Selfish vs. Global Behavior Promotion in Car Controller Evolution

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Cooperation and goals

Cooperative tasks:

- Achievement of the goal depends on the **cooperation** of many agents

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Should the fitness award selfish or global behavior?

Global vs. selfish behavior

What does the fitness assess?

Global behavior

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Selfish behavior

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Global vs. selfish behavior

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What does the fitness assess?

Global behavior

+ captures the actual degree of achievement
- long to compute: simulate the full system with many agents

Selfish behavior

+ "fast" to compute: simulate just one agent
- a proxy for the actual degree of achievement: how to choose?

An example

Road traffic system:

- Agents: car drivers
- System goal (two-fold):
  - reaching targets (efficiency)
  - avoiding collisions (safety)

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Implicitly cooperative

Global or selfish fitness while evolving a cooperative driver?

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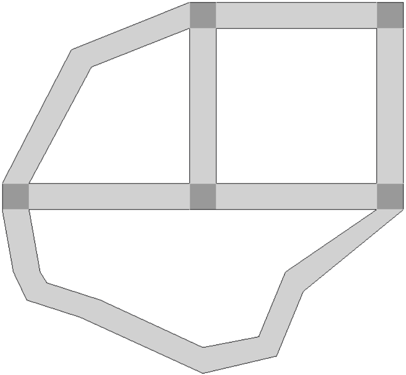
World

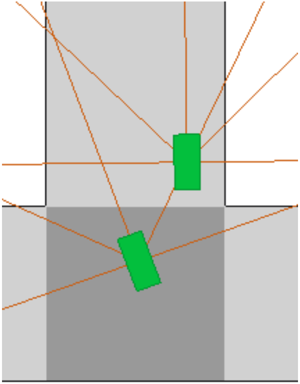
- 2D continuous space, discrete time world
- road (section, intersection), off-road
    - cars move on road only
    - cars collide with other cars and with road side



Car and agents

Car:

- each w/ 5×3 distance sensors
  - to roadside
  - to intersection
  - to other cars



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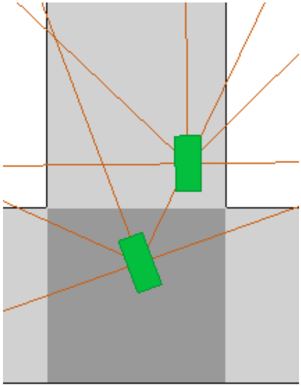

Agent (car driver/controller):

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Agent (car driver/controller):

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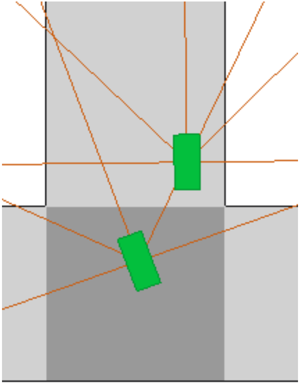
- neural network
  - input: 5×3 distance sensors, car speed, distance to target, direction of target
  - output: steering angle, acceleration/brake



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Global goal

Maximize traffic efficiency and safety

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- Efficiency: the global number of reached targets in the unit of time

$$E = \frac{1}{n_{\text{car}}} \sum_{j=1}^{n_{\text{car}}} \frac{1}{\tau} \left(t_j + 1 - \frac{l_j^f}{l_j^i} \right)$$

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- Safety: (opposite of) the global number of collisions in the unit of time

$$S = -\frac{1}{n_{\text{car}}} \sum_{j=1}^{n_{\text{car}}} \frac{c_j}{\tau}$$

Neuroevolution of the agents

Goal: evolve a the driver which maximizes, on average, traffic efficiency and safety

We used NEAT

Neuroevolution: global

- individual: controller
- fitness:
  - $f_{\text{glob}} = 100E + 0.1S$
  - n_{sim} simulations with n_{car} each, **all with the same controller** under evaluation

Neuroevolution: selfish

- individual: controller
- fitness:
  - $f_{\text{self}} = 100 E_{\text{self}} + 0.1 S_{\text{self}}$

$$E_{\text{self}} = \frac{1}{\tau}\left(t + 1 - \frac{l^f}{l^i}\right) \qquad S_{\text{self}} = -\frac{c}{\tau}$$

  - the controller under evaluation inserted in n_{sim} simulations with other $n_{\text{car}} - 1$ **different controllers**

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Global vs. selfish

Global

- one simulation to assess one controller

Selfish

- one simulation to assess n_{car} controllers at once, but on a proxy of their actual goal

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Two stages

Evolution:

- $n_{\text{sim}} = 3$, $n_{\text{car}} = 20$, $\tau = 30\,\text{s}$ (simulated)
- 10 runs, same wall time (24 h) per run for both approaches

Validation of best evolved controllers $(10 + 10)$:

- $n_{\text{sim}} = 10$, $n_{\text{car}} = \{5, \dots, 50\}$, $\tau = 60\,\text{s}$ (simulated)

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- homogeneous vs. heterogeneous
  - homogeneous: all cars driven by the same evolved controller
  - heterogeneous: 50% of cars driven by random (unskilled) controllers

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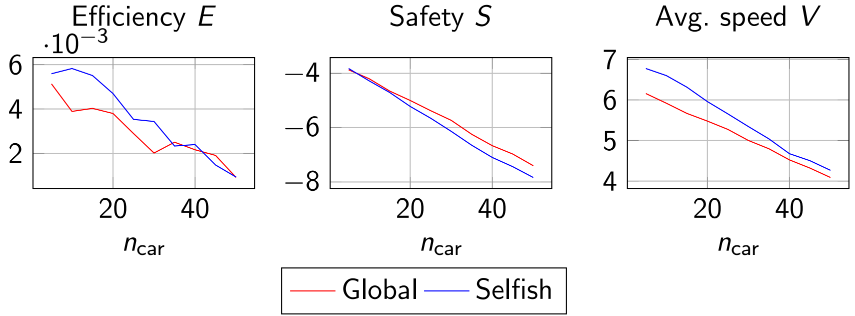
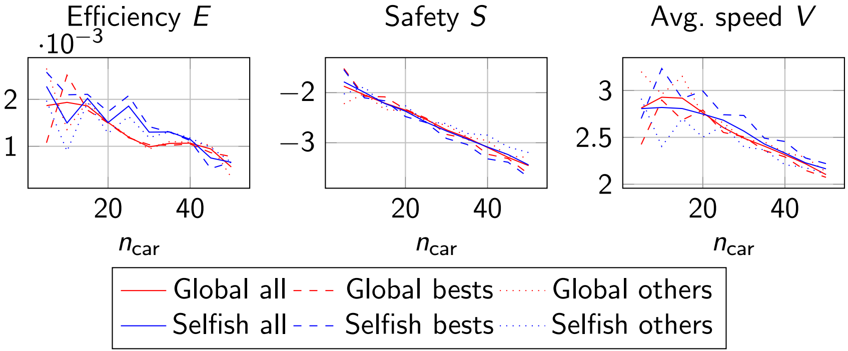
- homogeneous vs. heterogeneous
  - homogeneous: all cars driven by the same evolved controller
  - heterogeneous: 50% of cars driven by random (unskilled) controllers
  - "robustness" of evolved controllers to other driving behaviors

Homogeneous validation



- In general: the heavier the traffic, the lower efficiency and safety
- Trade-off between efficiency and safety: selfish are more efficient, less safe (reasonable)
- Selfish better with light traffic: more capable of "driving alone"
- Selfish always drive faster

Heterogeneous validation



- Fuzzier difference
- With medium traffic: selfish more efficient, equally safe → robust to presence of unskilled drivers?

Conclusions

In cooperative tasks tackled with neuroevolution:

- selfish-based fitness may replace global-based fitness
- opportunity for robustness
- how to choose a proper selfish-based fitness?

Thanks!