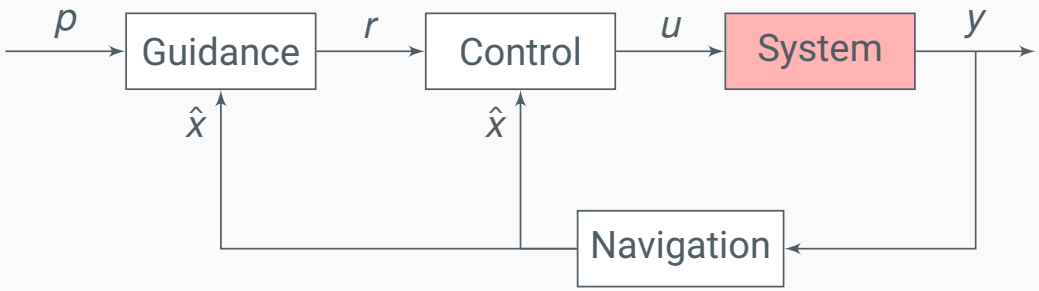
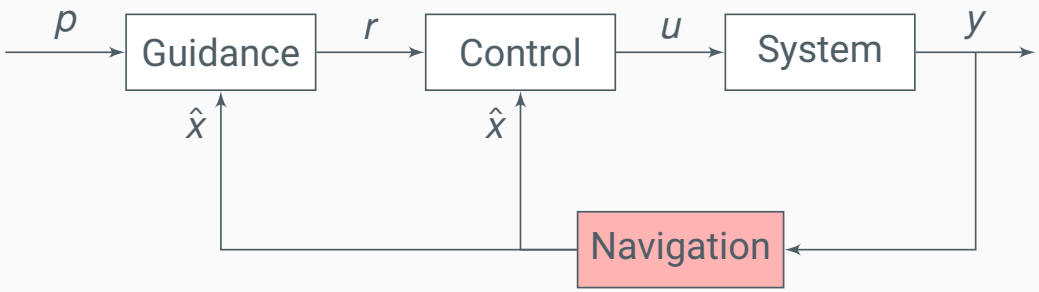


Figure 1: Guidance-Navigation-Control block diagram

System

System for which state x want to be controlled.



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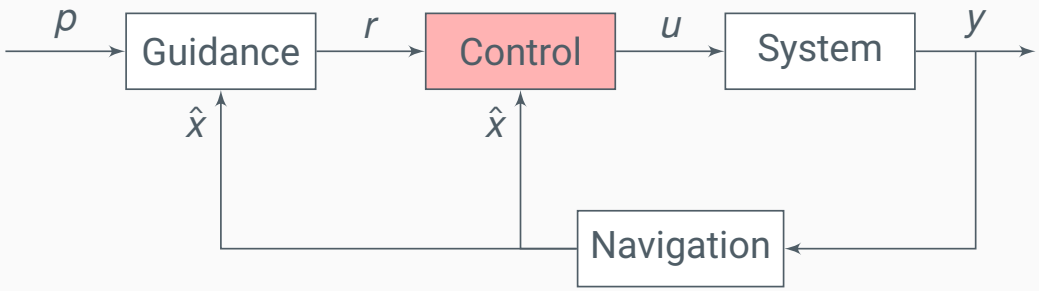
Navigation

Estimate the state $\hat{x}$ of the system using its output y.



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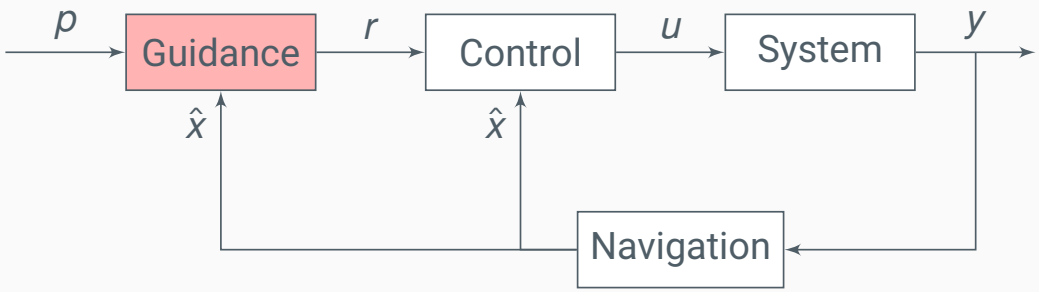
Control

Control the system toward the reference r from the guidance using estimated state $\hat{x}$.



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Guidance

Guide the system toward a desired state using the estimated output $\hat{x}$ and some input parameters p.

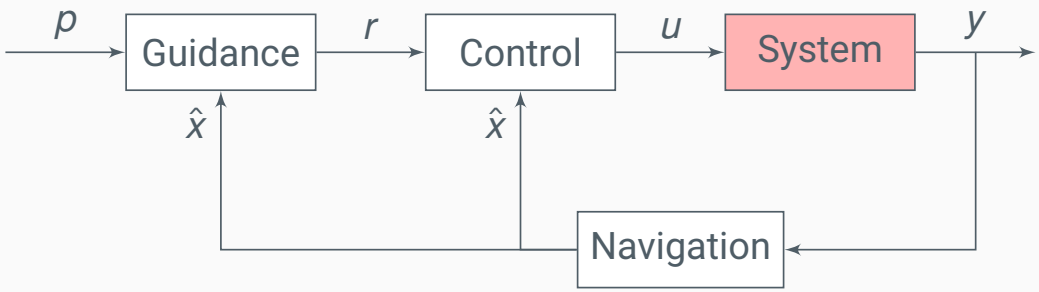

Figure 2: Guidance-Navigation-Control block diagram

Nonlinear systems

- Approximations in Navigation
- Approximations in Control

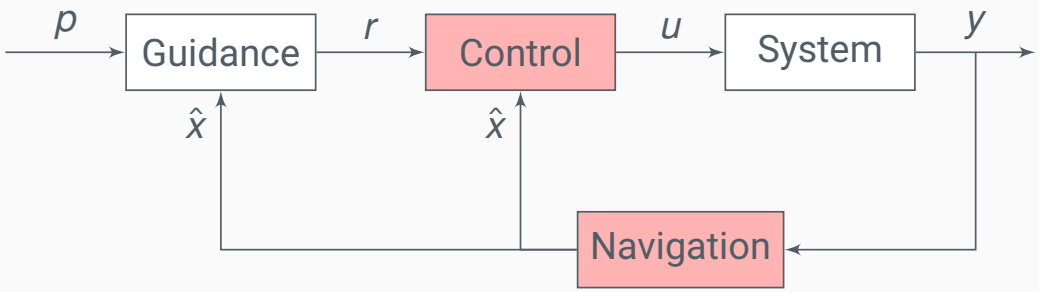

Figure 2: Guidance-Navigation-Control block diagram

Nonlinear systems

- Approximations in Navigation
- Approximations in Control

Set methods

- Deal with nonlinear equations
- Guaranteed results

Dead reckoning

- Proprioceptive informations (odometry, inertial, ...)
- Robot achieve dead reckoning

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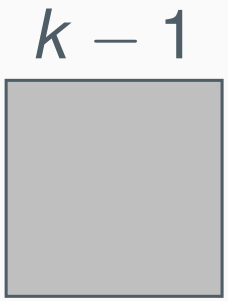

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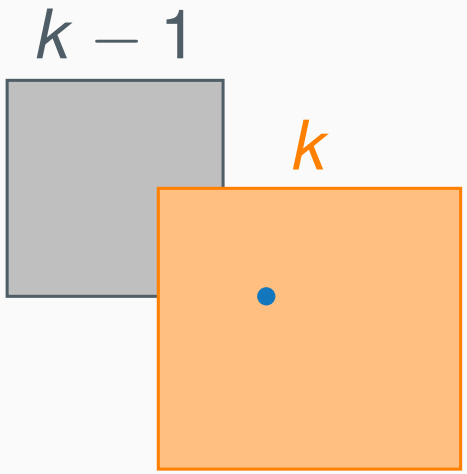

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- Field (magnetic, acoustic, bathymetric, ...)
- Give information about robot possible state
- Can contract the enclosing robot state

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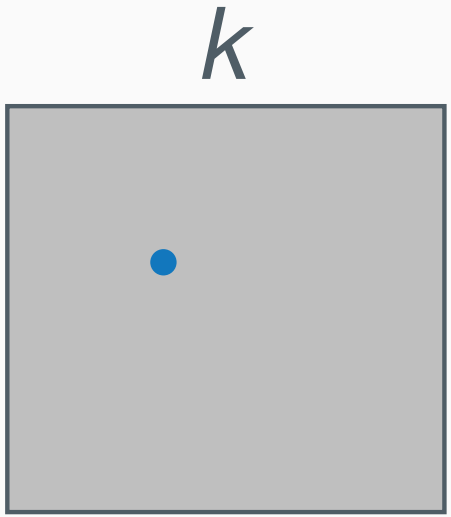

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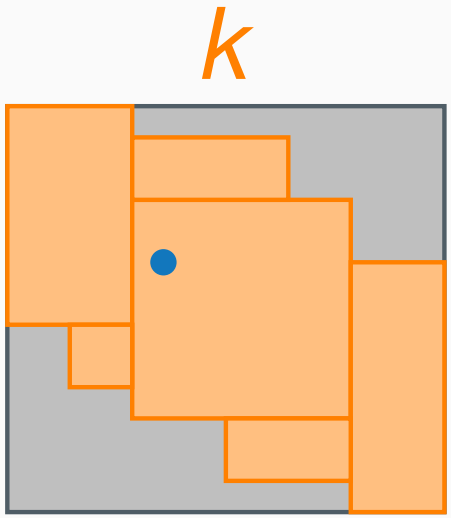

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- Using estimated robot state
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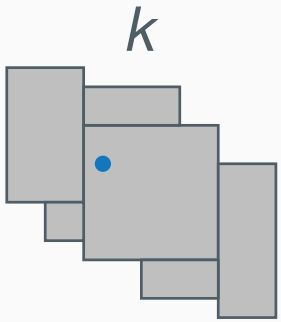

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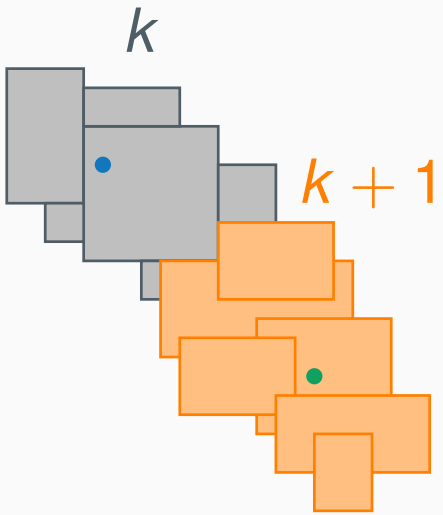

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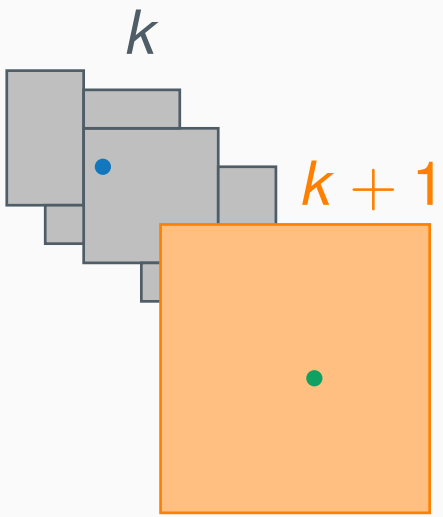

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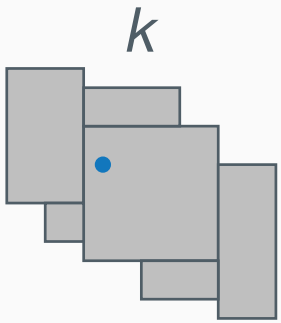

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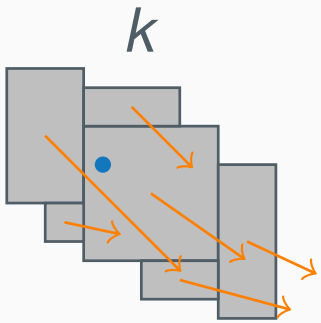

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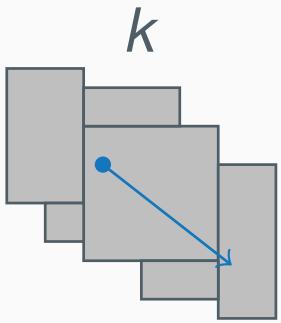

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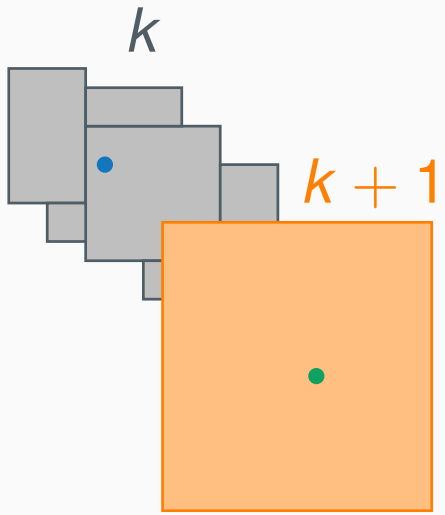


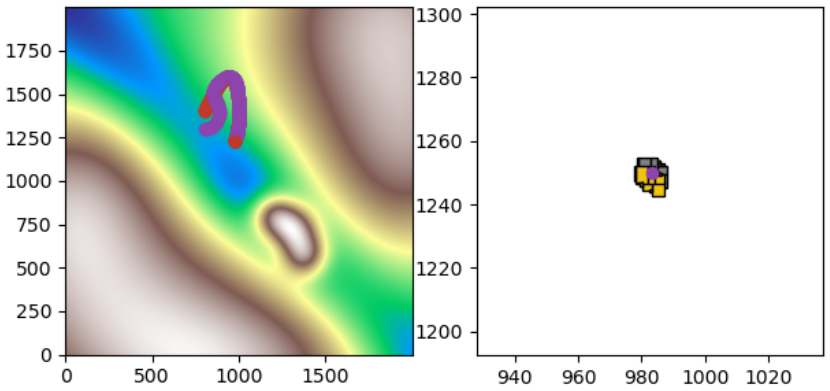
Scope of the example

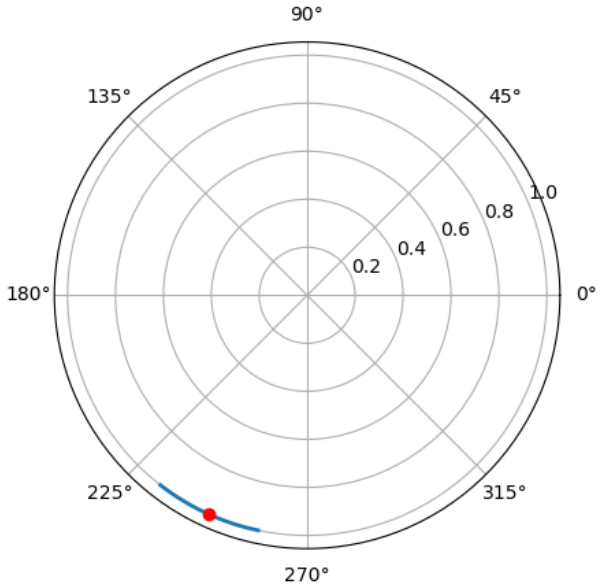
- Boat simulated with Dubins state equation
- Using simulated bathymetric map as measured field
- Control the boat to follow a Lissajous curve

Assumptions

- State estimation and control only using interval analysis
- Inertial drift set to 0.1 m per seconds
- Bathymetric measurements uncertainty set to 0.1 m

Example Simulation





Conclusion

- Works better in highly nonlinear fields
- Possibility to refine next state estimation by enclosing it in a sub-paving
- Still a simulation will be tried in guaranteed robot control experiments.