

Evolving Neural Controllers for Xpilot-AI Racing Using Neuroevolution of Augmenting Topologies

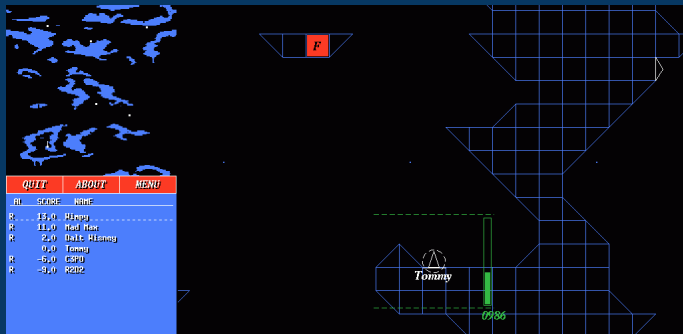
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Motivation

- ▶ Xpilot-AI is a 2D space simulator with inertia, friction, gravity.
- ▶ NEAT is able to evolve both structure and weights of neural networks.
- ▶ We aim to train adaptive controllers for new racing mode in the Xpilot environment.

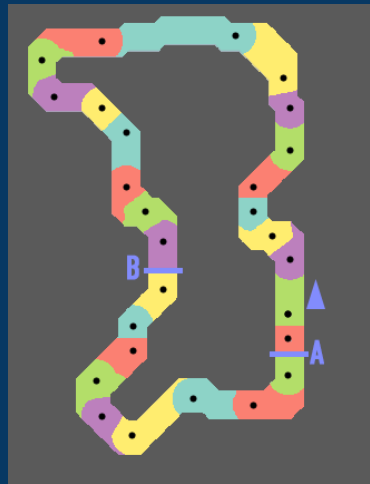
Xpilot & Xpilot-AI



- ▶ **Xpilot:** A classic open-source 2D multiplayer space combat game featuring physics-based movement (inertia, friction, gravity).
- ▶ **Xpilot-AI:** Academic adaptation of Xpilot designed for AI research and autonomous agent development.

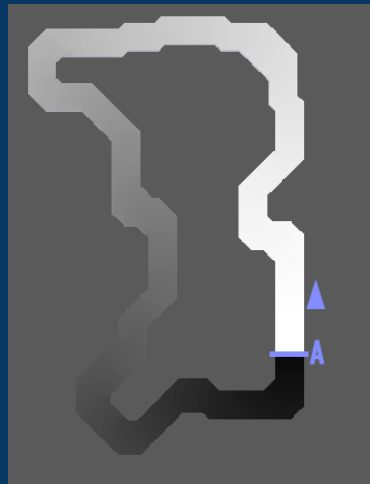
Xprace: New Racing Extension for Xpilot

- ▶ Designed for high-speed, continuous control evaluation
- ▶ Fully enclosed circuits with randomized corners and straights
- ▶ Crash = instant failure; no partial penalty
- ▶ Dual starting points (A and B) to avoid first-turn overfitting



Agent Observations and Outputs

- ▶ 23 input features: wall distances, angles, speed, waypoints.
- ▶ 2 output variables: turn angle and thrust scalar.
- ▶ Inputs enable spatial-understanding and dynamic adjustment.
- ▶ Vision modeled using geometry of ship and track layout.



Fitness Function Design

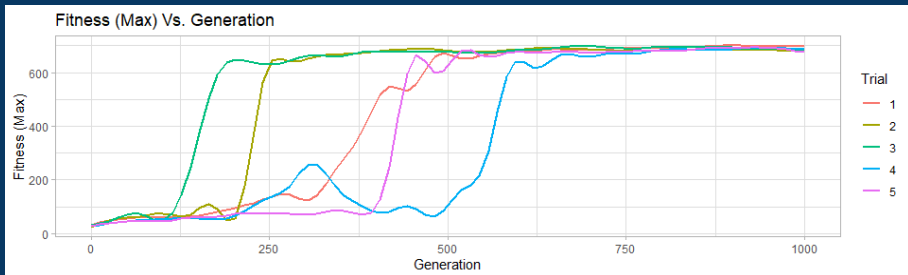
- ▶ Emphasizes progress first, then speed optimization.
- ▶ Completion bonus: $C^{1.1}$
- ▶ Speed bonus: $\text{Speed}^{1.1}/250$
- ▶ Lap time bonus: if finished, $(T + 75)^{1.2}$
- ▶ Final fitness: summed over both start points.

NEAT Configuration

- ▶ Population size: 200, 2 hidden layers, partial connectivity.
- ▶ Speciation and elitism ensure diversity.
- ▶ Stagnation limit: 50 generations to avoid local minima.
- ▶ Fitness aggregated over two starts per generation.

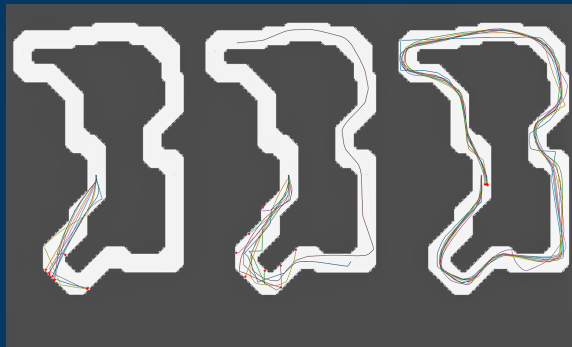
Performance Results

- ▶ All 5 trials successfully evolved full circuit completion.
- ▶ 32.8% lap time improvements for Point A and 26.2% lap time improvements for Point B
- ▶ Completion as early as generation 132.



Emergent Racing Behavior

- ▶ Learned human-like strategies:
 - ▶ “Outside-Inside-Outside” cornering.
 - ▶ Adaptive throttle and braking.
- ▶ Top agents emerged from different species.



Conclusion and Future Work

- ▶ NEAT enables robust controllers in physics-driven racing.
- ▶ Agents evolved without explicit path-following constraints.
- ▶ Future work:
 - ▶ Apply ES-HyperNEAT for higher-dimensional inputs.
 - ▶ Extend to multi-agent competitive racing.
 - ▶ Train across multiple track layouts.

Thank You!

Questions?