GP-RARS:
Evolving Controllers for the Robot Auto Racing Simulator

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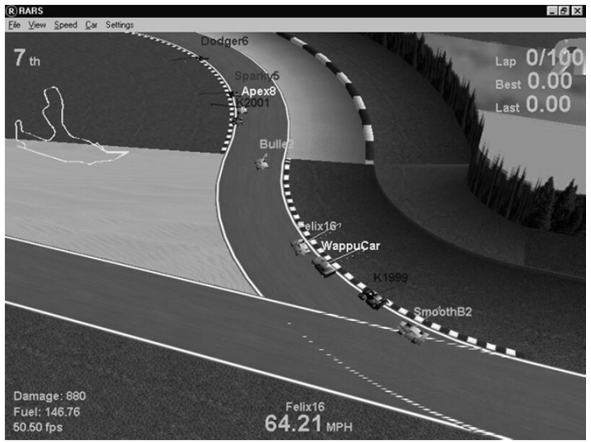
2011 “HUMIES” AWARDS FOR HUMAN-COMPETITIVE RESULTS



GECCO

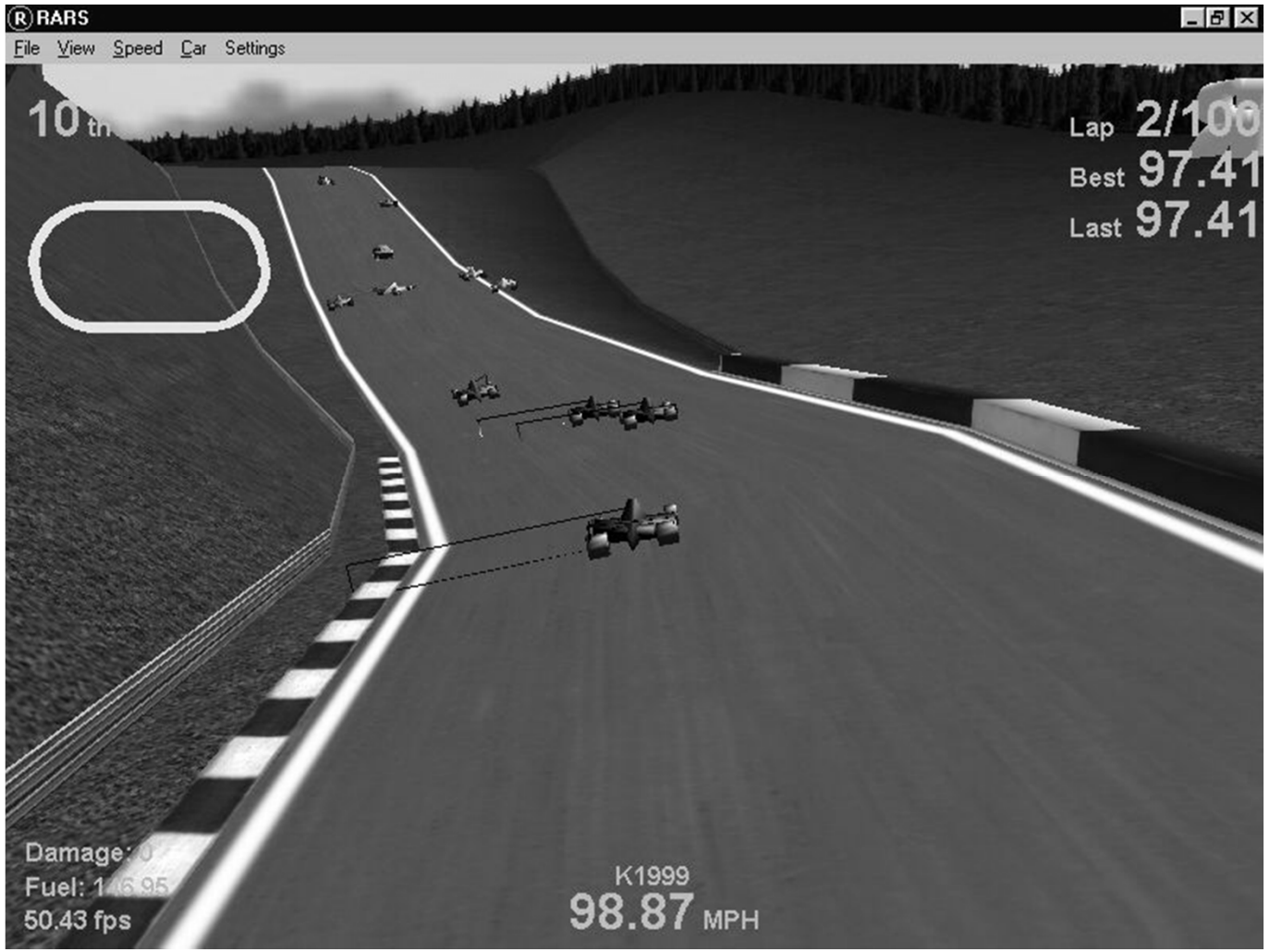
Genetic and Evolutionary Computation Conference

2011

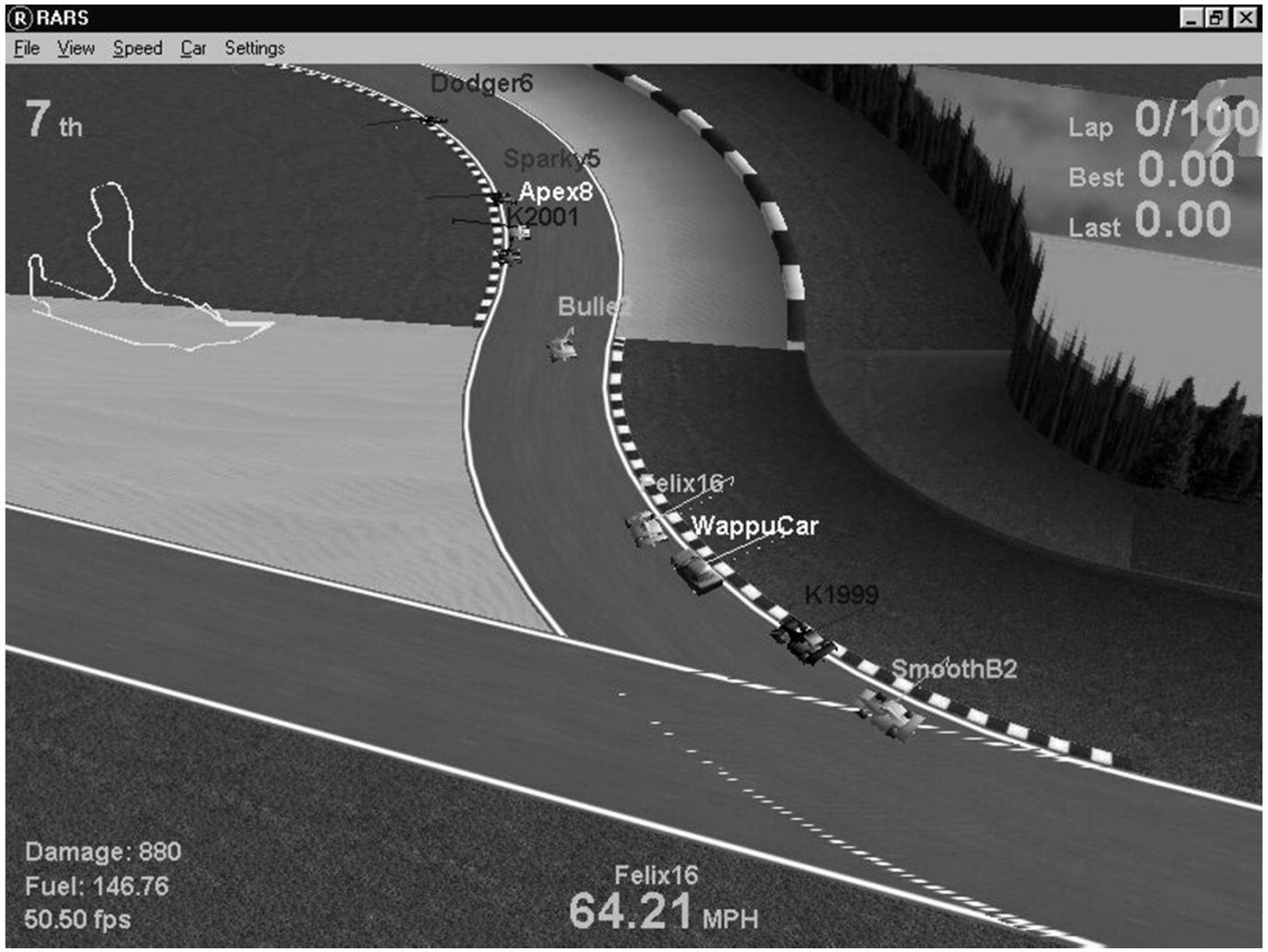
RARS: Robot Auto Racing Simulator

- Car-race simulation
- C++-based, open-source programming game
- Sophisticated physical model
- Gamer community

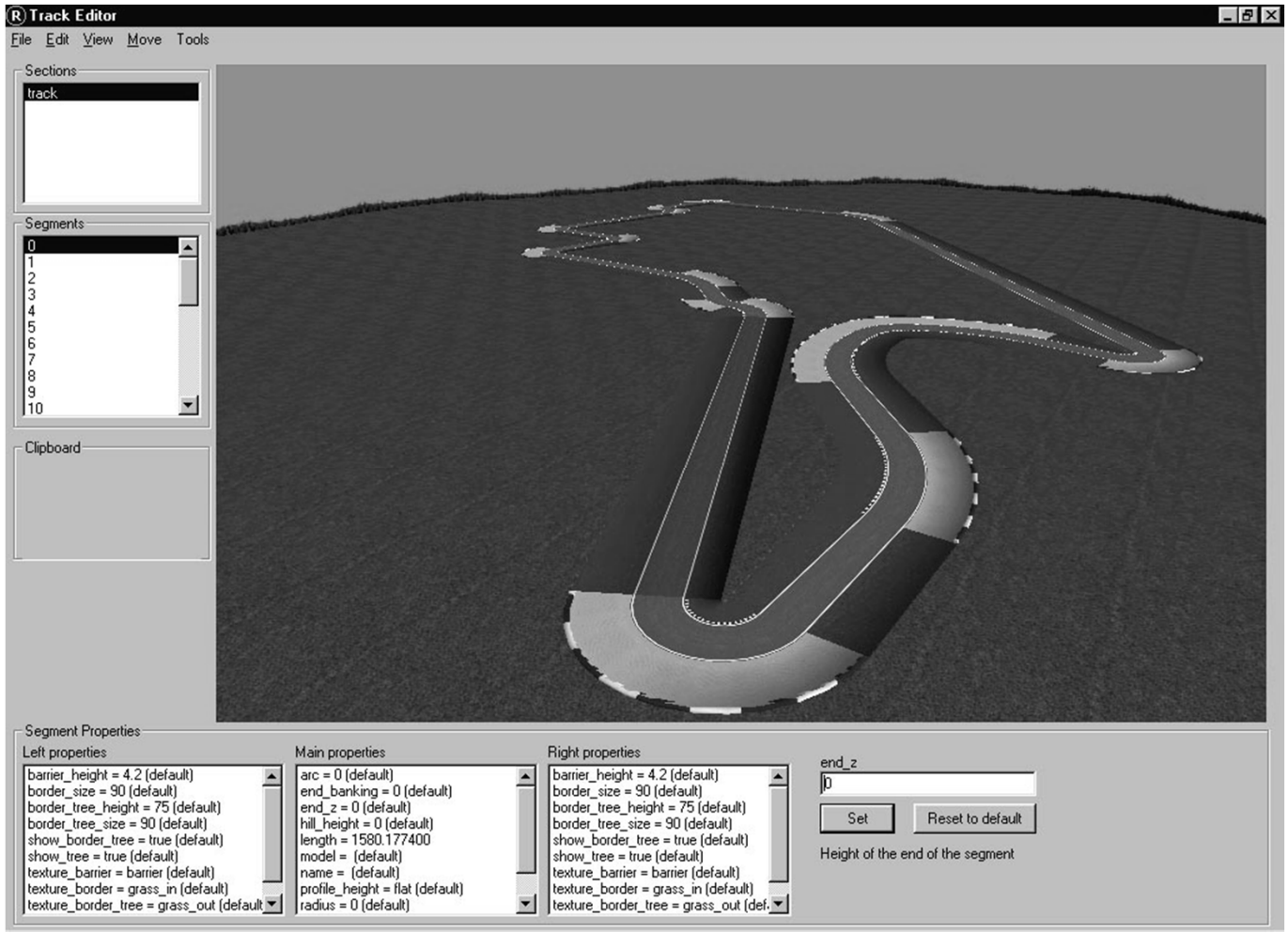
RARS


RARS
File View Speed Car Settings
Lap 2/100
Best 97.41
Last 97.41
Damage:
Fuel:
50.43 fps
K1999
98.87 MPH

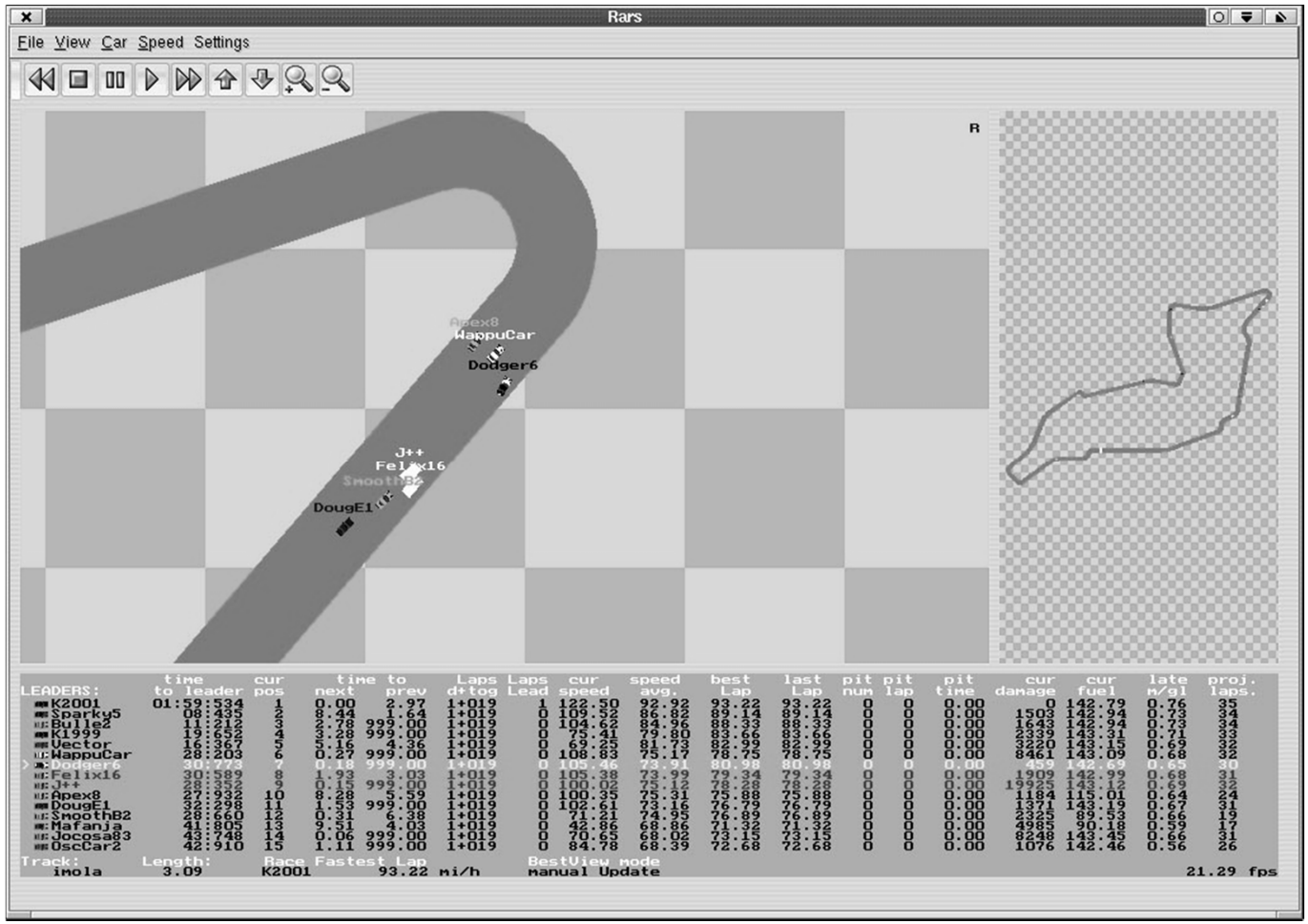
RARS


RARS
File View Speed Car Settings
7 th
Dodger6
Sparky5
Apex8
K2001
Bulle
Lap 0/100
Best 0.00
Last 0.00
Felix16
WappuCar
K1999
SmoothB2
Damage: 880
Fuel: 146.76
50.50 fps
Felix16
64.21 MPH

RARS


Track Editor
File Edit View Move Tools
Sections
track
Segments
0
1
2
3
4
5
6
7
8
9
10
Clipboard
Segment Properties
Left properties
barrier_height = 4.2 (default)
border_size = 90 (default)
border_tree_height = 75 (default)
border_tree_size = 90 (default)
show_border_tree = true (default)
show_tree = true (default)
texture_barrier = barrier (default)
texture_border = grass_in (default)
texture_border_tree = grass_out (default
Main properties
arc = 0 (default)
end_banking = 0 (default)
end_z = 0 (default)
hill_height = 0 (default)
length = 1580.177400
model = (default)
name = (default)
profile_height = flat (default)
radius = 0 (default)
Right properties
barrier_height = 4.2 (default)
border_size = 90 (default)
border_tree_height = 75 (default)
border_tree_size = 90 (default)
show_border_tree = true (default)
show_tree = true (default)
texture_barrier = barrier (default)
texture_border = grass_in (default)
texture_border_tree = grass_out (def
end_z
0
Set
Reset to default
Height of the end of the segment

RARS


Rars
File View Car Speed Settings
Apex8
WappuCar
Dodger6
J++
Felix16
DougE1
R
LEADERS: time to leader cur pos time to next time to prev Laps d+tog Laps Lead cur speed speed avg. best Lap last Lap pit num pit lap pit time cur damage cur fuel late m/gl proj. laps.
K2001 01:59.534 1 0.00 2.97 1+019 1 122.50 92.92 93.22 93.22 0 0 0.00 0 142.79 0.76 35
Sparky5 08:435 2 8.44 1.64 1+019 0 109.52 86.82 89.14 89.14 0 0 0.00 1503 142.94 0.73 34
Bulle2 11:212 3 2.78 999.00 1+019 0 104.62 84.96 88.33 88.33 0 0 0.00 1643 142.94 0.73 34
K1999 19:652 4 3.28 999.00 1+019 0 75.41 79.80 83.66 83.66 0 0 0.00 2339 143.31 0.71 33
Vector 16:367 5 5.16 4.36 1+019 0 69.25 81.73 82.99 82.99 0 0 0.00 3220 143.15 0.69 32
WappuCar 28:203 6 0.27 999.00 1+019 0 108.83 75.17 78.75 78.75 0 0 0.00 8461 143.09 0.68 32
Dodger6 30:738 7 0.44 999.00 1+019 0 105.98 73.61 80.38 80.38 0 0 0.00 8401 142.99 0.68 31
Felix16 30:589 8 1.93 3.03 1+019 0 105.38 73.99 79.34 79.34 0 0 0.00 1909 142.99 0.68 31
J++ 28:352 9 0.15 999.00 1+019 0 100.02 75.12 78.28 78.28 0 0 0.00 19925 143.12 0.69 32
Apex8 27:932 10 8.28 5.59 1+019 0 100.35 75.31 75.88 75.88 0 0 0.00 1184 115.01 0.64 24
DougE1 32:298 11 1.53 999.00 1+019 0 102.61 73.16 76.79 76.79 0 0 0.00 1371 143.19 0.67 31
SmoothB2 28:660 12 0.31 6.38 1+019 0 71.21 74.95 76.89 76.89 0 0 0.00 2325 89.53 0.66 19
Mafanja 41:805 13 9.51 4.03 1+019 0 42.86 68.86 71.32 71.32 0 0 0.00 4985 90.18 0.59 17
Jocosa83 43:748 14 0.06 999.00 1+019 0 70.65 68.02 73.15 73.15 0 0 0.00 8248 143.45 0.66 31
OscCar2 42:910 15 1.11 999.00 1+019 0 84.78 68.39 72.68 72.68 0 0 0.00 1076 142.46 0.56 26
Track: imola
Length: 3.09
Race Fastest Lap K2001 93.22 mi/h
BestView mode manual Update
21.29 fps

Controlling the Car

- **movement:** **desired speed variable**
- **steering:** **wheel angle variable**
- **fuel & damage:** **pit stop request flag**

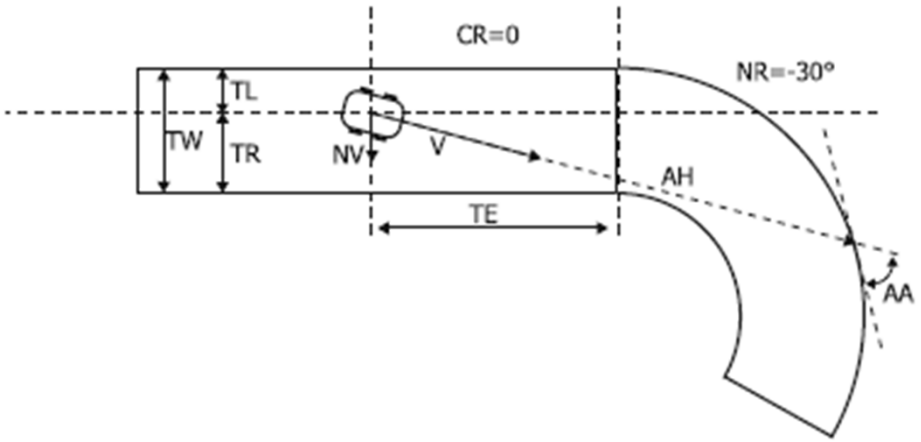
Car Sensors

situation variables:

- current speed, drift speed and heading
- current track segment ID
- position on current track segment
- distances from left and right road shoulders
- distance to next track segment
- radii and lengths of current and next track segments

additional data:

- complete track layout
- nearby cars information



The Challenge

Find a winning controller,

such that racecar completes <u>entire</u>

track in as little time as possible

Evolutionary Setup

- GP
- Each individual is composed of two trees:
  - steering tree
  - throttling tree
- Fitness evaluation performed on one track, believed to exhibit variegated track features
- Two fitness measures were used:
  - race distance
  - modified race time

Results

We put the two top evolved drivers through their paces:

GP-Single-1

GP-Single-2

Results

- **Comparison with other drivers on track used during evolution**
- **All other drivers written by humans**

Rank	Driver	Lap Time (seconds)
1	GP-Single-2	159.8 ± 0.6 (std. error: 0.06)
2	Vector	160.9 ± 0.1 (0.01)
-	GP-Single-1	160.9 ± 0.3 (0.03)
4	WappuCar	161.7 ± 0.1 (0.01)
5	Apex8	162.5 ± 0.2 (0.02)
6	Djoefe	163.7 ± 0.1 (0.01)
7	Ali2	163.9 ± 0.1 (0.01)
8	Mafanja	164.3 ± 0.2 (0.02)
9	SBv1r4	165.6 ± 0.1 (0.01)
10	Burns	167.8 ± 5.6 (0.56)
11	Eagle	169.3 ± 0.6 (0.06)
12	Bulle	169.4 ± 0.3 (0.03)
13	Magic	173.9 ± 0.1 (0.01)
14	JR001	178.3 ± 0.2 (0.02)

Results

Comparison on 16 different tracks, none of which seen during evolution

single-car

single-lap

Rank	Driver
1	Vector
2	GP-Single-2
3	GP-Single-1
4	Mafanja
5	SBv1r4
6	Eagle
7	WappuCar
8	Djoefe
9	Burns
10	Magic
11	Ali2
12	Apex8
13	JR001
14	Bulle

multi-car

3-lap

Rank	Driver
1	GP-Single-2
2	Mafanja
3	Vector
4	GP-Single-1
5	Djoefe
6	Burns
7	WappuCar
8	Bulle
9	Ali2
10	Magic
11	SBv1r4-1
12	Eagle
13	Apex8
14	JR001

Superb generalization capabilities:

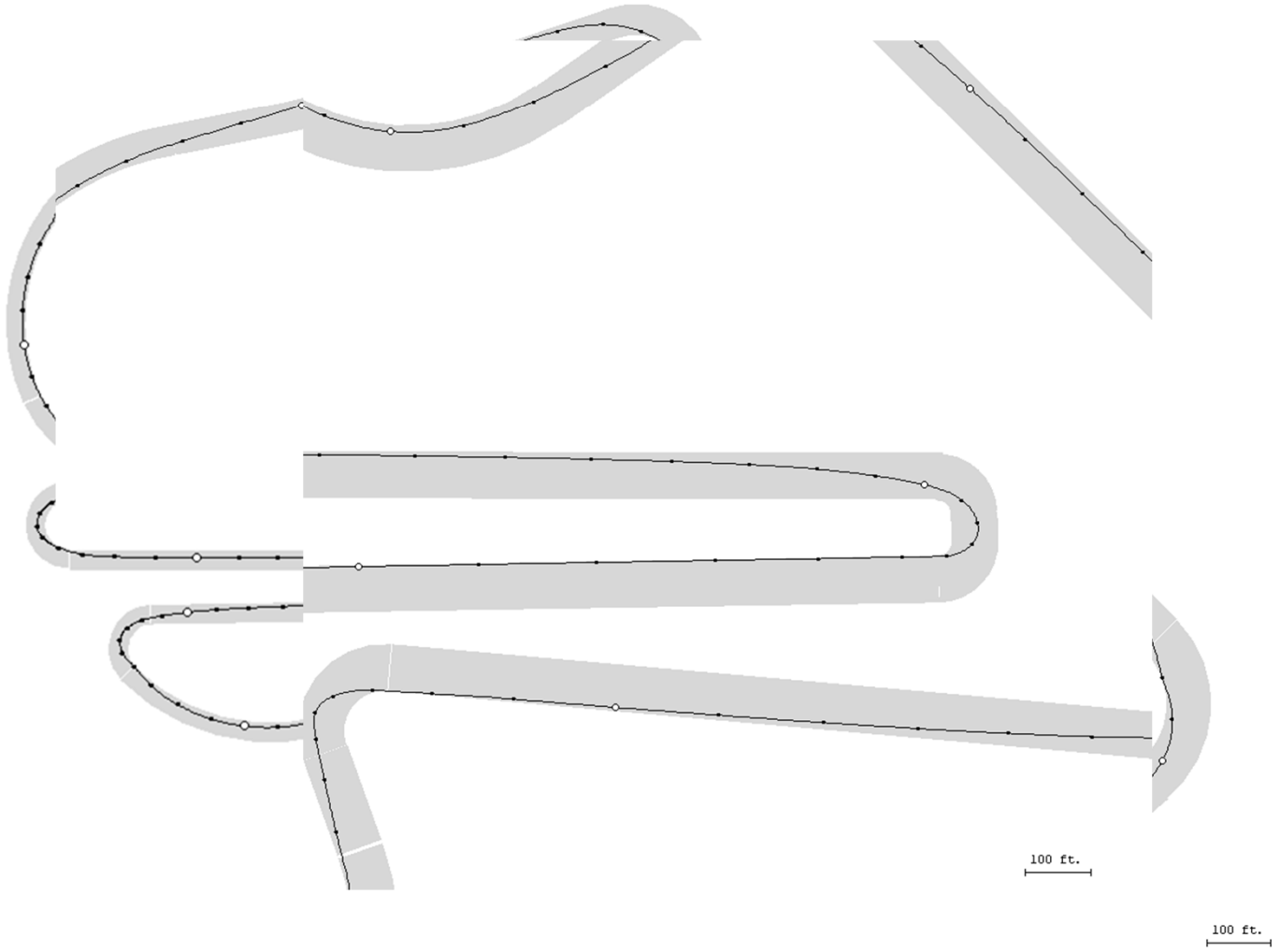
to different tracks, multi-car, multi-lap

Results

Comparison of evolved drivers with machine-generated drivers

Author	Track	Lap Time (seconds)		
		Reported	GP-Single-1	GP-Single-2
Ng et al.	v03	59.4	55.5 ± 1.4 (std. error: 0.14)	**49.3** ± 0.1 (0.01)
	oval	33.0	31.0 ± 0.1 (0.01)	**30.7** ± 0.1 (0.01)
	complex	209.0	**199.4** ± 5.9 (0.59)	204.4 ± 1.3 (0.13)
Coulom	clkwis	38.0	37.7 ± 0.1 (0.01)	**36.5** ± 0.1 (0.01)
Cleland	v01	37.4	37.9 ± 1.6 (0.16)	**35.0** ± 0.1 (0.01)

GP-Single-2 Driving on Complex Track



Human-Competitive Criteria

(B) The result is equal to or better than a result that was accepted as a new scientific result at the time when it was published in a peer-reviewed scientific journal.

Using genetic programming to evolve driver controllers we were able to outperform human-crafted controllers and machine-designed ones on a variety of game tracks.

As such, the result is clearly better than previously published ones.

Human-Competitive Criteria

(F) The result is equal to or better than a result that was considered an achievement in its field at the time it was first discovered.

(G) The result solves a problem of indisputable difficulty in its field.

Programming controllers for simulated race cars is arduous, as evidenced in the proliferation of such competitions in recent years.

We were able to show significant improvement over previous solutions to the problem.

Human-Competitive Criteria

(H) The result holds its own or wins a regulated competition involving human contestants (in the form of either live human players or human-written computer programs).

Our evolved drivers were able to beat the competition, attaining a top accumulated score on 16 tracks, none of which were seen during training.

Results clearly show the superiority of our evolved controllers, both against machine-learning techniques as well as against human-written controllers.

Why is Result Best? (1)

- **Controlling a moving vehicle is considered a complex problem, both in simulated and real-world environments.**
- **Dealing with physical forces, varying road conditions, unexpected opponent behavior, damage control, and many other factors, render the car-racing problem a fertile grounds for artificial intelligence research, and an enormous challenge for developers of racecar controllers.**

Why is Result Best? (2)

In addition to the undisputed performance of our game controllers, the evolved solutions reflect two intrinsic qualities that are not always observed in human-competitive solutions:

generalization and simplicity

Why is Result Best? (3)

- **The controllers were able to perform outstandingly on diverse instances of the given problem, which were not included in the training set, and hence are highly general.**

- **In addition, the evolved source code is simple and clear, thus enabling humans to understand the inner workings of the controllers and embed the evolved results in both human-made and computer-made future solutions.**

Why is Result Best? (4)

Last, but not least, beyond the various comparative measures and analyses, showing the winning performance of our controllers, we have demonstrated that the evolved drivers are <u>really</u> doing a fine job of driving about the course, which can be readily appreciated by the naked eye...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