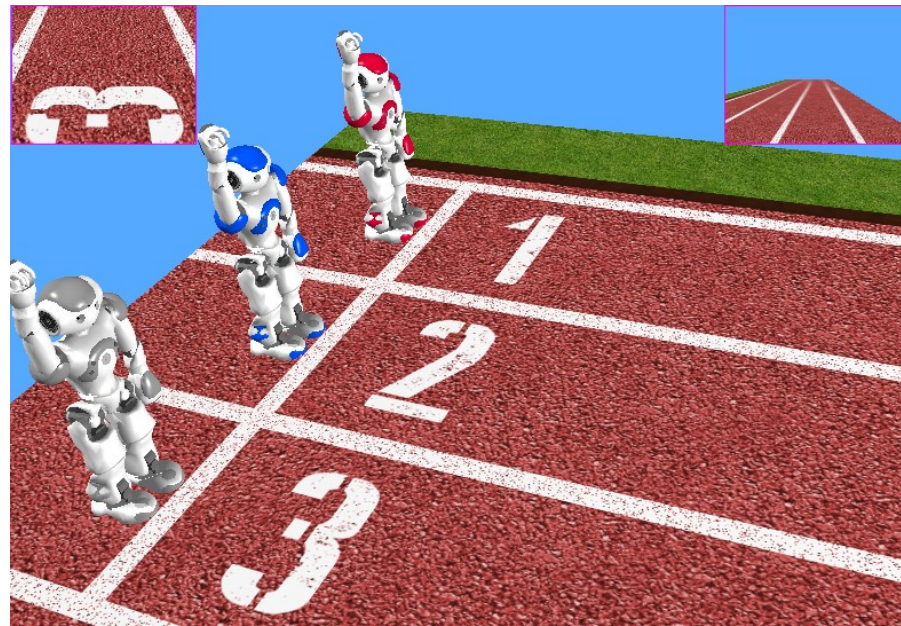


# NAO race

## A Simulation Benchmark For Walking Humanoids



Olivier Michel  
Cyberbotics Ltd.

# NAO race



# NAO race

**WARNING:**

**THIS PRESENTATION INCLUDES  
MANY BRAND ADVERTISING**



# NAO race

0–100 km/h time

time	model	year
2.2	Porsche 918 Spyder	2015
2.3	Ariel Atom V8	2010
2.4	LaFerrari	2015
2.4	Bugatti Veyron Supersport World Record Edition	2010
2.5	Porsche 911 Turbo S	2014
2.5	Caparo T1	2007
2.6	McLaren P1	2013
2.7	Nissan GT-R NISMO	2015
2.7	Lamborghini Aventador LP700-4	2012
2.78	SSC Ultimate Aero TT	2007
2.79	Caterham 7 620 R	2015
2.8	Tesla Model S P90D	2015

# NAO race

## Fuel economy ratings (MPG)

MPG	model
50	Toyota Prius
50	Toyota Prius c
47	Honda Accord Hybrid
45	Honda Civic Hybrid
45	Volkswagen Jetta Hybrid
42	Ford Fusion Hybrid
42	Lexus CT 200h
42	Toyota Prius v
41	Toyota Camry Hybrid LE
40	Ford C-Max Hybrid
40	Lincoln MKZ Hybrid
40	Mitsubishi Mirage

# NAO race

## Euro NCAP five stars security rating

stars	model	adult occupant	child occupant	pedestrian	safety assist
*****	Audi Q7	94%	88%	70%	76%
*****	Ford Galaxy	87%	87%	79%	71%
*****	Ford S-MAX	87%	87%	79%	71%
****	Mazda CX-3	85%	79%	84%	64%
****	Mitsubishi L200	81%	84%	76%	64%
*****	Renault Kadjar	89%	81%	74%	71%
*****	Toyota Avensis	93%	85%	78%	81%
*****	Volvo XC90	97%	87%	72%	100%
*****	VW Touran	88%	89%	71%	76%
***	Fiat Panda Cross	70%	77%	50%	46%
****	Hyundai i20	85%	73%	79%	64%
*****	Skoda Superb	86%	86%	71%	76%

# NAO race



# NAO race

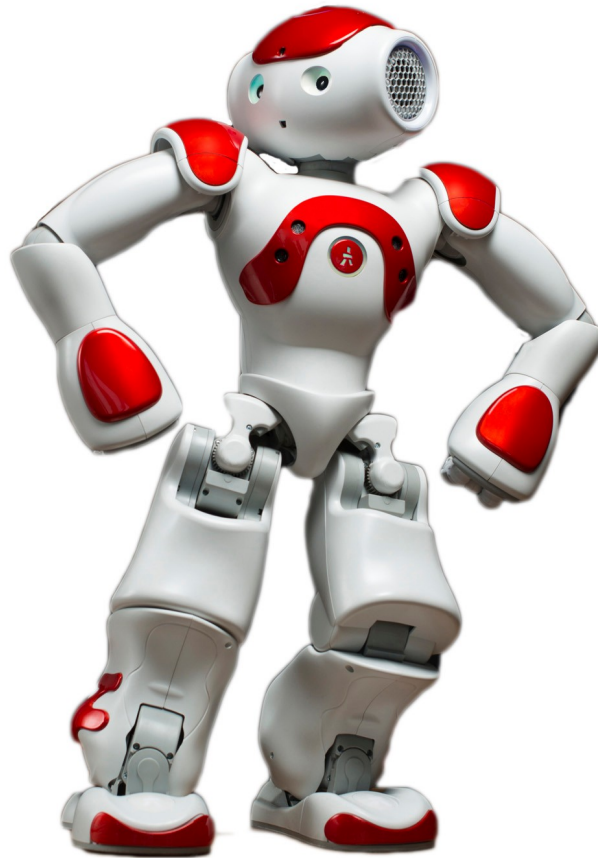
## 100m race



Rank	Time	Wind (m/s)	Athlete	Country	Date	Location	
	<b>9.58 WR</b>	+0.9	Usain Bolt	Jamaica	16 August 2009	Berlin	1
2.69		+2.0	Tyson Gay	United States	20 September 2009	Shanghai	2
		-0.1	Yohan Blake	Jamaica	23 August 2012	Lausanne	2
		+0.2	Asafa Powell	Jamaica	2 September 2008	Lausanne	4 9.72
		+0.9	Justin Gatlin	United States	15 May 2015	Doha	5 9.74
		+0.9	Nesta Carter	Jamaica	29 August 2010	Rieti	6 9.78
			Maurice Greene	United States	16 June 1999	Athens	7 9.79 +0.1
			Steve Mullings	Jamaica	4 June 2011	Eugene	8 9.80 +1.3
			Richard Thompson	Trinidad and Tobago	21 June 2014	Port of Spain	9 9.82 +1.7
			Donovan Bailey	Canada	27 July 1996	Atlanta	+0.7
			Juney Surin	Canada	22 August 1999	Seville	10 9.84 +0.2
			Trayvon Bromell	United States	25 June 2015	Eugene	+1.3
			Trayvon Bromell	United States	6 July 1994	Lausanne	+1.2
			Obba Babatundé	Nigeria	12 May 2006	Ad-Dawhah	13 9.85 +1.7
			Mike Rodgers	United States	4 June 2011	Eugene	+1.3
			Carl Lewis	United States	25 August 1991	Tokyo	+1.2
			Frankie Fredericks	Namibia	3 July 1996	Lausanne	-0.7
			Ato Boldon	Trinidad and Tobago	19 April 1998	Walnut	+1.8
			Francis Obikwelu	Portugal	22 August 2004	Athens	+0.6
			Keston Bledman	Trinidad and Tobago	23 June 2012	Port of Spain	+1.4
			Jimmy Vicaut	France	4 July 2015	Saint-Denis	+1.3



# NAO race



The NAO robot would take about 100x more time to run 100m.

# NAO race



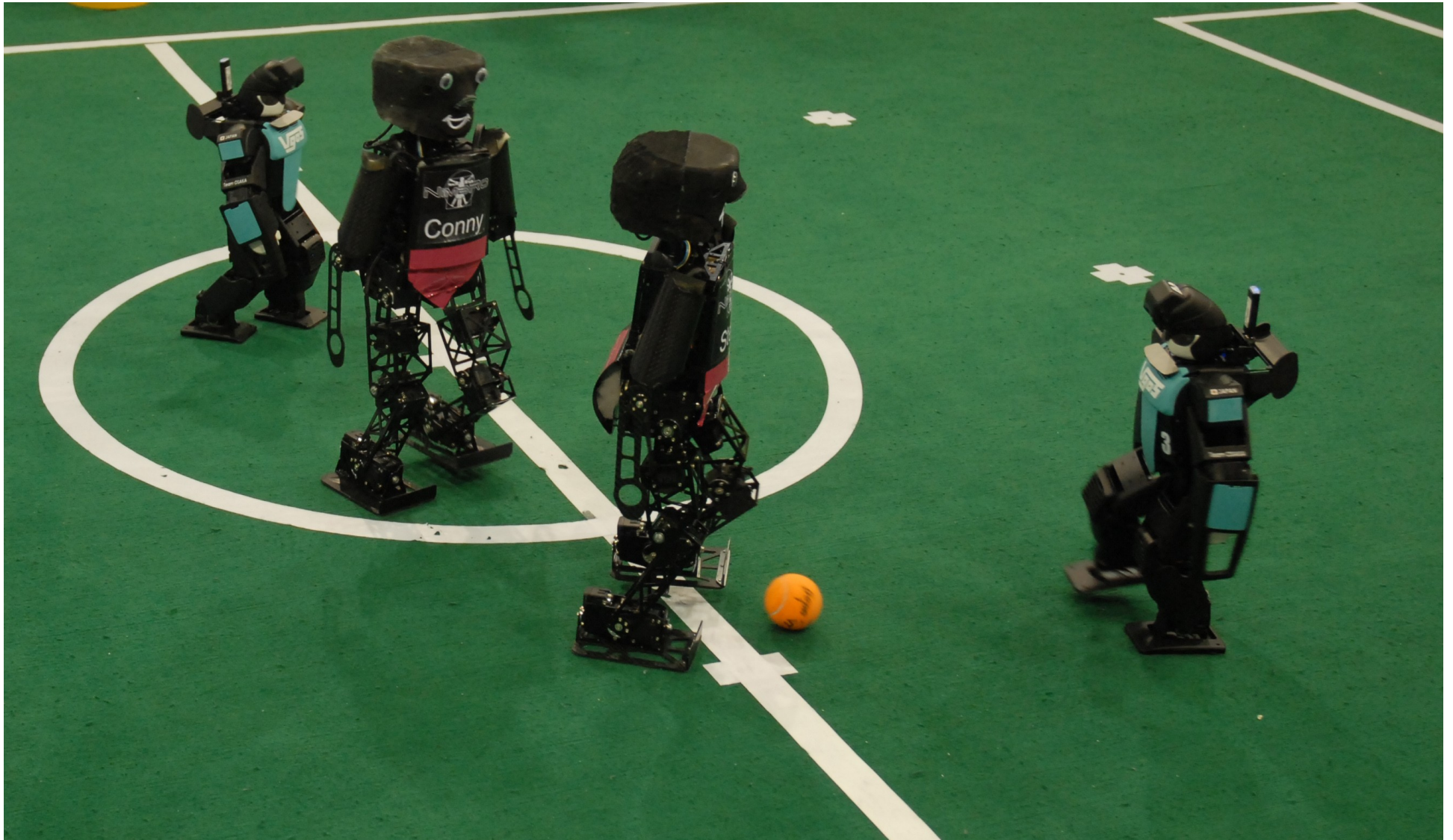
My car would take about 7 seconds to run 100m.

# NAO race





# NAO race













# NAO race

## Football : FIFA ranking

FIFA.com FIFA Ranking													
Men's Ranking													
Federations / CAF / CONCACAF / CONMEBOL / OFC / AFC / UEFA All conf.													
2015 (100 %) 2014 (50 %) 2013 (30 %) 2012 (20 %)													
Total Points	Previous Points	+/-	Positions	Avg.	AVG.WGT	Avg.	AVG.WGT	Avg.	AVG.WGT	Avg.	AVG.WGT	Rank	Team
1442 (1441.80)	1425	0	▲	599.70	599.70	1058.69	529.35	650.08	195.03	588.59	117.72	1	Argentina
1269 (1268.57)	1244	0	▲	530.35	530.35	915.19	457.59	748.61	224.58	280.23	56.05	2	Belgium
1248 (1248.04)	1226	0	▲	357.08	357.08	1169.57	584.79	511.18	153.35	764.11	152.82	3	Germany
1224 (1223.54)	1218	0	▲	442.63	442.63	908.70	454.35	764.10	229.23	486.63	97.33	4	Colombia
1189 (1208.79)	1186	0	▲	558.94	558.94	776.42	388.21	609.64	182.89	393.77	78.75	5	Brazil
1185.96)	1177	0	▲	600.93	600.93	633.04	316.52	444.83	133.45	675.29	135.06	6	Portugal
1166	0	▲	786.91	786.91	392.44	196.22	458.36	137.51	275.57	55.11		7	Romania
1124	2	▲	579.37	579.37	702.71	351.35	413.79	124.14	469.70	93.94		8	Chile
1115	0	▲	817.58	817.58	287.93	143.96	329.63	98.89	425.79	85.16		9	Wales
-2		▼	705.38	705.38	408.40	204.20	338.91	101.67	657.88	131.58		10	England

# NAO race

## Tennis: ATP ranking

RANKING ↗	MOVE ↗	COUNTRY ↗	PLAYER ↗	AGE ↗	POINTS ↗	TOURN PLAYED ↗	POINTS DROPPING ↗	NEXT BEST ↗			
-			Novak Djokovic	28	14,865	18	720	0	1		
-			Roger Federer	34	9,065	18	720	0	2		
			Andy Murray	28	8,840	23	360	180	3	-	
			Kei Nishikori	25	6,205	22	1,200	180	4	-	
			Stan Wawrinka	30	5,710	22	360	45	5		
			Tomas Berdych	29	5,230	22	360	90	6		
			David Ferrer	33	3,695	21	90	0	7		L
			Nadal	29	3,680	22	0	0	8		Rafael N
				26	3,550	22	2,000	45	9		Marin Cilic
				24	2,880	22	180	55	10		Milos Raonic

# NAO race

## Chess: ELO ranking

Classic		Rapid		Blitz		Top100		Enter name or country								
#	▲	↑↓	◆	Name	◆	Flag	◆	Classic	+/-	◆	Rapid	◆	Blitz	◆	Age	◆
1				Carlsen				2850.1	-2.9		2847.0		2914.0		24	
2		↑2		Nakamura				2816.2	+2.2		2850.0		2887.0		27	
3				Topalov				2813.1	-2.9		2772 i		2647.0		40	
4		↓2		Anand				2803.1	-12.9		2800.0		2791.0		45	
5		↑1		Giri				2798.1	+5.1		2720.0		2793.0		21	
6		↓1		Caruana				2796.1	-11.9		2829.0		2665.0		23	
7		↑4		Aronian				2784.1	+19.1		2830.0		2817.0		32	
8		↓1		Ding Liren				2782.0	0.0		2712.2		2688 i		22	
9		↓1		Kramnik				2777.0	0.0		2798.0		2763.0		40	
10				Grischuk				2774.1	+3.1		2846.0		2814.0		31	
11		↑1		Karjakin				2762.0	0.0		2805.0		2759.0		25	
12		↓3		So				2760.1	-12.9		2635.0		2726 i		21	
13		↑3		Vachier-Lagrave				2758.0	+14.0		2756.0		2854.0		24	
14		↓1		Tomashevsky				2758.0	0.0		2731.0		2694.0		28	
15		↓1		Li Chao				2756.0	0.0		2616.4		2651 i		26	
16		↓1		Jakovenko				2748.0	0.0		2726 i		2630 i		32	
17				Adams				2742.0	0.0		2753.0		2752.0		43	
18		↑1		Gelfand				2741.0	0.0		2751.0		2743.0		47	
19		↑1		Radjabov				2738.0	0.0		2741.0		2808.0		28	
20		↑1		Harikrishna				2737.0	0.0		2694.0		2680.0		29	

# NAO race

## Football: ELO ranking

Ratings and Statistics as of Monday September 7 2015																
rank	team	rating	highest		1 yr change		matches							goals		rank
			rank	rating	rank	rating	total	home	away	neutral	wins	losses	draws	for	against	
	Germany	2096	1	2200	0	-81	900	388	369	143	526	192	182	2033	1055	1
	Argentina	2055	1	2117	+1	-10	981	345	385	251	528	210	243	1861	1043	2
	Brazil	2009	1	2153	+2	+40	935	327	301	307	589	153	193	2031	868	3
	Colombia	1984	4	2016	0	-4	531	157	189	185	205	184	142	664	644	4
	Chile	1955	5	1974	+2	+1	729	287	265	177	278	294	157	1042	1054	5
	Spain	1952	1	2143	0	-12	652	288	256	108	379	126	147	1277	598	6
	France	1916	1	2106	+1	-22	781	395	296	90	374	239	168	1371	1068	7
	England	1910	1	2042	+6	+73	952	418	435	99	542	181	229	2133	946	8
	Netherlands	1900	1	2133	-7	-210	751	348	307	96	379	204	168	1549	943	9
	Belgium	1887	2	1916	-1	-3	721	349	317	55	295	270	156	1222	1170	10
	Portugal	1881	2	1983	+1	+24	559	262	216	81	261	169	129	910	677	11
	Uruguay	1866	1	2035	-2	-6	894	300	385	209	390	286	218	1427	1130	12
	Italy	1852	1	2079	0	-2	767	343	280	144	403	151	213	1307	764	13
	Mexico	1847	5	1936	-3	-24	857	272	234	351	428	222	207	1538	902	14
	Ecuador	1798	11	1862	+1	-25	483	150	174	159	137	224	122	570	798	15
	Ukraine	1793	14	1821	+3	-23	220	102	96	22	97	60	63	305	217	16
	United States	1786	9	1872	-2	-42	656	366	212	78	280	234	142	936	873	17
	Switzerland	1783	8	1876	-1	-36	754	364	335	55	256	332	166	1085	1298	18
	Peru	1783	12	1856	+12	+76	586	223	211	152	187	257	142	737	851	19
	Sweden	1763	15	1950	+2	-7	981	429	445	107	483	287	211	1996	1304	20



# NAO race

## **ABSOLUTE BENCHMARKS**

- Cars (0-100km/h, MPG, Euro NCAP)
- 100m. race
- ...

## **RELATIVE BENCHMARKS**

- Soccer (human & robot)
- Tennis
- Chess\*
- ...

# NAO race

professional mobile robot simulation



CYBERBOTICS

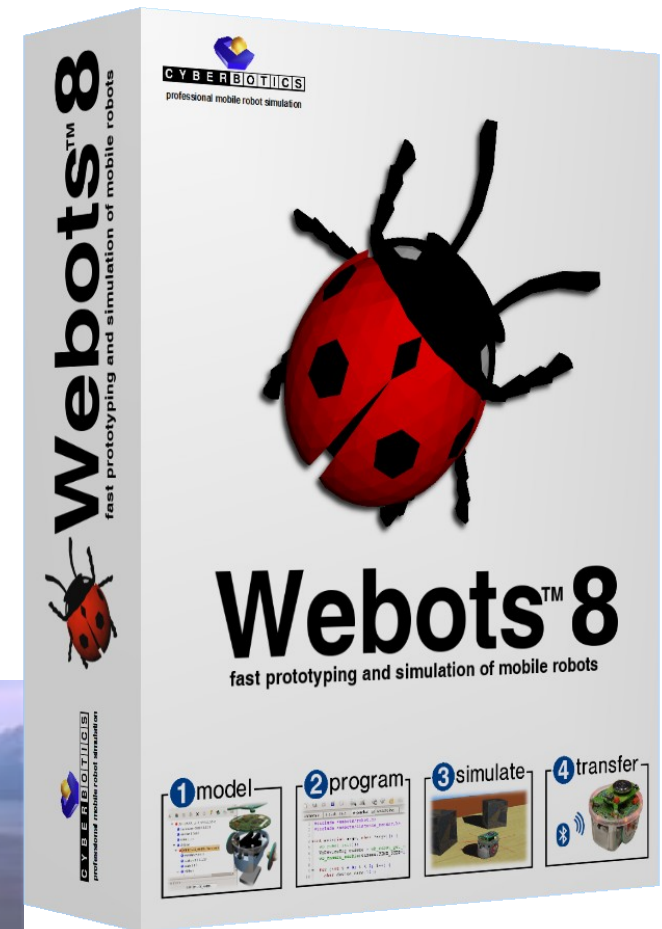
Spin off from EPFL, Lausanne, Switzerland

Company founded in 1998, now 5 employees

International collaborations (Sony, SRI, EPFL, universities, ICEA & RHEA European projects)

Over 1200 customers worldwide (including universities and corporate research centers)

Webots used both for research and education



€ 2'500

# NAO race

[webots.mp4](#) movie

# NAO race

## Cyberbotics robotics benchmarks

- Rat's Life (simulation): 1999 & 2008
- Rat's Life (real): 1999 & 2008
- Roboka: 2005 – 2006 [roboka.mpg](#) movie
- Robostadium: 2008 – 2009
- NAO race: 2015



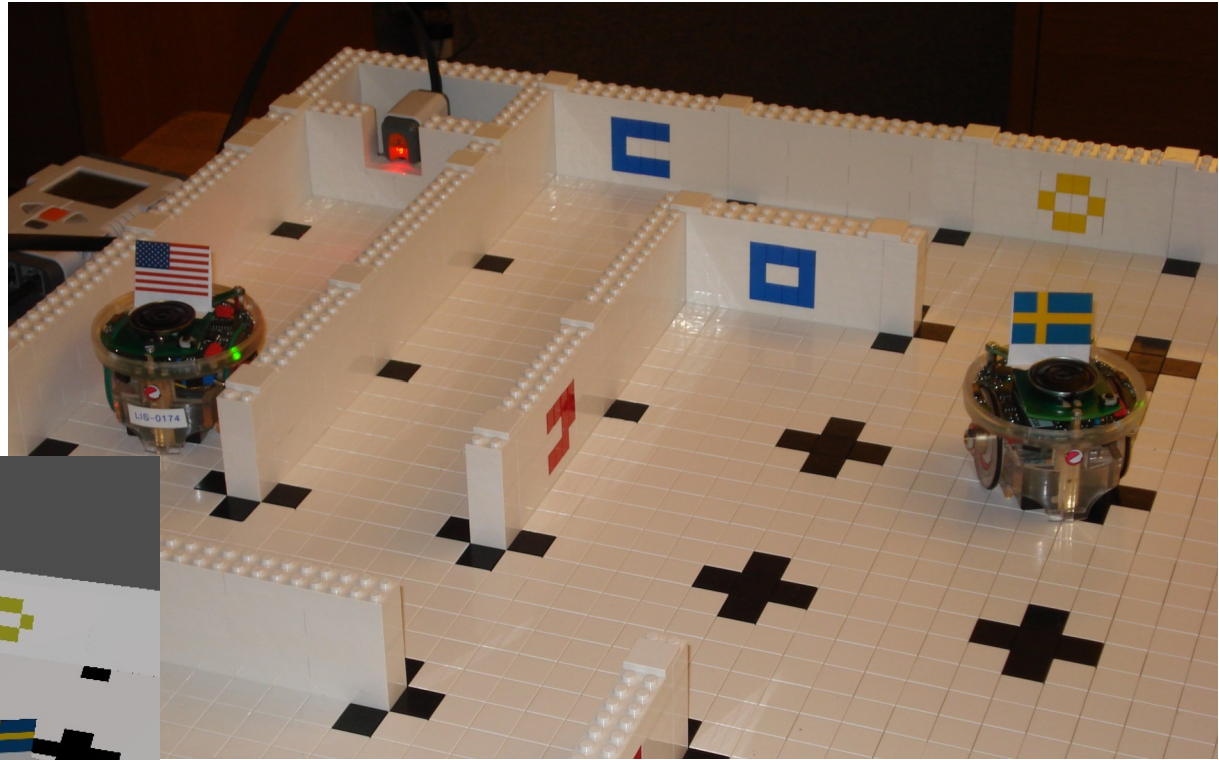
# NAO race

## Rat's Life mazes

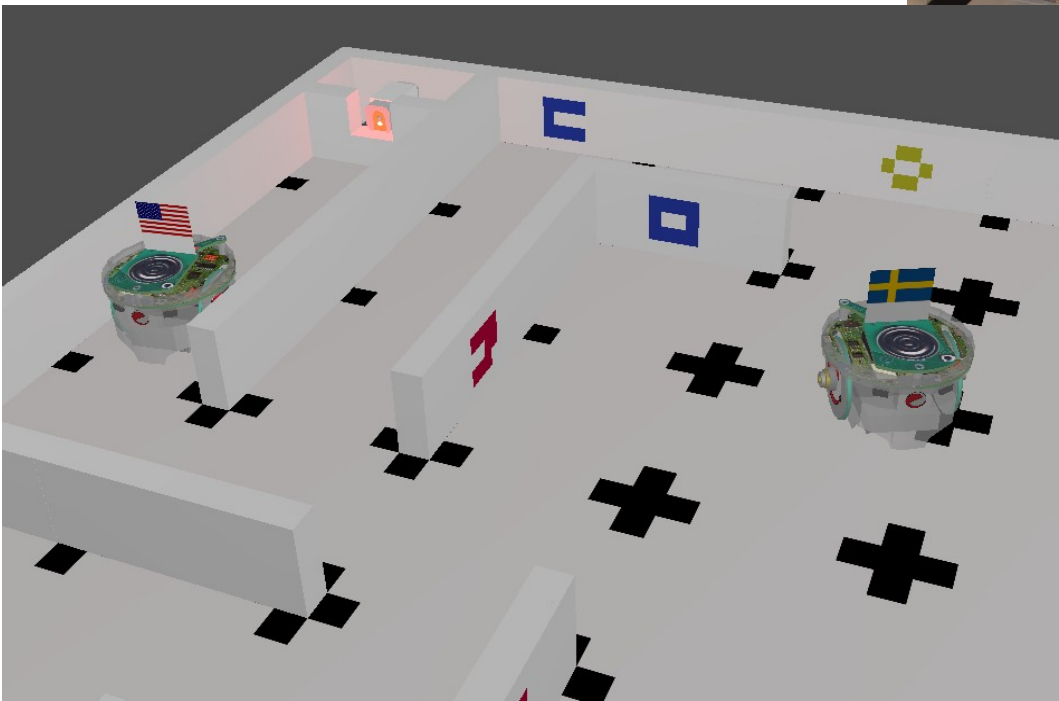
Real maze (LEGO)

Random configurations

Landmarks (color and shape)



real setup



simulated setup

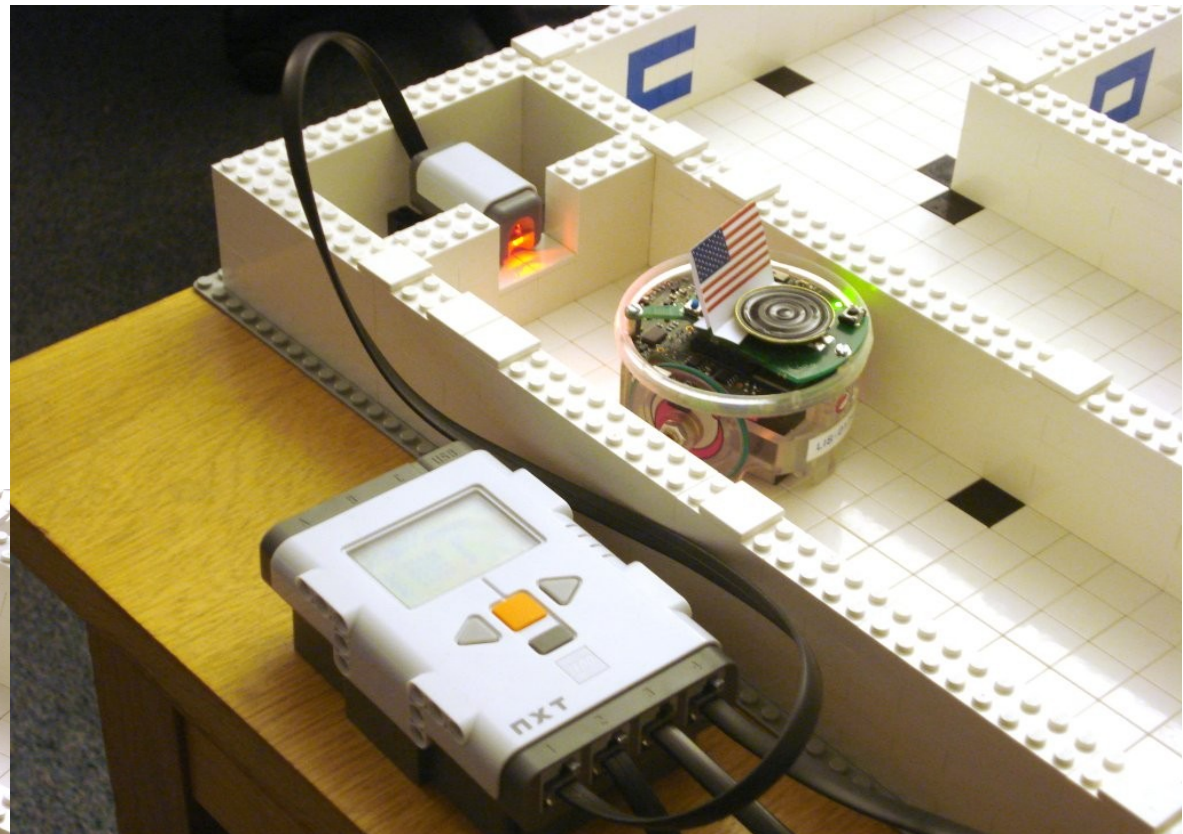
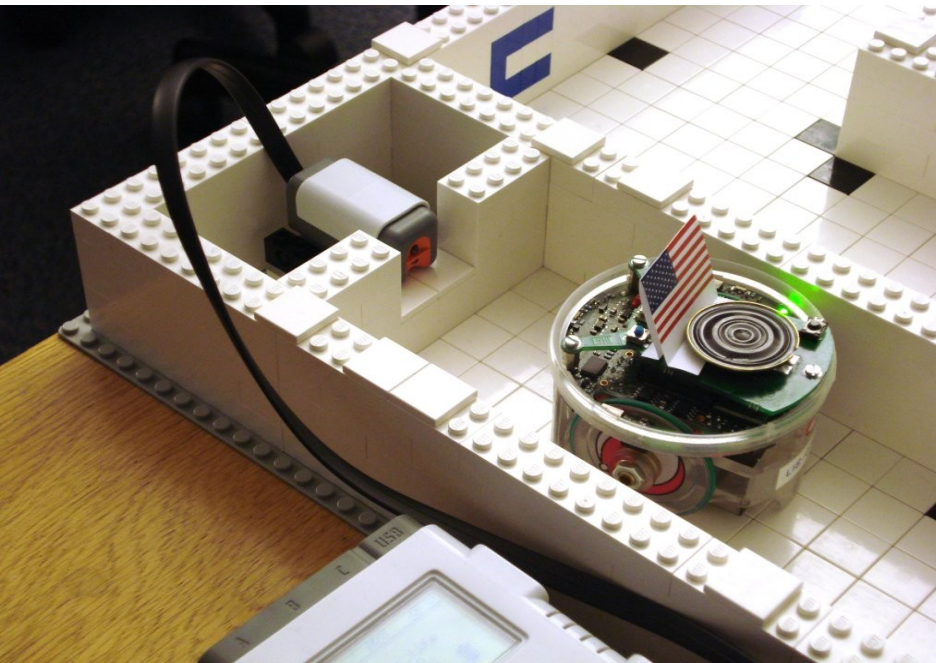
# NAO race

## Rat's Life: feeder system

Standard LEGO component (NXT)

Centrally controlled

Based on the LEGO distance sensor



Reward mechanism (inspired from rats experiments)

Simulation of energy in the robot



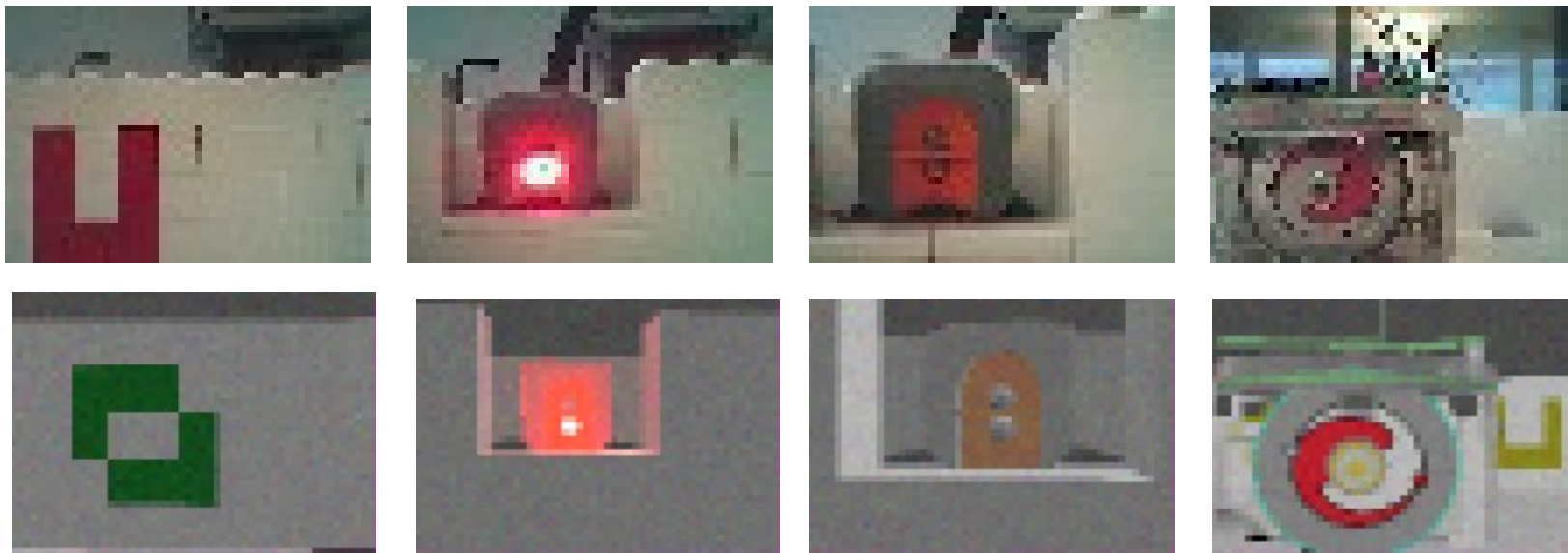
# NAO race

## Rat's Life: transfer to real robots

Remote control of real e-puck robots

Control running on the computer

Calibration of the simulated camera (noise, anti-aliasing)



# NAO race

## Rat's Life: strategies ratslife.avi movie

Explore efficiently the  
maze and avoid to get stuck  
(wall following)

Recognize landmarks

Build a representation of  
the environment (SLAM,  
place cells)

Recognize a feeder (image  
processing)

Approach the feeder,  
dock and retrieve food

Remember the location of  
previously found feeders as  
well as dead ends (learning  
from past experiences)

Navigate optimally to these  
interesting locations (spatial  
cognition, goal directed  
navigation)

Optimize energy management

Prevent the other robot from  
getting food



# NAO race

## **Rat's Life: GA-like step by step evolution (70 teams running over 12 months)**

Random walk exploration → extinct

Follow wall exploration (right hand) → evolved


Wait in front of the feeder → extinct

Landmark association with reward / failure → probably survived

Self Localization And Mapping (SLAM) → survived, dominant

Aggressive behaviors → survived, but rare

# NAO race




































TUESDAY, 04 MARCH 2008

- Home
- Hall of Fame**
- News
- Movies
- Call for Contest
- Rules
- Real World
- Forums
- FAQ
- USER MENU**
- My Details
- My Files
- LOGIN FORM**

Hi, Olivier

### HALL OF FAME

Last round completed Mar-03-2008 - 17 active competitors out of 70

Rank	Country	Flag	Rat's name	Author	Ready	Last update	Progress	Movies
1			Tony	Anthony Morse		Mar-03-2008 15:56	+1	
2			SergE	Sergey		Feb-27-2008 19:00	-1	
3			Ratchou	Xavier		Mar-03-2008 19:56	+1	
4			antoinea101	Antoine Albertelli		Feb-24-2008 23:43	-1	
5			SORAN	M. Serdar		Mar-03-2008 19:58	+2	
6			szgy	Gyula Szabó D.		Feb-12-2008 09:52	-1	
7			fabien	Fabien Rohrer		Feb-21-2008 20:20	-1	
8			Ratatouille	Manuel		Mar-04-2008 00:21	+5	
9			piRAT	Christian Conus		Feb-03-2008 22:28	-1	

### SHOUT BOX

**Latest Message:**  
13 hours, 33 minutes ago

.....

**Tony :** Welcome new contestants 😊

**Olivier :** Congrat's SergE!

**fabien :** I think that there will be soon infinite matches, too. So, a possible solution is to remove the supplementary batteries.

Name:

Message:

### WHO'S ONLINE

We have 2 members online

- **Olivier**
- **Ratatouille**

# NAO race

## Robotstadium

Based on the Robocup SPL

Automatic referee

Automatic matches online

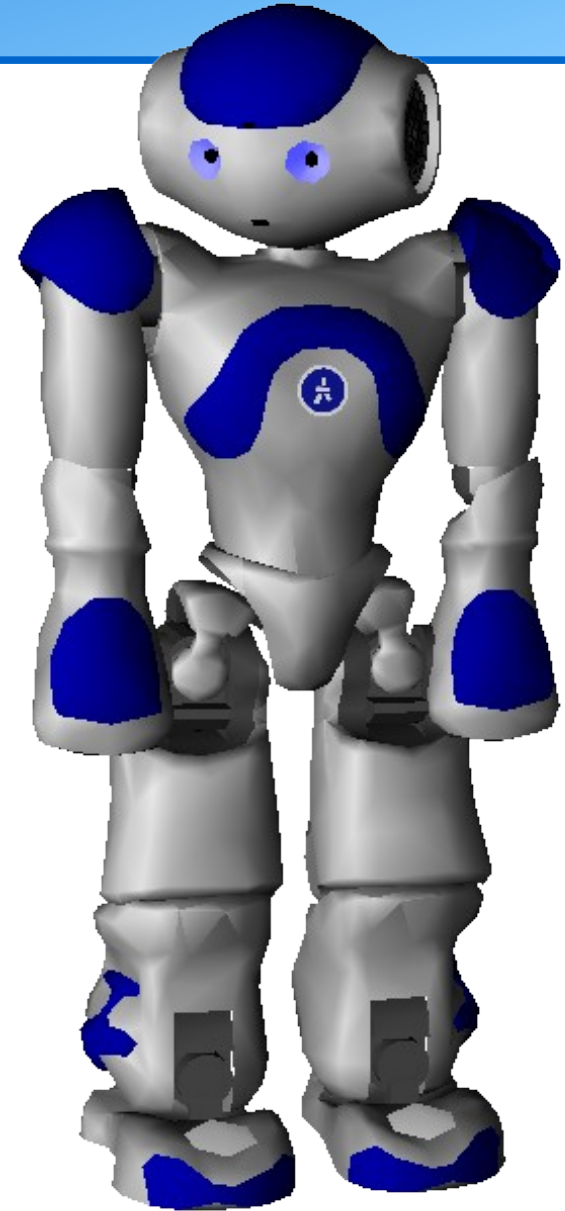
Automatic ranking (bubble sort)

17 participating teams

[robotstadium.avi](#) movie

# NAO race

- 22 servo motors with position and force feedback (control in position, velocity or torque)
- 8 force sensors (4 in each feet)
- 4 foot bumpers
- 2 color cameras (multiplexed)
- 4 ultra-sound sensors
- Accelerometer and gyro
- Receiver and emitter devices (to communicate with team and referee)
- LEDs (foot, torso, eyes, ears)



# NAO race

robotstadium - Mozilla Firefox

http://robotstadium.org/index.php?option=com\_hall\_of\_fame&task=view&Itemid=8

Software Cyberbotics Search Engines Robots Yahoo Conferences Robot Portals Talking robots Slashdot Google News Suisse

Disable Cookies CSS Forms Images Information Miscellaneous Outline Resize Tools View Source Options

**robotstadium**  
online robot soccer competition  
RoboCup

FRIDAY, 27 JUNE 2008

**MAIN MENU**

- Home
- Movies
- Hall of Fame
- Rules
- Forum
- FAQ

**USER MENU**

- My Details
- My Files

**LOGIN FORM**

Hi, Olivier

**HALL OF FAME**

Last round completed Jun-26-2008 - 10 active competitors out of 117

Rank	Country	Flag	Team name	Author	Ready	Last update	Progress	Movies
1			Cracoucass	Cracoucass	✓ (Java)	Apr-30-2008 17:06	-	
2			Kouretes	Eleftherios Chatzilaris	✓ (Java)	Jun-27-2008 10:44	-	0-0
3			Teddy	Teddy	✓ (URBI)	Jun-09-2008 14:16	-	0-1
4			Bothari	Bothari	✓ (URBI)	Jun-25-2008 02:27	-	1-1
5			Adam	Adam	✓ (Java)	Jun-26-2008 06:40	-	0-1
6			Tibal	Bulliot	✓ (Java)	Jun-26-2008 08:59	-	0-0
7			Yukinari Toyota	Yukinari Toyota	✓ (Java)	Jun-14-2008 22:33	-	0-0
8			TRETARRE François	TRETARRE François	✓ (Java)	Jun-22-2008 17:02	-	0-0
9			Borregos_RoboCup	Borregos RoboCup	✓ (URBI)	Jun-21-2008 21:14	-	0-0
10			Clément PETIT	Clément PETIT	✓ (URBI)	Jun-27-2008	-	0-0

**SHOUT BOX**

Latest Message:  
2 hours, 18 minutes ago  
Olivier: The round just started (13:40 CET)  
Olivier: The round just started at 12:30 (CET)  
Olivier: The ball coordinates sent by the supervisor are not available during the matches (only for training on your local computer)

Name: Olivier  
Message:  
  
Smilies?

**WHO'S ONLINE**

We have 2 guests and 3 members online

- Olivier
- Jerem
- Ted

Find:    ☐ Highlight all ☐ Match case

Done



# NAO race

Absolute Benchmark: NAO race simulation

"NAO race.mp4" movie

# NAO race

## Relevance

- Popular open robotics research problem
  - open loop motion (→ Evolutionary Computation)
  - sensors in the loop (gyro, accelerometer, camera, etc.)
  - ZMP (Zero Moment Point)
  - CPG (Central Pattern Generator)
- Based on realistic simulation → transfer to real world
- Absolute benchmark
  - valid over a long period of time
  - easy comparisons
- results 100% reproducible, by anybody, for ever
- **Good performance results → progresses in robotics**

# NAO race

## Efficiency


- Easy to use
  - simple and easy-to-understand performance metrics
  - free of charge
  - web & desktop versions
  - python programming
  - sample source code available
  - tools (motion editor, supervisor process)
- Entertaining
  - real time competition → challenge
  - online community (forum, social networks)
  - prizes

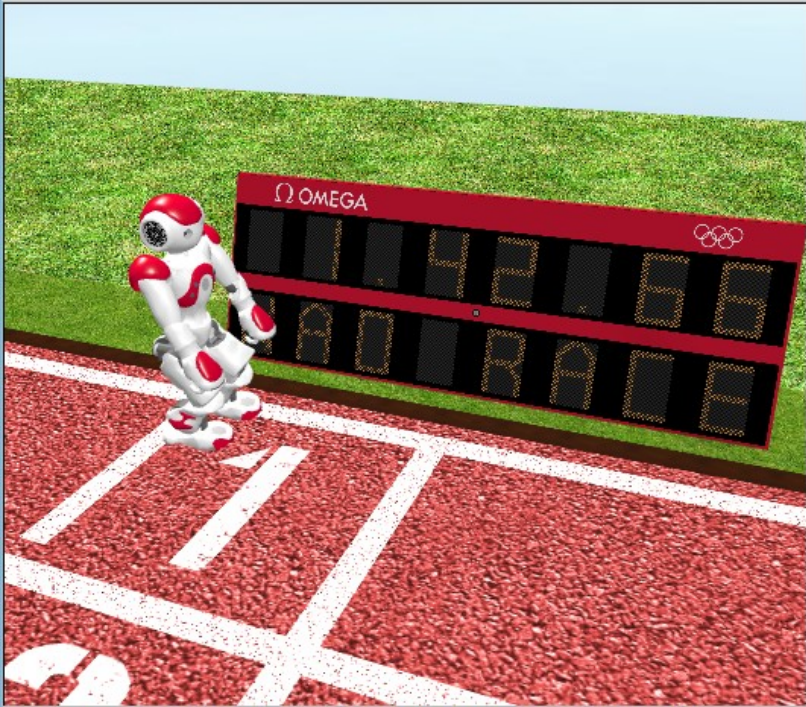
# NAO race

NAO race

cyberbotics2.cyberbotics.com:1234/nao\_race/

Most Visited GitHub cyberbotics phpMyAdmin

 **NAO race**   ☒ follow robot



```
1 # File:      nao_race.py
2 # Date:      August 2015
3 # Description: This controller makes the NAO robot walk along a 1
4 # Author:     Olivier.Michel@cyberbotics.com
5
6 from controller import Robot, Motor, Camera, Motion
7
8 class NaoRace(Robot):
9     def initialization(self):
10         # this is the time step (ms) used in the motion file
11         # no need to step faster than this
12         self.timeStep = 40
13         # get pointers to the 12 motors of the legs
14         self.RHipYawPitch = self.getMotor('RHipYawPitch')
15         self.LHipYawPitch = self.getMotor('LHipYawPitch')
16         self.RHipRoll = self.getMotor('RHipRoll')
17         self.LHipRoll = self.getMotor('LHipRoll')
18         self.RHipPitch = self.getMotor('RHipPitch')
19         self.LHipPitch = self.getMotor('LHipPitch')
20         self.RKneePitch = self.getMotor('RKneePitch')
21         self.LKneePitch = self.getMotor('LKneePitch')
22         self.RAnklePitch = self.getMotor('RAnklePitch')
23         self.LAnklePitch = self.getMotor('LAnklePitch')
24         self.RAnkleRoll = self.getMotor('RAnkleRoll')
25         self.LAnkleRoll = self.getMotor('LAnkleRoll')
26         # getting pointer to the 2 shoulder motors
27         self.RShoulderPitch = self.getMotor('RShoulderPitch')
28         self.LShoulderPitch = self.getMotor('LShoulderPitch')
29
```

nao\_race.py  
forward.motion

```
[14:45:16] [webots] INFO: Streaming server created: "0.0.0.0:2000"
[14:45:16] [webots] INFO: nao_race: Starting: "python2.7 "nao_race.py" "
[14:45:16] [webots] INFO: race_stopwatch: Starting: ""/tmp/webots/instances/139973457730160/controllers/race_stopwatch/race_stopwatch""
[14:45:16] [webots] INFO: supervisor_server: Starting: "python2.7 "supervisor_server.py" "
[14:45:16] [webots] [supervisor_server] 2015-09-08 14:45:11,373 [INFO ] Start tornado on port 2003.
[14:45:16] [webots] Connecting to the Webots instance (supervisor port=2003)...
[14:45:16] Initialisation completed successfully
[14:45:17] [webots] INFO: Streaming server: New client [66775728] (1 connected client(s))
```



# NAO race

thank you

<http://contest.theconstructsim.com>