Motion Planning | **Collision Avoidance**
Autonomous Mobile Robots

Martin Rufli – IBM Research GmbH

Margarita Chli, Paul Furgale, Marco Hutter, Davide Scaramuzza, Roland Siegwart

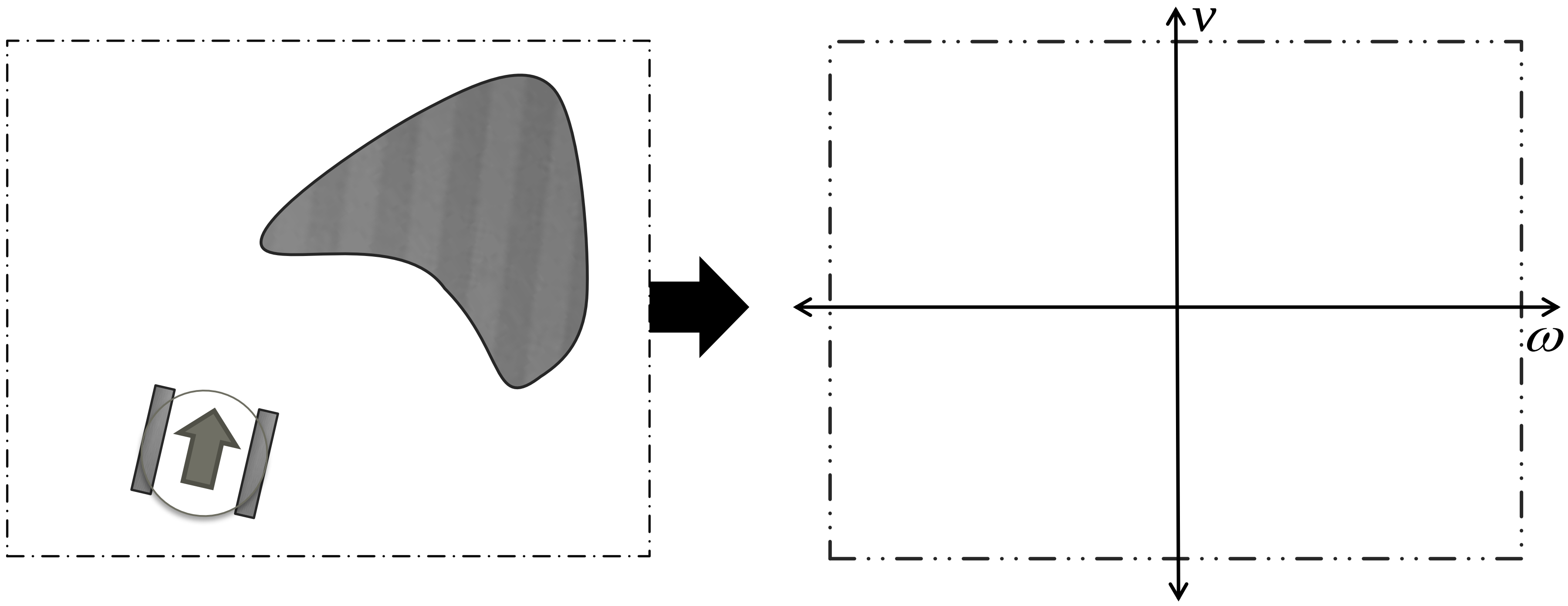
Classic collision avoidance | overview

- Methods compute actuator commands based on local environment
- They are characterized by
  - Being light on computational resources
  - Being purely local and thus prone to local optima
  - Incorporation of system models

Dynamic Window Approach (DWA) | working principle

- Robot is assumed to instantaneously move on circular arcs (v,ω)
- 2D evidence grid is transformed into (v,ω) input-space based on robot deceleration capabilities / kino-dynamics, leading to V_o
- Static window V_s constrains velocities
- Dynamic window V_d accounts for vehicle dynamics
- Selection of (v,ω)-pair within $V_r = V_o \cap V_s \cap V_d$ maximizing objective containing heading, distance to goal and velocity terms

Dynamic Window Approach (DWA) | working principle



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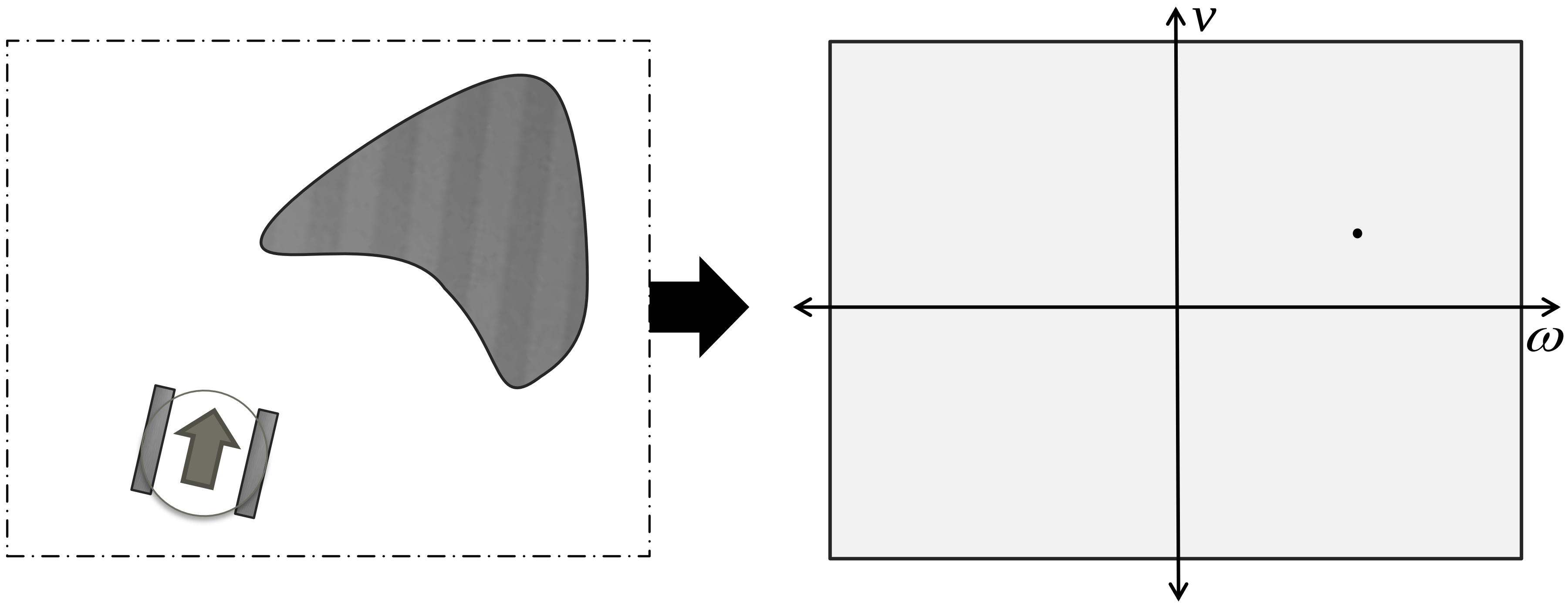

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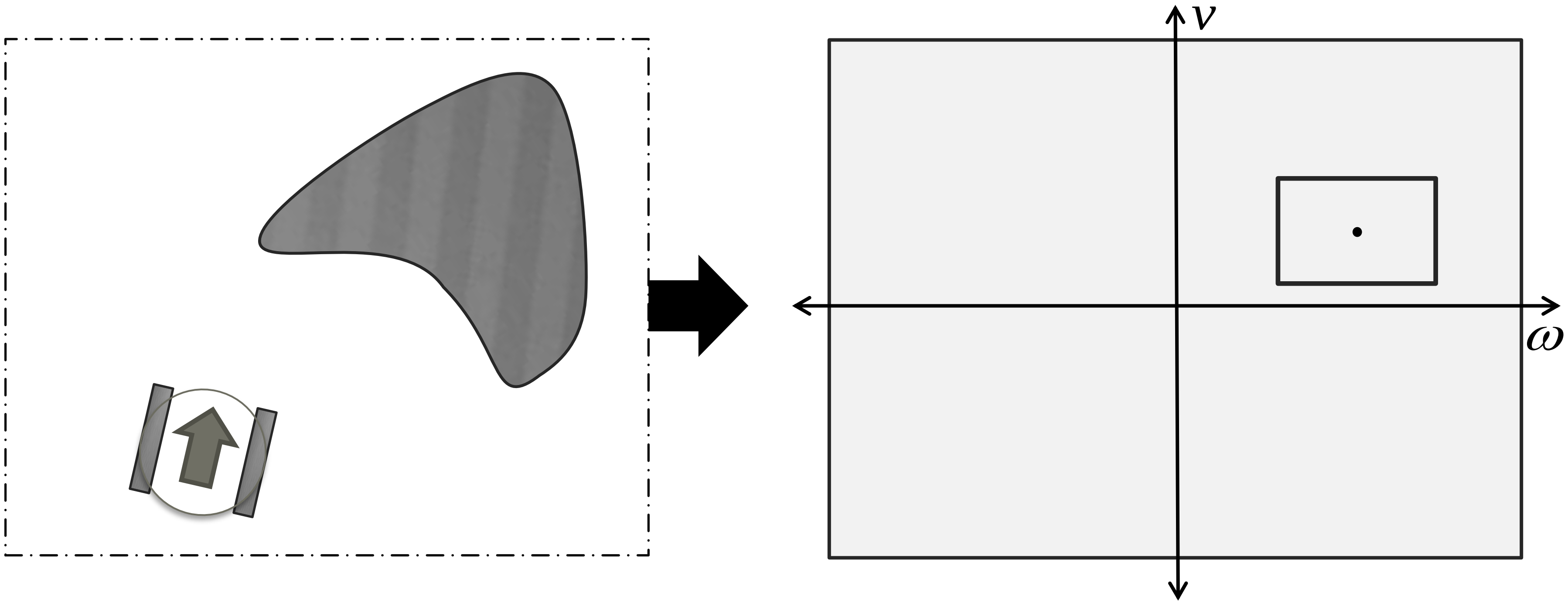

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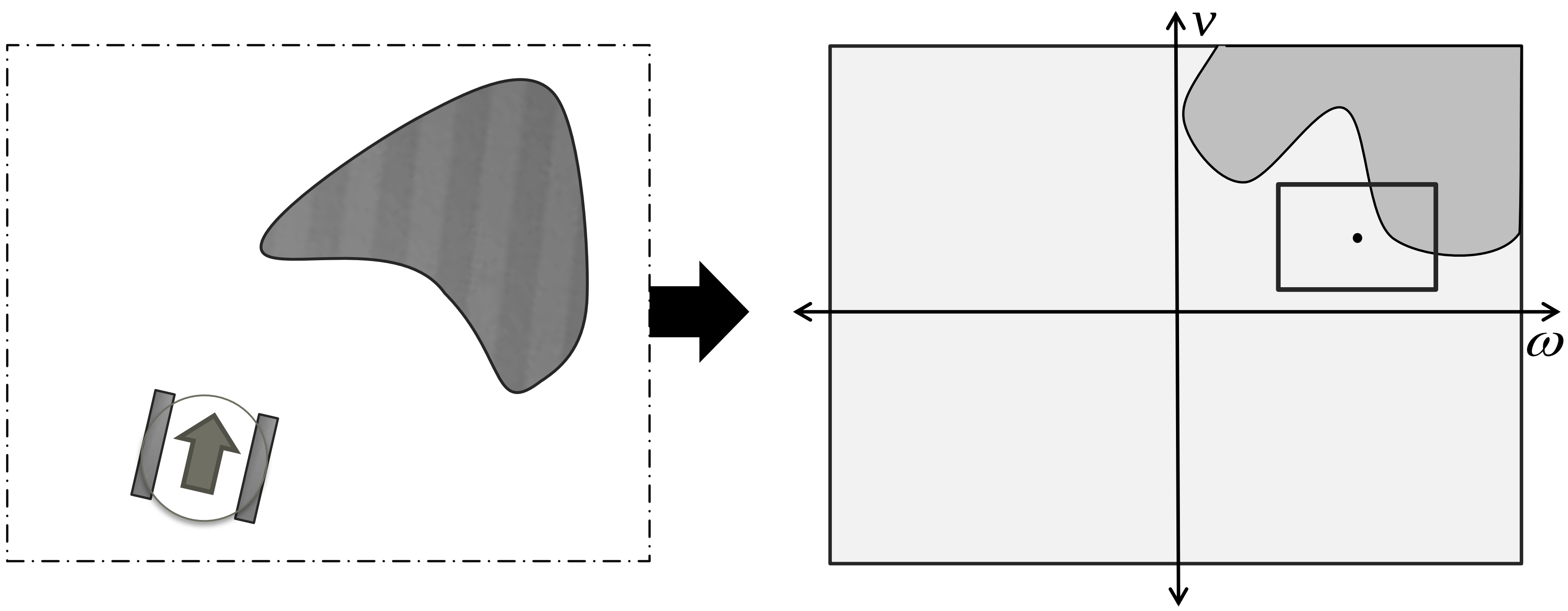

Dynamic Window Approach (DWA) | properties

- DWA accounts for robot kino-dynamics
- Cost function is prone to local optima
- The method assumes that objects are static

Velocity Obstacles (VO) | working principle

- The robot is assumed to move on piece-wise linear curves
- The Velocity Obstacle is composed of all robot velocities leading to a collision with an obstacle before a horizon time τ

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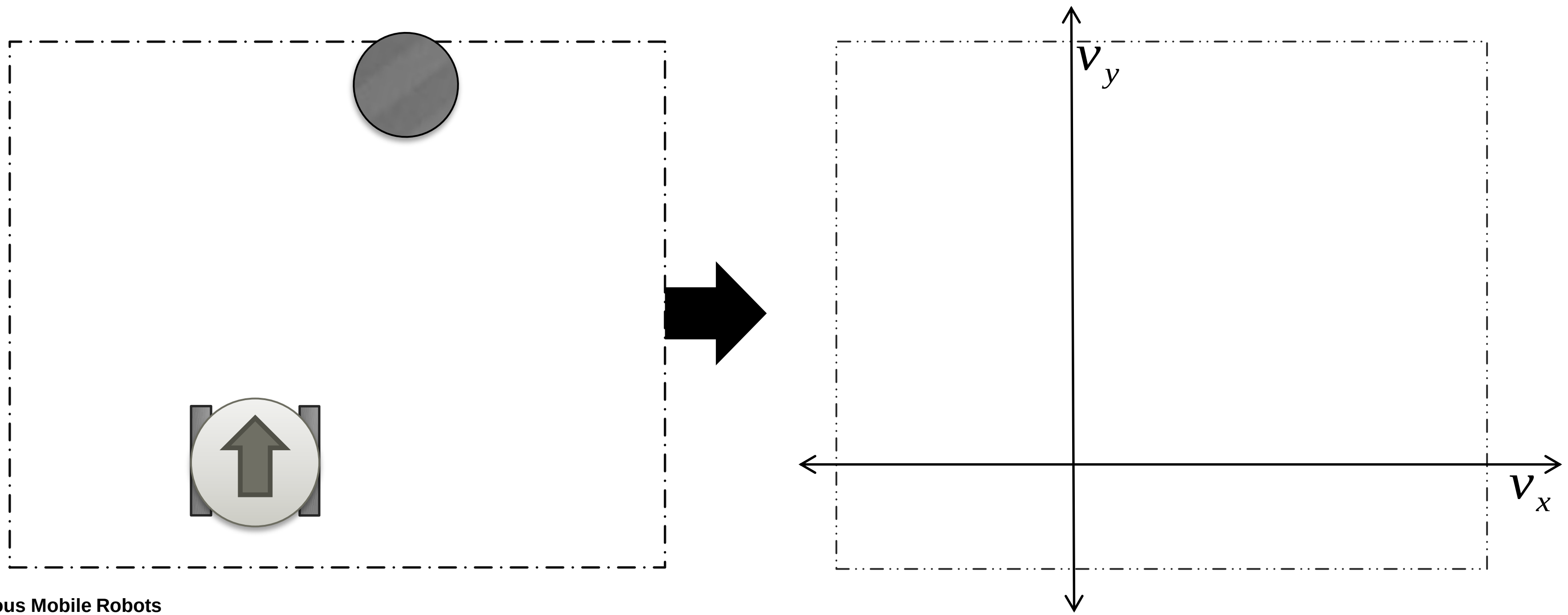

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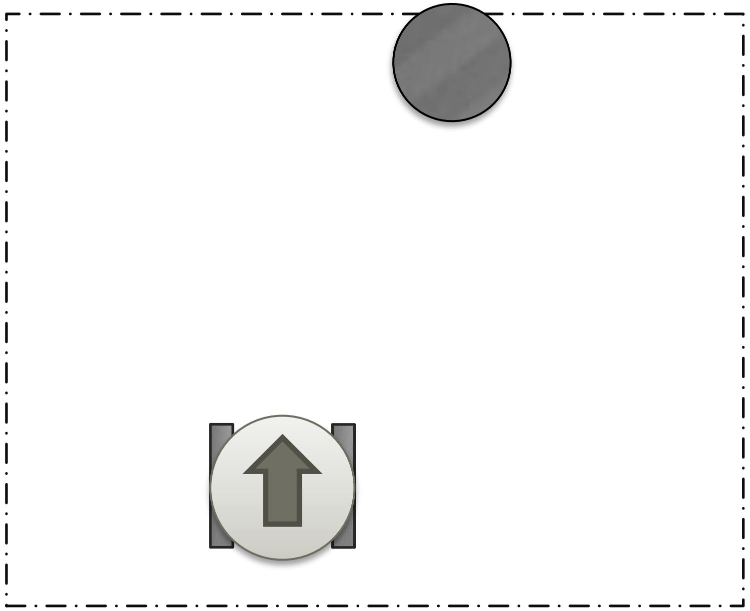

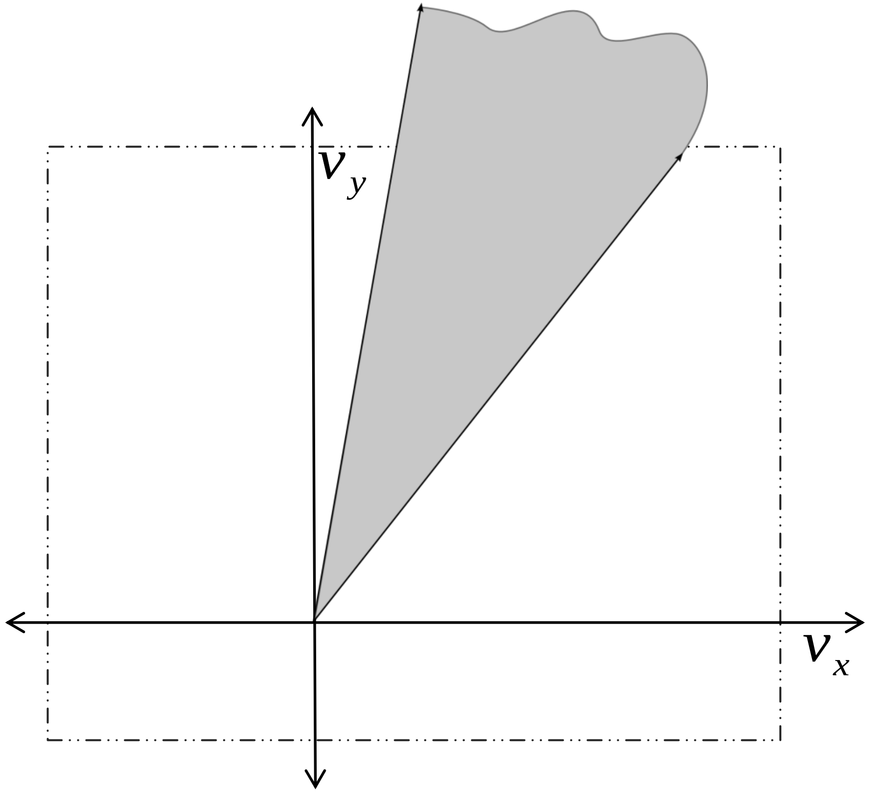

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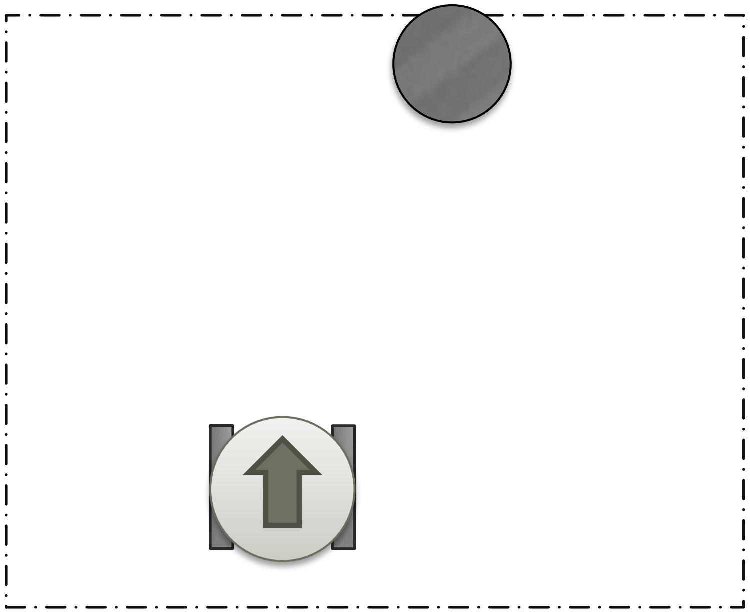

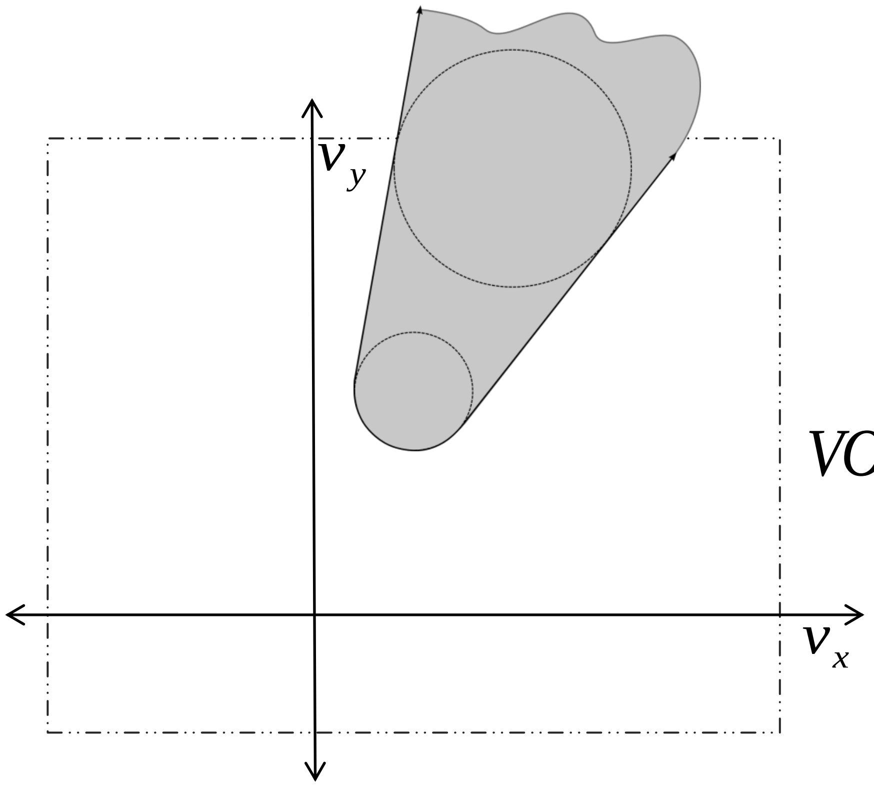

$$\left\|\boldsymbol{p}_{RO} + \boldsymbol{v}_R t\right\| < r_R + r_O$$

$$VO_{RO}^{\tau} = \bigcup_{0 \le t \le \tau} D\left(-\frac{\boldsymbol{p}_{RO}}{t}, \frac{r_{RO}}{t}\right)$$

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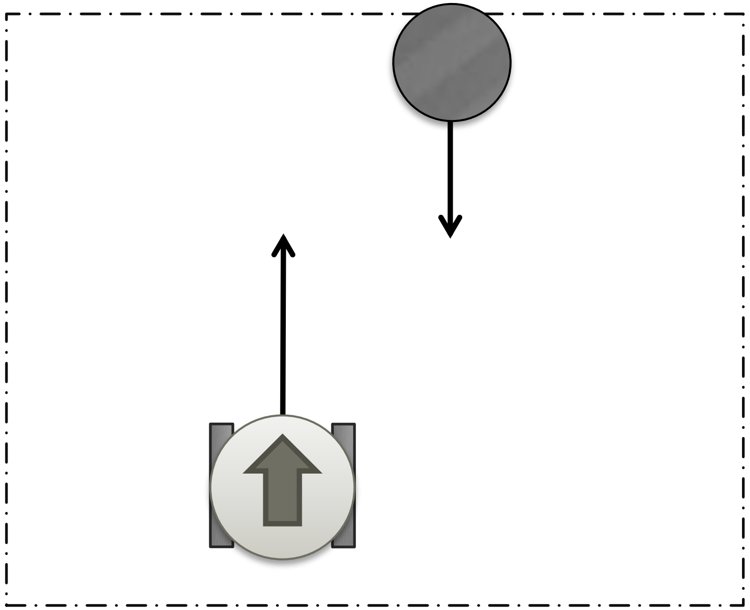

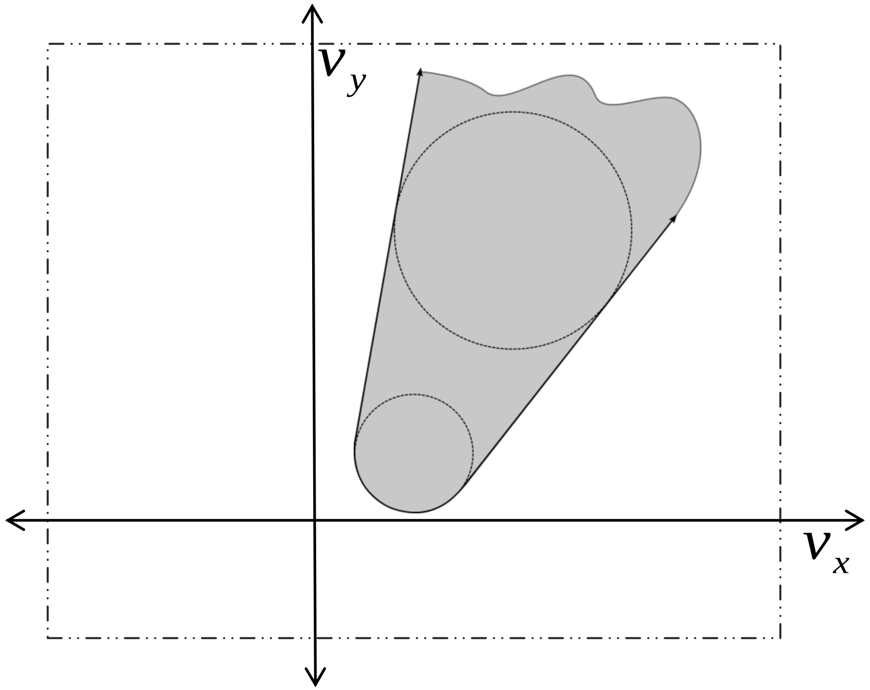

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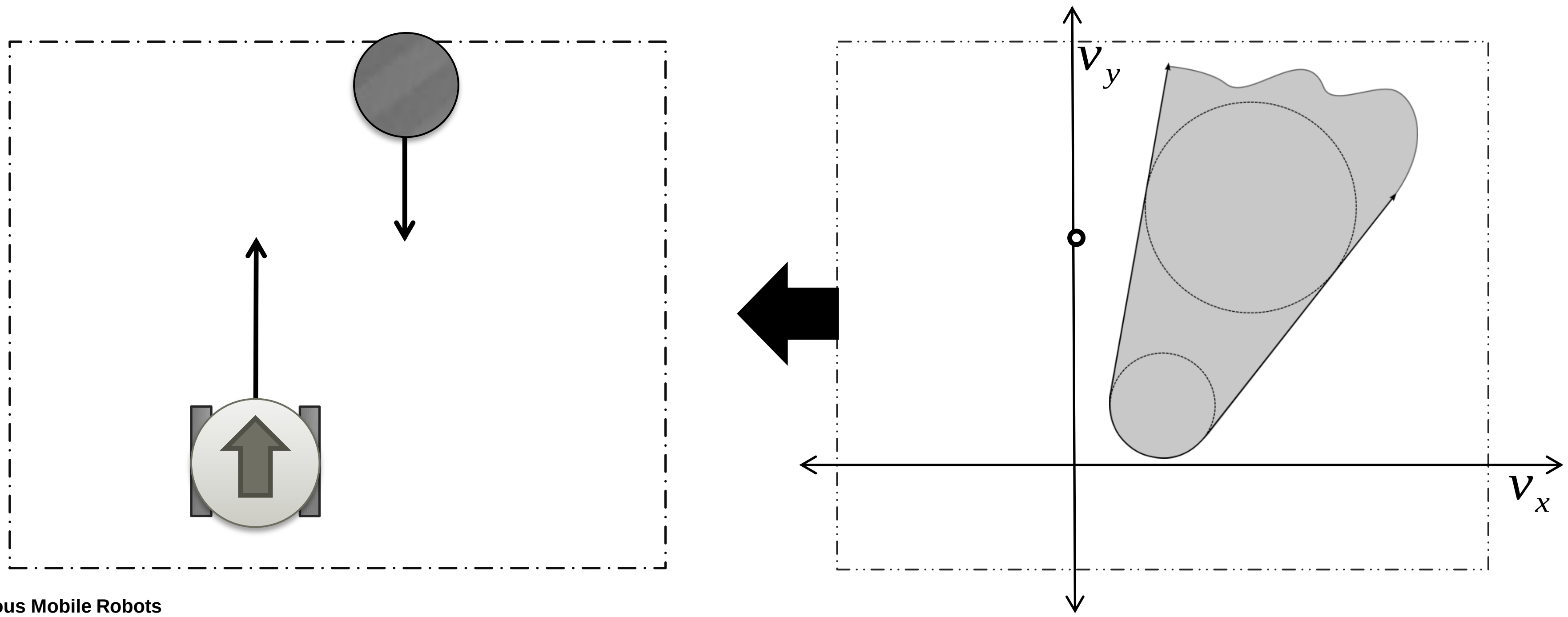

Velocity Obstacles (VO) | properties

- VO considers the velocity of other objects
- It is prone to local optima
- It does not model interaction effects

Interactive collision avoidance | overview

- Methods compute actuator commands based on local environment
- They are characterized by
  - Being light on computational resources
  - Being purely local and thus prone to local optima
  - Incorporation of system models and higher-order reflection

Reciprocal Velocity Obstacles | working principle

- The robot is assumed to move on piece-wise linear curves
- Identical to the Velocity Obstacles method, except that collision avoidance is shared between interacting agents – fairness property

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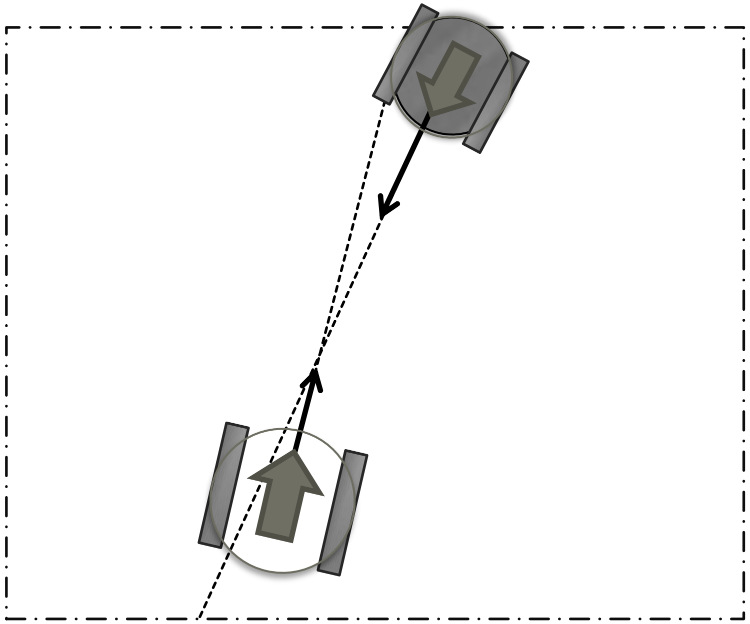

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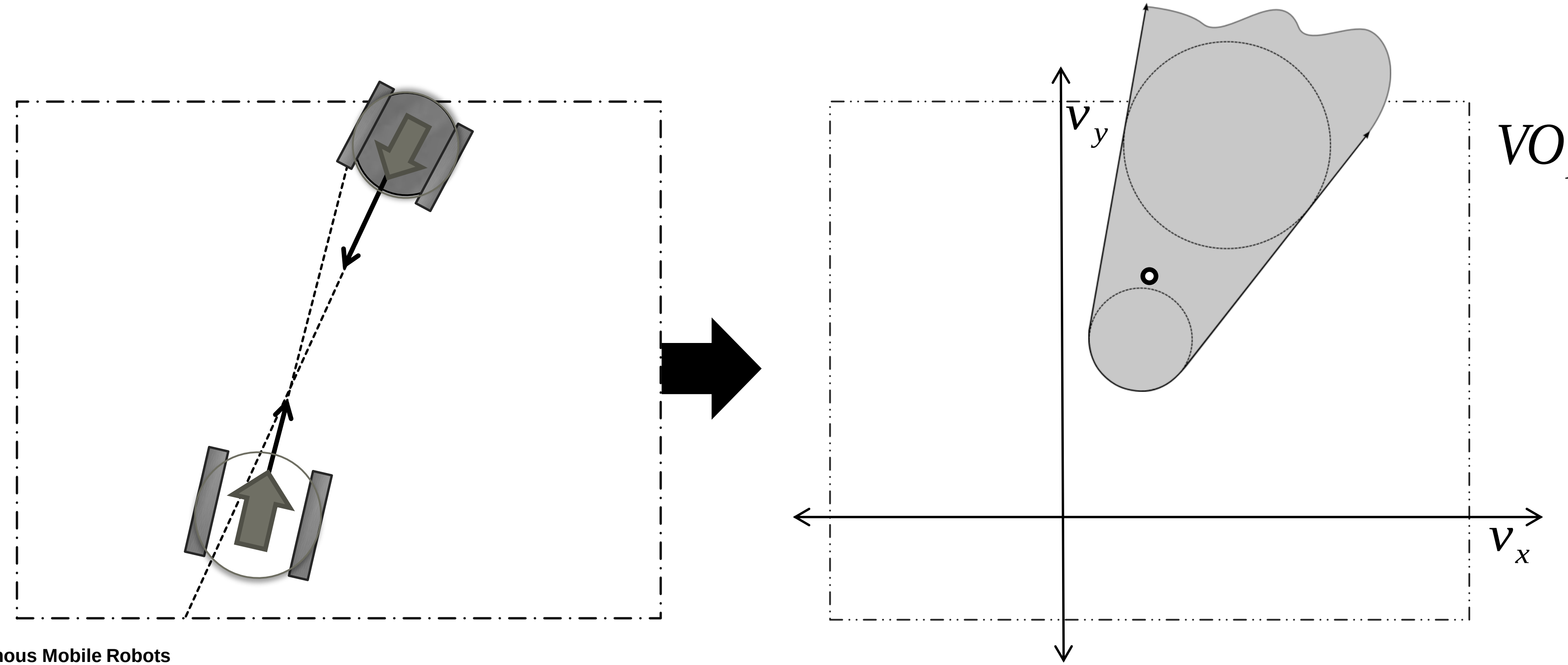

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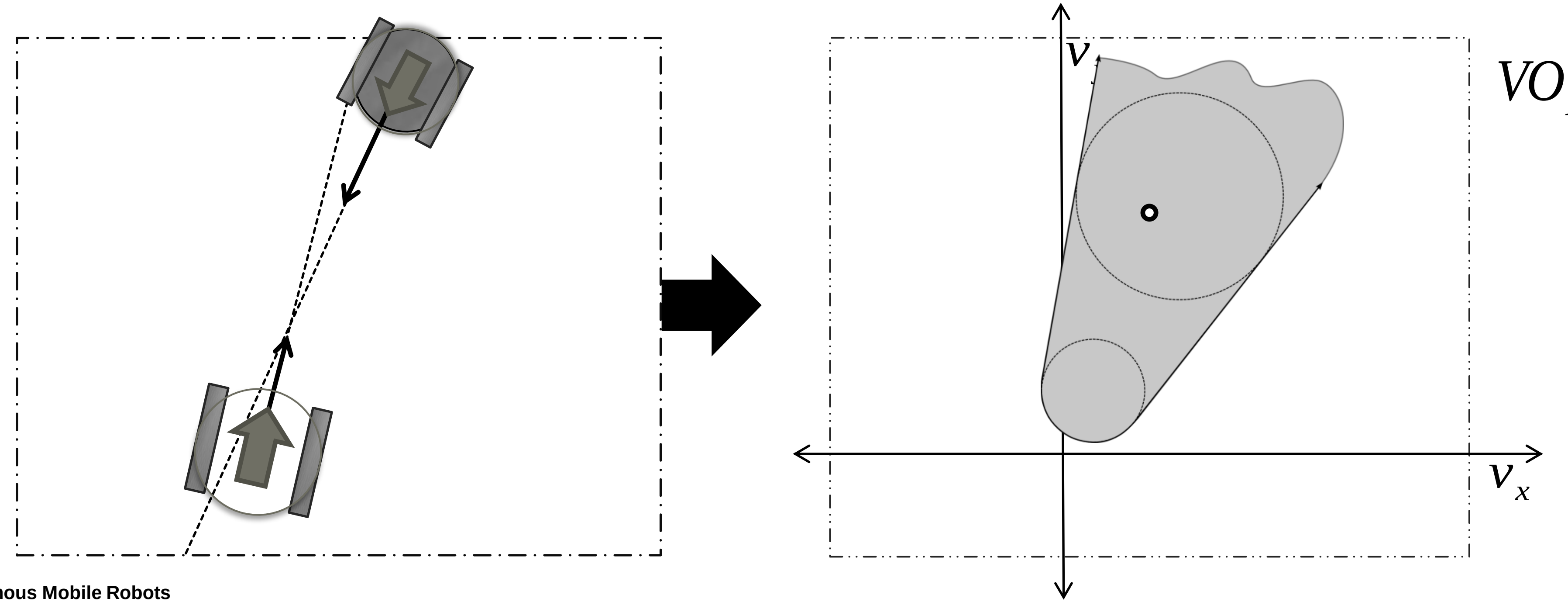

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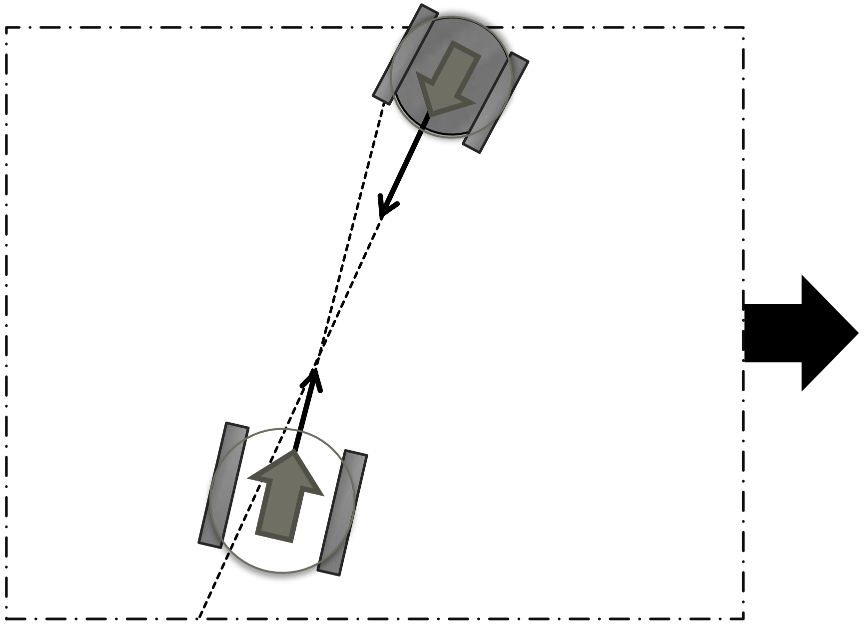

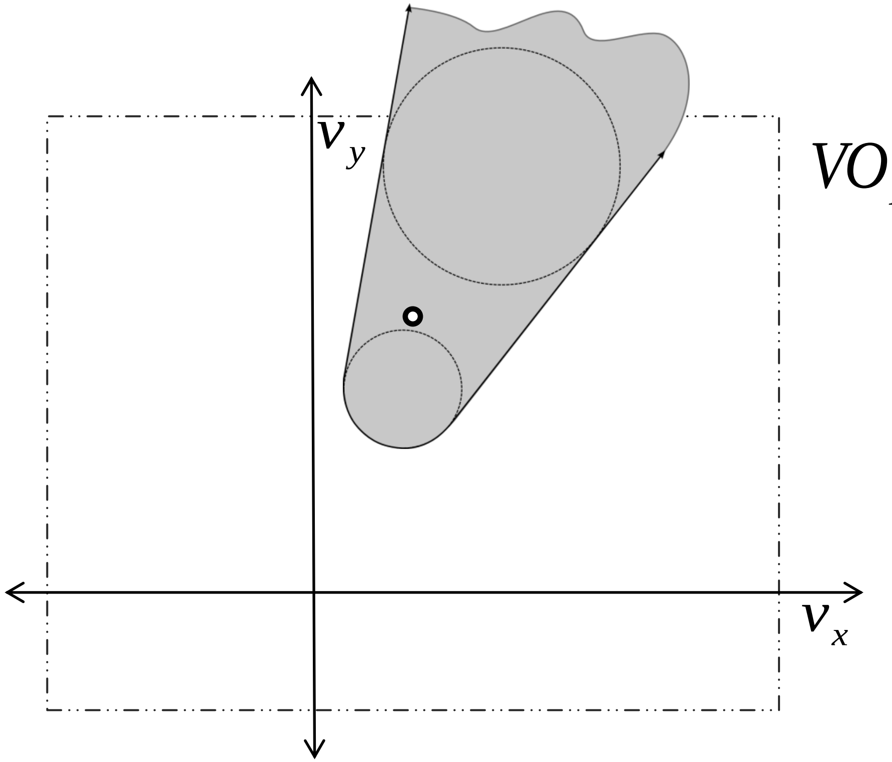

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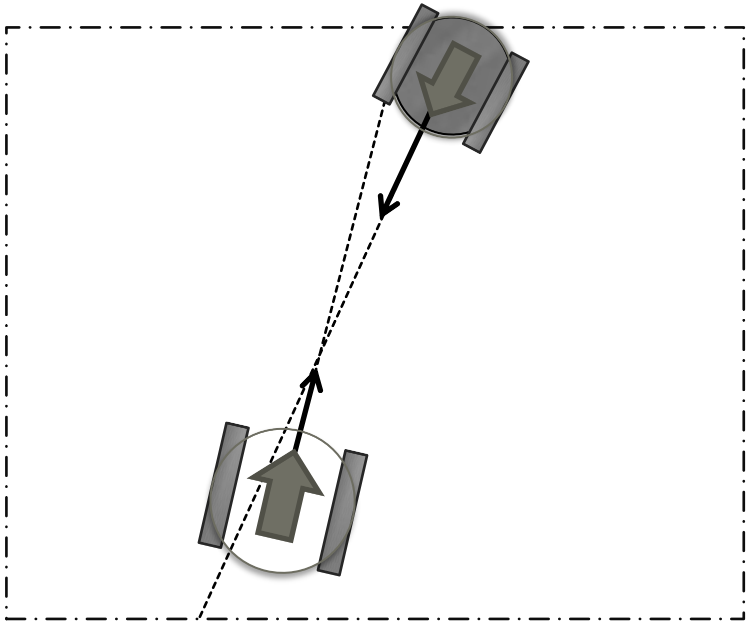

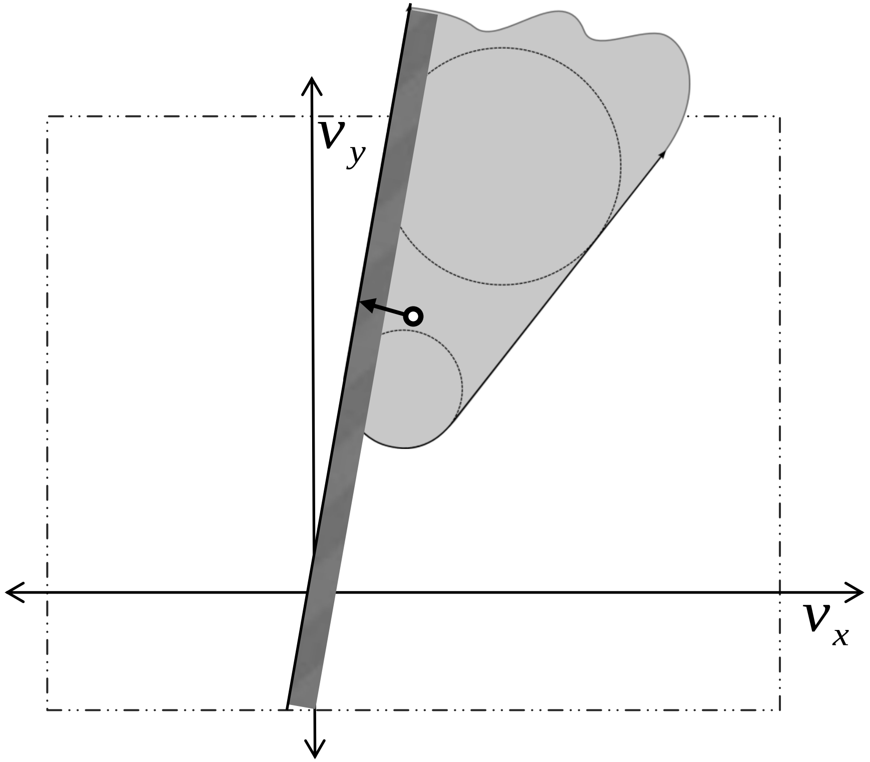

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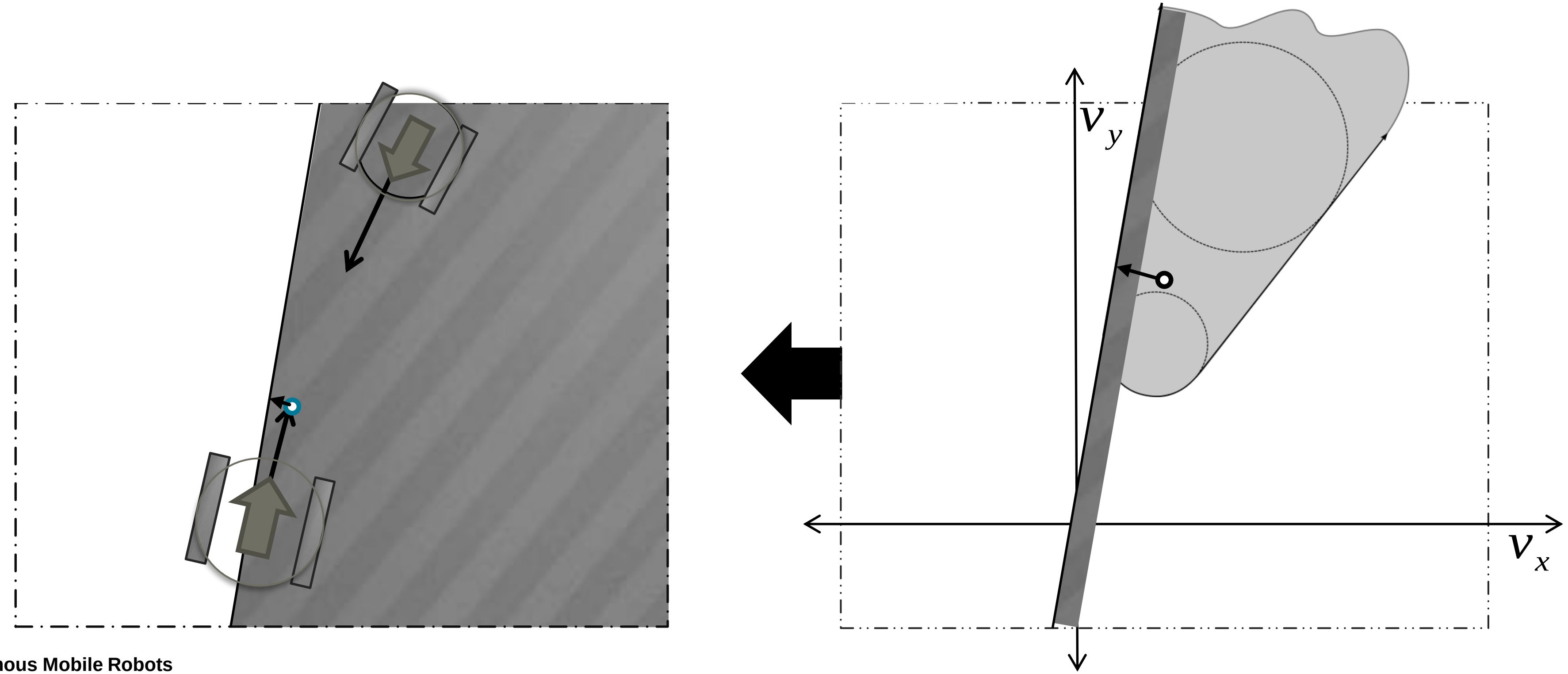

Reciprocal Velocity Obstacles | properties

- Cost function is prone to local optima
- Interaction is handled via a fairness property
- The method is restricted to agents with omni-directional actuation

Collision Avoidance | further reading

- Integration of more complex motion models into reciprocal collision avoidance
- Integration with global search methods
  - M. Rufli, J. Alonso-Mora, and R. Siegwart. "*Reciprocal Collision Avoidance with Motion Continuity Constraints*". IEEE Transactions on Robotics, 2013.