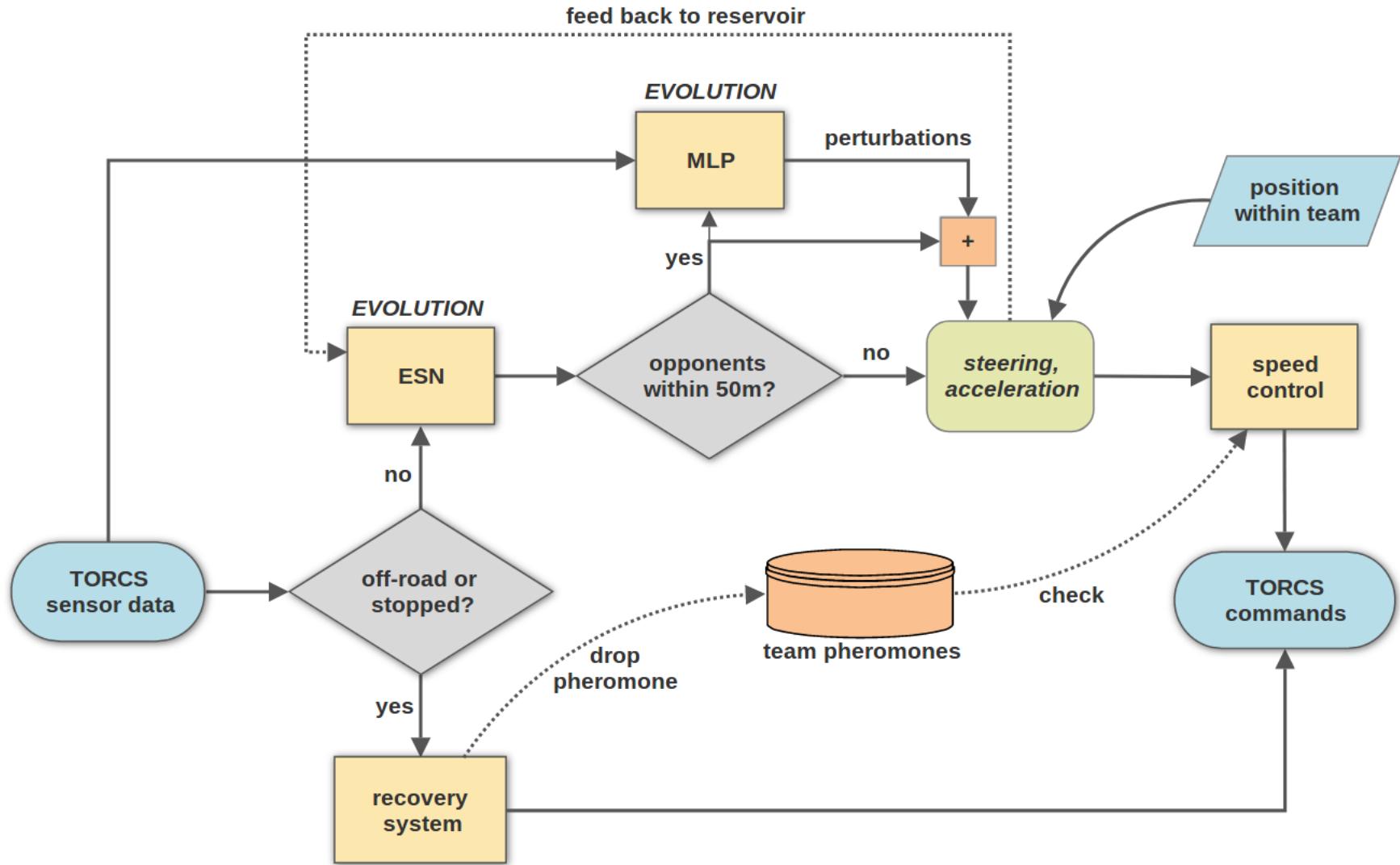


Developing a Competitive TORCS Controller using Evolutionary Strategies

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Controller Architecture



Echo State Network

- Complex short-term memory facilitates smooth actions
- Separation between reservoir and readout
 - Training speed up
 - Reservoir optimisation through evolutionary strategies
- Training data collected from TORCS driver '*damned*'

Evolutionary Strategies

Table 1: Evolutionary Algorithm Design

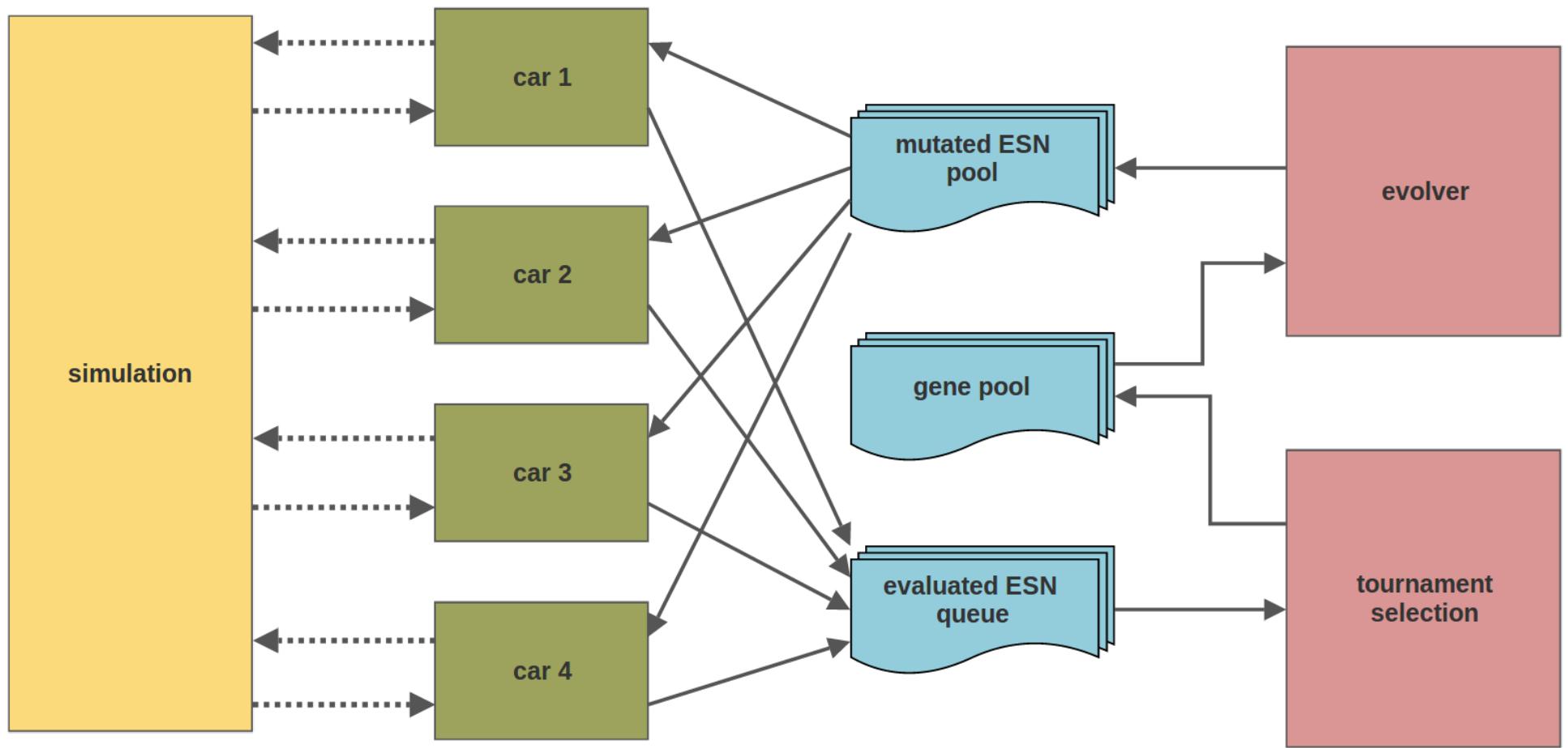
Method	Parameters			
	Off-Line	On-Line	MLP	
Representation	weight matrix			
Cross-over	uniform	$p_{\text{cx}} = 0.2$ $p_{\text{ind}} = 0.1$	N/A	N/A
Mutation	Gaussian	$p_m = 0.75$ $p_{\text{ind}} = 0.05$ $\sigma = 0.3$	$p_{wm} = 0.1$ $p_{sm} = 0.3$ $\sigma = 0.1$	$p_m = 0.95$ $p_{\text{ind}} = 0.25$ $\sigma = 0.4$
Parent selection	random			
Survivor selection	tournament	size = 10	size = 10	size = 5
Generational strategy	(μ, λ)	(20, 80)	steady state	(20, 60)

$$f_{\text{offline}} = \sum_{\text{tracks}} \left(d_{\text{raced}} - 0.1 \sum_{t=0}^T d_c - 0.01 \sum_{t=0}^T \theta - 100 \cdot n_{\text{stop}} - 100 \cdot n_{\text{offroad}} \right)$$

$$f_{\text{mlp}} = \sum_{\text{tracks}} \left(5 \cdot n_{\text{win}} + \frac{d_{T/3}}{20} + \frac{d_{2T/3}}{100} + \frac{d_T}{200} + \sum_{t=0}^T \frac{v_t}{10^3} - 2 \cdot n_{\text{dam}} - n_{\text{lost}} \right)$$

$$f_{\text{online}} = \sum_{t=0}^T f_t + d_{\text{raced}} - P \quad \text{where} \quad f_t = \theta_t + c_t + b_t - r_t$$

On-Line Evolution

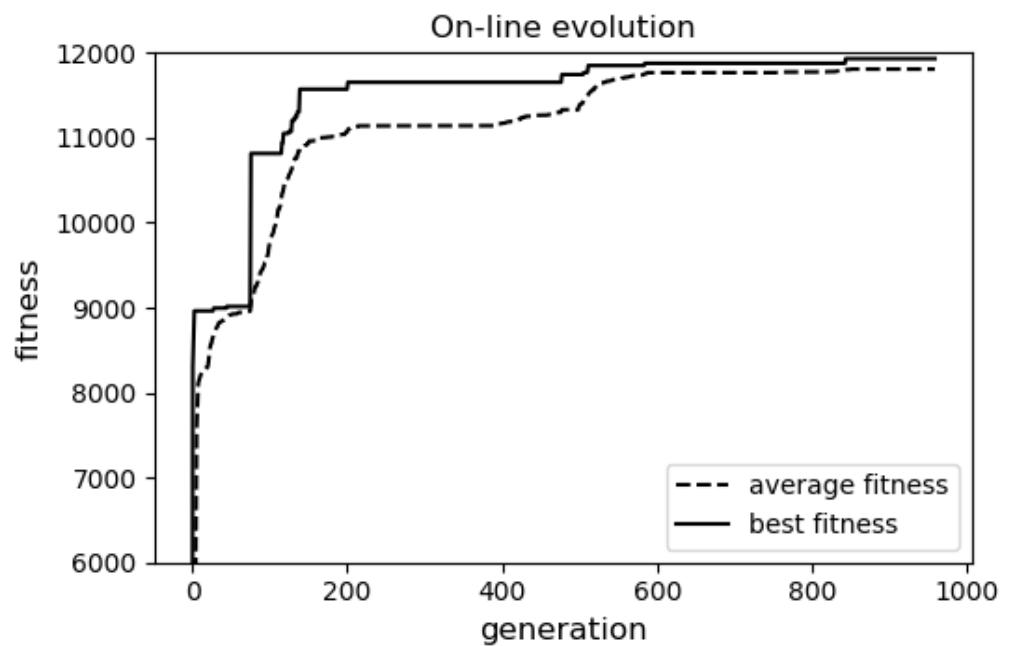
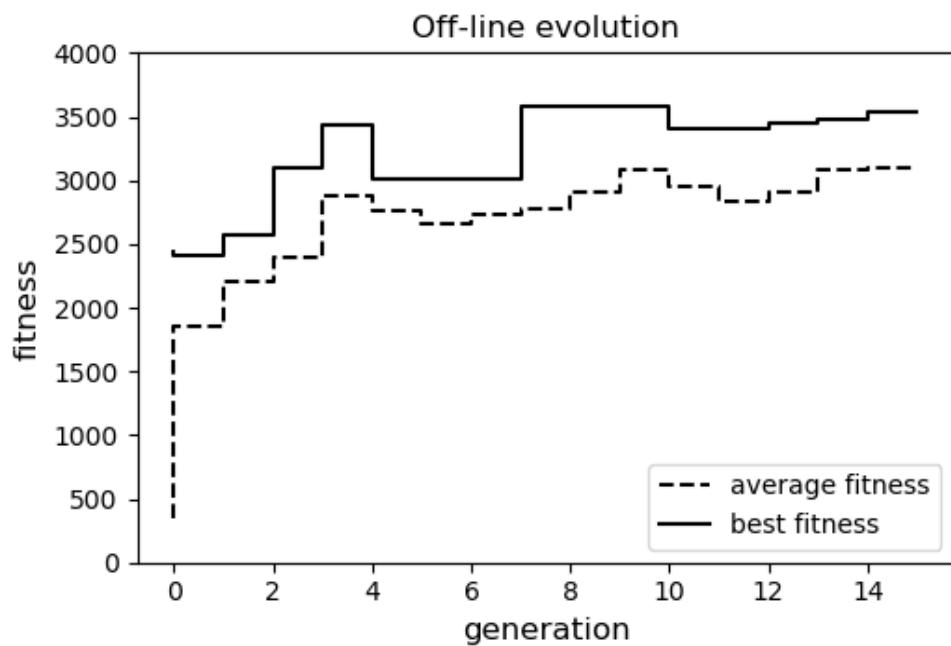


Team Strategy

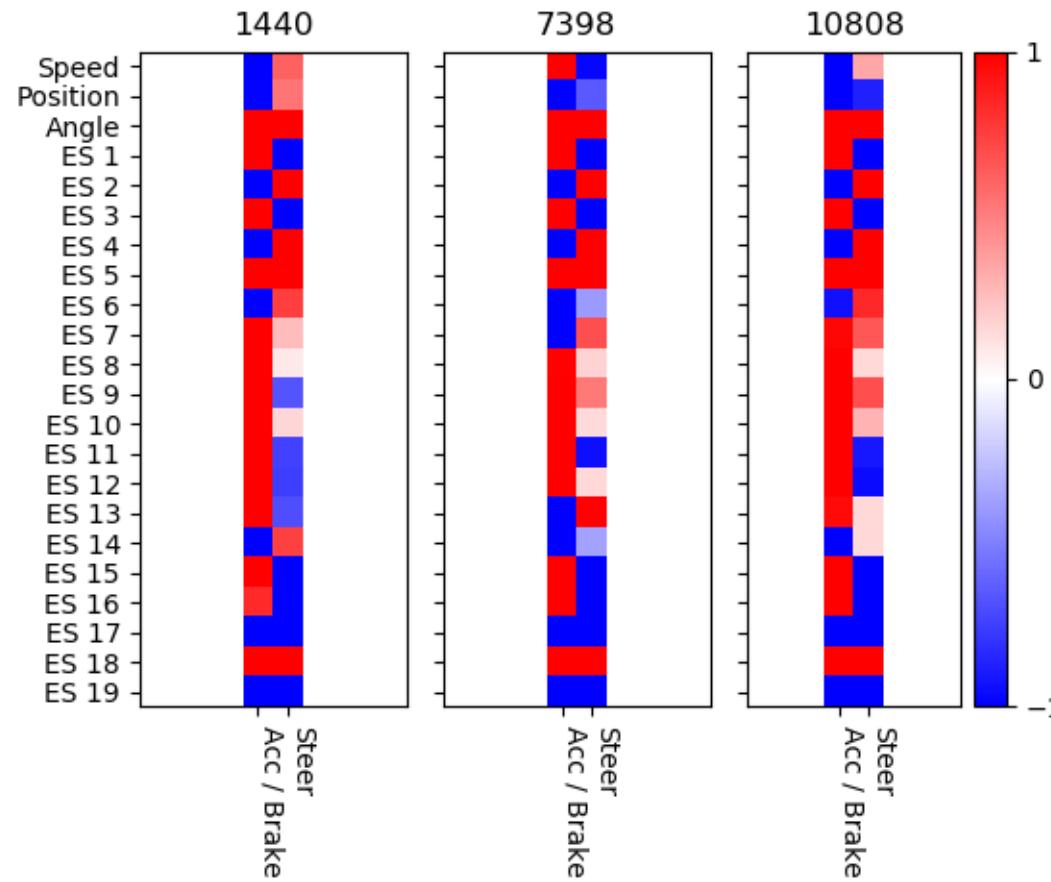
- Pheromones
 - Warning team mates of difficult track sections
 - Cars slow down on detection of nearby pheromone
- Blocking Strategy
 - If trailing team mate: block approaching opponents
 - Improves overall team performance



Results: Progress of Evolution



Results: Progress of ESN Driving Logic



Results: Performance Estimation

Table 2: Improvements in the network through evolution. Lap times in races without opponents.

	cg-track-3	e-track-4	dirt-5	alpine-2	wheel-1
simple ESN	5:55:36	d.n.f.	3:00:25	d.n.f.	d.n.f.
evolved ESN (early stage)	1:54:74	4:37:89	1:27:58	3:14:53	2:52:08
evolved ESN (final stage)	1:42:66	3:52:72	1:11:67	2:25:40	2:41:46

Table 3: Overtaking (a) and team strategy (b). Opponents are 10 bots with max speed capped at 110kph for fair comparison. Starting in 6th and team mate (when applicable) in 7th position.

(a) position after 30 seconds

	e-track-4	e-road
ESN only	9th	9th
ESN+MLP	5th	6th

(b) 10 opponents (best final position)

	cg-track-3	e-track-4	e-road
solo	11th	11th	9th
team	8th	6th	3rd