Distributed V-Formation with Dynamic Neighborhood Resizing

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TECHNISCHE UNIVERSITÄT WIEN

logics LOGICAL METHODS IN COMPUTER SCIENCE

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Problem

Hypothesis: Bird flocking can be modeled as a Markov decision process

V-formation preserves energy

How to reach and maintain a V-formation for an arbitrary flock of B birds in distributed way?

Challenges

- Environmental uncertainties
- Nonlinear cost function
- Enormous state-space
- Real variables

Model

States (positions,velocities)**:** $s(t) = \{x_i(t), v_i(t)\}_{i=1}^{B}$

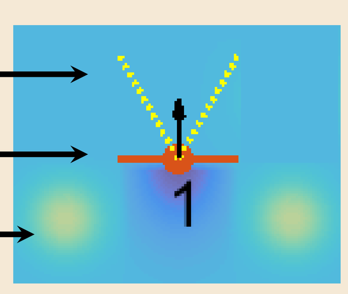
Transitions:

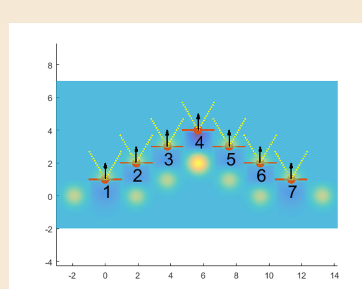
$$x_i(t+1) = x_i(t) + v_i(t+1) + \xi,$$
$$v_i(t+1) = v_i(t) + a_i(t) + \nu,$$

$a_i(t)$ – controlled accelerations, ξ, ν – noises

Costs: $\sum$ of squared distances from the optimal

- clear view
- velocity matching
- upwash benefit





$$J(s_{a^h}(t+h)) \to \min_{a^h(t)}$$

s.t. $||v_i(t)|| \leqslant v_{max}, ||a_i^h(t)|| \leqslant \rho||v_i(t)|| \; \forall\, i = \overline{1, B}$

h – look-ahead

Solution Approaches

- ~~Rule-based~~ – limited applicability
- ~~Model-Predictive Control~~ – no guarantees

Our Approach

Input: an MDP in an arbitrary initial state

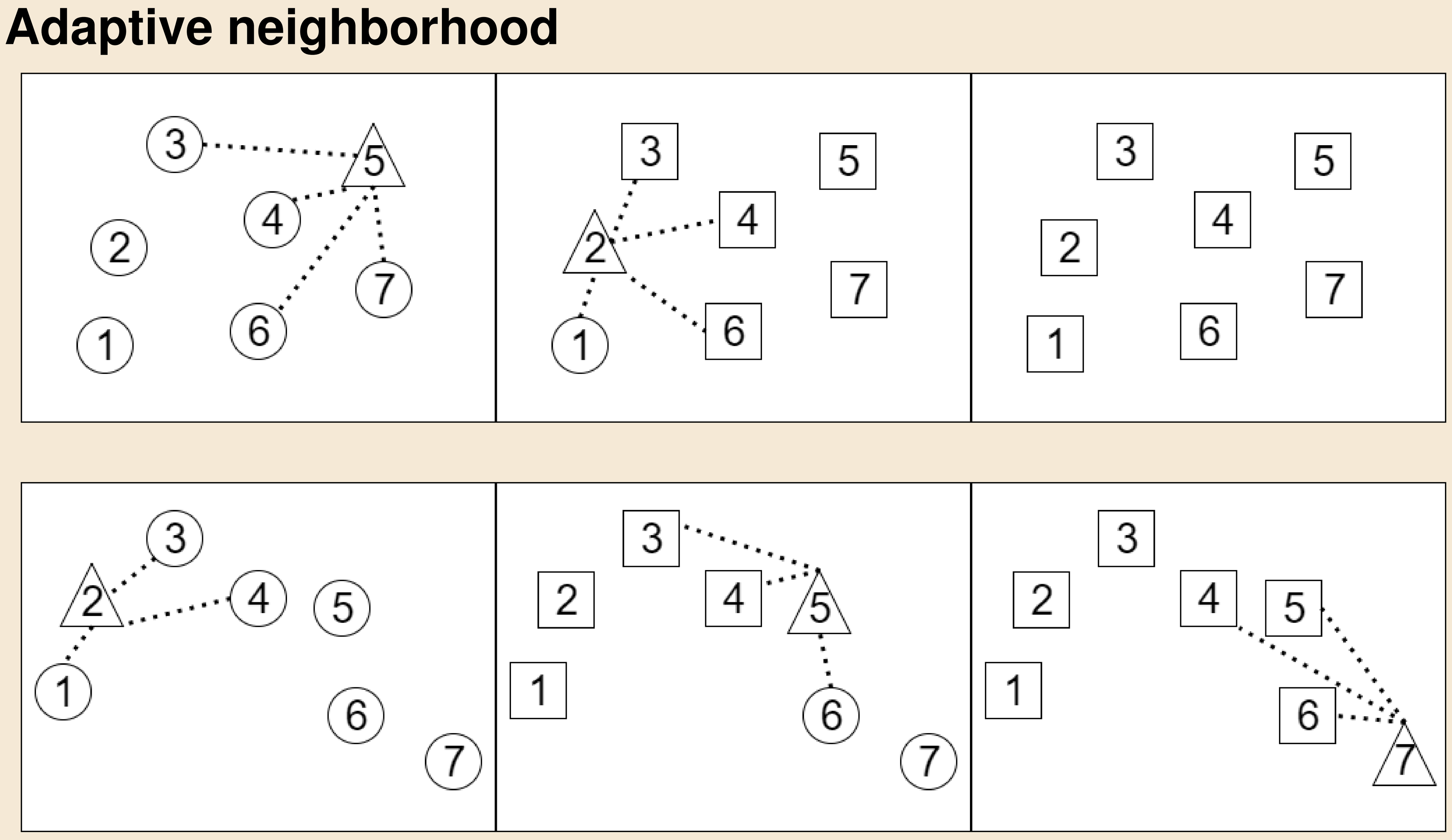
Output: distributed optimal control

Distributed Adaptive Horizon Adaptive Neighborhood Model Predictive Controller combines:

- Adaptive-size PSO to obtain optimal control sequence iteratively $\Rightarrow$ **speed**
- Adaptive level-based horizon $\Rightarrow$ **convergence**
- Adaptive neighborhood resizing $\Rightarrow$ **efficiency**

Distributed Control with Local Information and Consensus

Adaptive neighborhood



`NeighSize`$(J, J', k) = \min\left(\max\left(\lceil log_2(J)\rceil, 0\right) + k_{min}, k_{max}\right)$

Adaptive horizon