DISTRIBUTED FLIGHT FORMATIONS

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DECLARATIVE FLOCKING

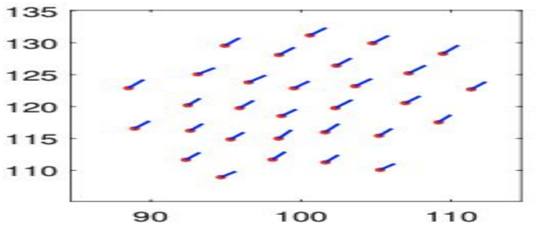
A control law for flocking is designed based on a cost function capturing *cohesion* and *separation*

Cohesion causes the agents to move towards the centroid of its local neighborhood and *separation* makes them move away from their neighbors

Model Predictive Control (MPC) is used to define controllers in a centralized and distributed settings

MPC solves the optimization problem to maximize the flocking cost function to generate an agent's acceleration

Agents starting from random initial positions successfully converge to a flock using declarative flocking



Converged flock of 30 agents using Declarative Flocking. The red points represent the agents and the blue lines represent their velocity vectors

NEURAL FLOCKING

Distributed Neural Flocking Controller (DNC) is synthesized using Deep Learning from a centralized flocking controller.

Control objectives such as flocking, collision avoidance, obstacle avoidance and target seeking are defined using suitable cost functions

Deep neural network is used to learn these control objectives from the flock trajectories generated by the centralized MPC controllers

The DNC is verified using Statistical Model Checking by computing confidence intervals for its convergence rate and convergence time

KEY FINDINGS

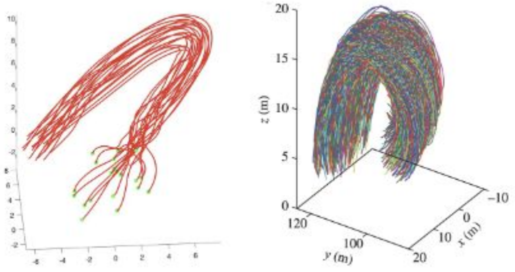
> DNN is initially trained and tested on **15** agents

> DNN generalizes very successfully upto **40** agents

> DNN outperforms traditional approaches like MPC in terms of scalability and computation time

> DNN is also capable of learning other flight formations such as V-formation

> A Counter-example guided k-fold Retraining methodology can be used to augment the learning procedure to improve DNN performance



U-turn trajectories with AWN-DMPC for 20 agents (left)
U-turn trajectories of starlings observed in nature (right)

FLOCKING MANEUVERS

Distributed MPC with Acceleration-weighted Neighborhooding (AWN-DMPC) is used to synthesize a controller for high-speed maneuvers

AWN exploits the imbalance in agent accelerations during a turning maneuver to ensure that actively turning agents are prioritized.

Only few agents (initiators) are aware of the maneuver objective. AWN-DMPC controller ensures this local information is propagated throughout the flock

AWN-DMPC is capable of performing high-speed maneuvers for large flock sizes with only 4 initiators.