Motion Planning | **Potential Field Methods**
Autonomous Mobile Robots

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Potential Field methods | overview

- Methods produce a potential field whose gradient the robot follows
- They are characterized by
  - Being global, but at times remaining prone to local optima
  - Implicit incorporation of (basic) system models

Local Potential Fields | working principle

- The method generates an attractive potential function centered at the goal and local repulsive potentials around obstacles

$$U_{\text{att}}(\boldsymbol{q}) = \frac{1}{2} k_{\text{att}} (\boldsymbol{q} - \boldsymbol{q}_{\text{goal}})^2$$

$$U_{\text{rep}}(\boldsymbol{q}) = \begin{cases} \frac{1}{2} k_{\text{rep}} \left(\frac{1}{\rho(\boldsymbol{q})} - \frac{1}{\rho_{\text{lim}}} \right)^2 & \text{if } \rho(\boldsymbol{q}) \leq \rho_{\text{lim}} \\ 0 & \text{otherwise} \end{cases}$$

- The robot follows the gradient (force vector) of the overall summed potential

Local Potential Fields | working principle

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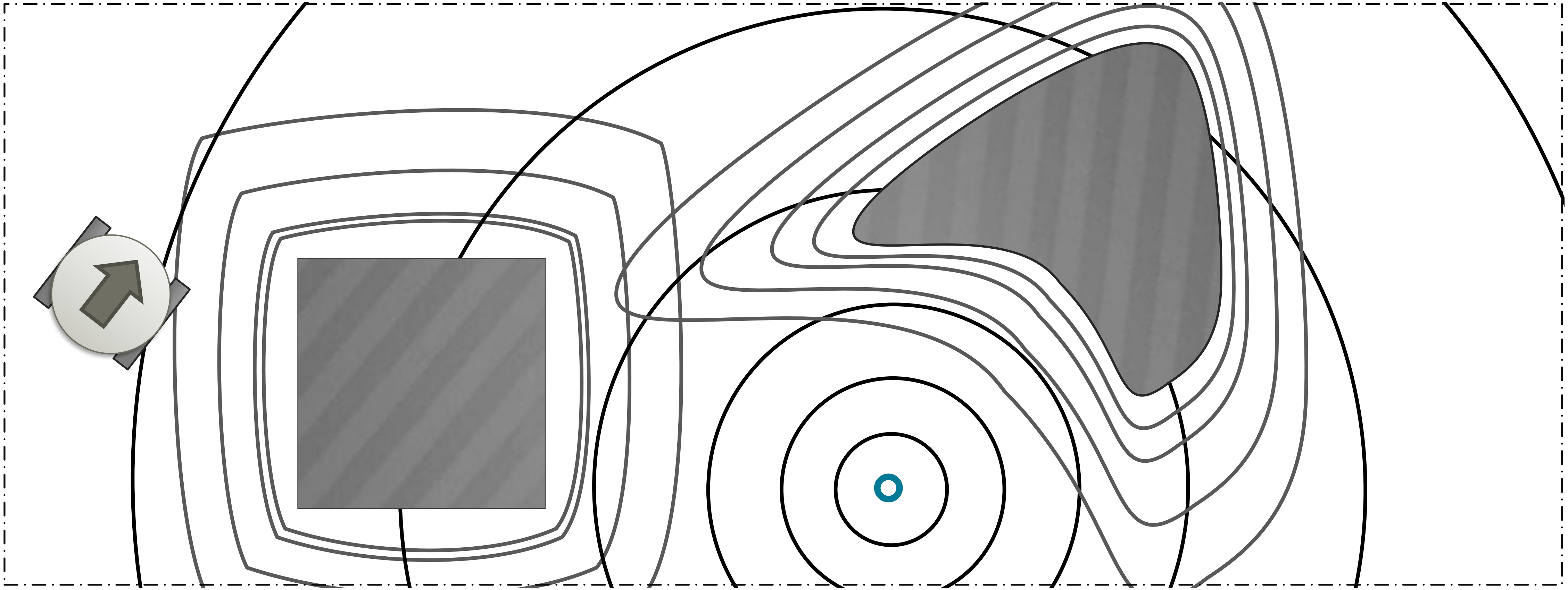

Local Potential Fields | properties

- Solutions form a control policy
- Solutions may be subject to to local minima due to the localness of the repulsive potentials
- The formulation does not allow for the incorporation of agent dynamic constraints

Harmonic Potential Fields | working principle

- Robot follows solution to the Laplace Equation $\Delta U = \sum \frac{\partial^2 U}{\partial^2 q_i} = 0$
- Boundary conditions, any mixture of
  - Neumann: Equipotential lines lie orthogonal to obstacle boundaries
  - Dirichlet: Obstacle boundaries attain constant potential

Harmonic Potential Fields | working principle

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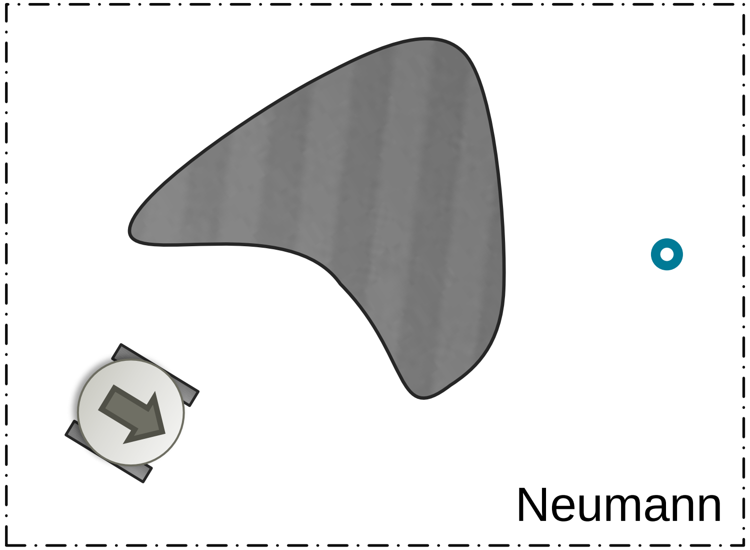
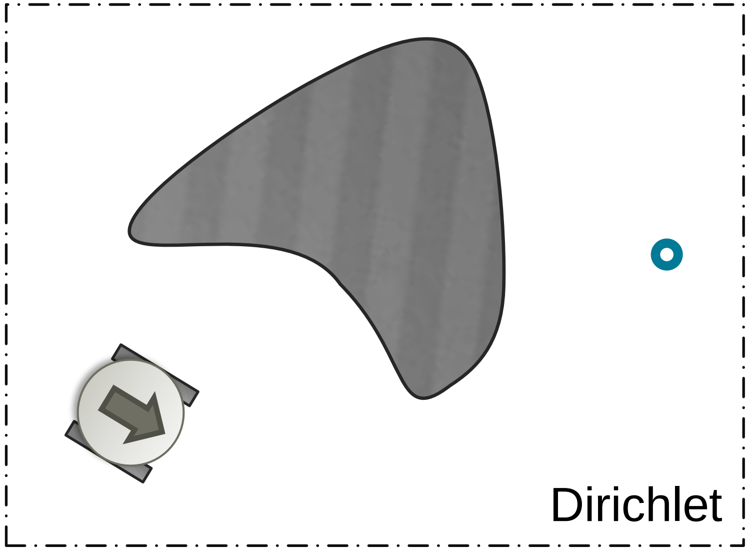
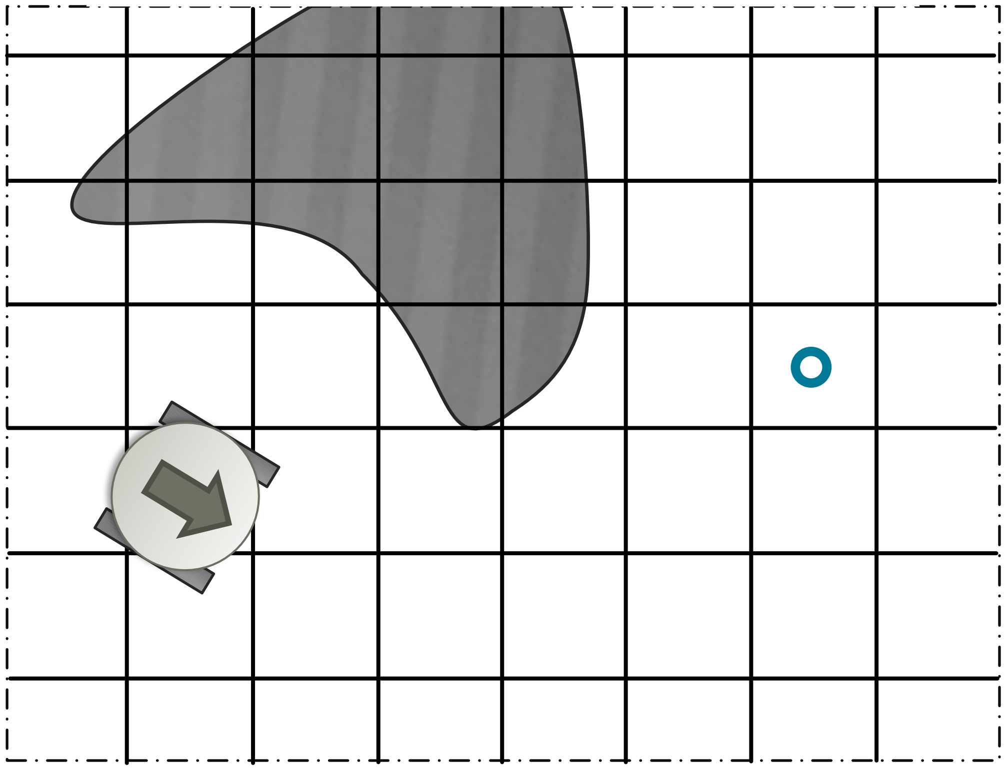




Harmonic Potential Fields | numeric solution



$$\Delta U = \sum \frac{\partial^2 U}{\partial^2 q_i} = 0$$

$$\nabla U(\boldsymbol{q})_i \approx \frac{U(\boldsymbol{q}+\delta \mathbf{e}_i) - U(\boldsymbol{q})}{\delta}$$

$$U^{k+1}(\mathbf{q}) = \frac{1}{2n} \sum_{i=1}^{n} \left(U^k(\mathbf{q}+\delta \mathbf{e}_i) + U^k(\mathbf{q}-\delta \mathbf{e}_i) \right)$$

Harmonic Potential Fields | properties

- Solutions form a control policy
- Solutions are free of local optima
- Closed-form solutions exist for simple object shapes only

Potential Field methods | further reading

- Consideration of orientation constraints
  - R. A. Grupen, C. I. Connolly, K. X. Souccar, and W. P. Burleson: "Toward a Path Co-processor for Automated Vehicle Control". In *Proceedings of the IEEE Symposium on Intelligent Vehicles*, 1995.

- Approximate integration of agent dynamic constraints
  - A. A. Masoud. Kinodynamic Motion Planning: "A Novel Type of Nonlinear, Passive Damping Forces and Advantages". *IEEE Robotics & Automation Magazine,* 17(1):85–99, 2010.
  - C. Louste and A. Liegois. Path planning for Non-holonomic Vehicles: "A Potential Viscous Fluid Method". *Robotica,* 20:291–298, 2002.