ECAL 11 Submission 152

****

If you want to **change any information** about your paper or withdraw it, use links in the upper right corner.

All **reviews sent to you** can be found at the bottom of this page.

****

Paper 152

Title:	Evolving Robot Gaits in Hardware: the HyperNEAT Generative Encoding Vs. Parameter Optimization
Paper:	PDF
Category:	Full Papers [8 pages]
Keywords:	Robotic gaits Quadruped robot Evolved gaits HyperNEAT
Topics:	Emergent Engineering, Evolutionary & Learning Dynamics, Morphogenesis, Generative & Developmental Systems
Abstract:	Creating gaits for legged robots is an important task to en- able robots to access rugged terrain, yet designing such gaits by hand is a challenging and time-consuming process. In this paper we investigate various algorithms for automating the creation of quadruped gaits. Because many robots do not have accurate simulators, we test gait-learning algorithms entirely on a physical robot. We compare the performance of two classes of gait-learning algorithms: locally searching parameterized motion models and evolving artificial neural networks with the HyperNEAT generative encoding. Specifically, we test six different parameterized learning strategies: uniform and Gaussian random hill climbing, pol- icy gradient reinforcement learning, Nelder-Mead simplex, a random baseline, and a new method that builds a model of the fitness landscape with linear regression to guide further exploration. While all parameter search methods outperform a manually-designed gait, only the linear regression and Nelder-Mead simplex strategies outperform a random baseline strategy. Gaits evolved with HyperNEAT perform considerably better than all parameterized local search methods and produce gaits nearly 9 times faster than a hand-designed gait. The best HyperNEAT gaits exhibit complex motion patterns that contain multiple frequencies, yet are regular in that the leg movements are coordinated.
Time:	Apr 17, 13:29 GMT
Fax:	
Address:	239 Upson Hall Ithaca 14853 United States

Authors

Authors:

Paper 152

Name	Email	Country	Affiliation	
Jason Yosinski	ecal.jyo@0sg.net	United States	Cornell University	✔
Jeff Clune	jeffclune@cornell.edu	United States	Cornell University	✔
Diana Hidalgo	djh283@cornell.edu	United States	Cornell University	
Sarah Nguyen	smn64@cornell.edu	United States	Cornell University	
Juan Cristobal Zagal	jczagal@ing.uchile.cl	Chile	University of Chile	
Hod Lipson	hod.lipson@cornell.edu	United States	Cornell University	

Note: the rightmost column marks corresponding authors

Reviews

Review 1

Overall rating:	**3** (strong accept)
Confidence:	**3** (high)
Novelty	4 (good)
Quality of introduction	4 (good)
Quality of state of the art description	4 (good)
Quality of method description	5 (excellent)
Quality of results description	5 (excellent)
[Article only] Has the capacity to produce an important Alife journal publication (after extension)	3 (maybe)
[Abstract only] Did the authors properly refer to the prior publication	1 (yes)
Presentation form	3 (oral)
Review:	This paper compares the performance of six different parameter optimization algorithms and the well-known evolutionary-method HyperNEAT for the automatic design of gaits for a physically-implemented robot. Positively surprisingly, all the computation, including the optimization algorithms, is executed in the robot itself. The authors should notice that the web link to the supplemental videos and algorithms provided in the text does not work. It would be interesting to know the fitness of the hand-designed and hand-parameterized gait.

I miss a discussion of why the hardware platform chosen for gait evaluation produces so noisy results and what could be improved in this respect. Would more precise servos help to minimize this noise?

As a suggestion for future work, in order to minimize human intervention and optimization times, it may be possible to record the robot position by an integrated GPS device. This would allow running multiple fitness evaluations without human intervention, given a big enough space for the robot to move autonomously.

In short, the paper neatly presents an attractive study of several algorithms for physical-fitness optimization with interesting results. I recommend the acceptance of this paper for oral presentation.

Specific comments:

p3, left, 1st paragraph: "HyperNEAT, but even this took less than one second to run on the on-board computer". I guess that a complete evolution of a gait took more than one second, since the evaluation part is physically implemented. Does the 1 second value in the text refer to the reproduction and selection part of the algorithm? Please, specify.

p3, left, 4th paragraph: "we linearly interpolated the motion of the robot between the ready position and the commanded gait". It is not clear if the interpolation is done to just calculate the fitness or to affect the robot gait configuration. I guess it is the later, but it would be clearer to state this fact with something like "during the first and last seconds of an evaluation, the instant gait configuration of the robot is the interpolation between the initial ready position and g(t)…"

Review 2

Overall rating:	**2** (accept)
Confidence:	**3** (high)
Novelty	4 (good)
Quality of introduction	5 (excellent)
Quality of state of the art description	3 (fair)
Quality of method description	4 (good)
Quality of results description	5 (excellent)

[Article only] Has the capacity to produce an important Alife journal publication (after extension)	3 (maybe)
[Abstract only] Did the authors properly refer to the prior publication	1 (yes)
Presentation form	3 (oral)
Review:	This paper is interesting in that it evolves robot gaits completely on board a physical robot using a setup that should be fairly easily reproducable. It is also of interest that HyperNEAT which has previously been used to evolve gaits for simulated robots is here successfuly employed to evolve gaits entirely on a physical robot. The paper is generally well written. Some comments: The url given for the videos of evolved gaits and for the source code: http://bit.ly/ecalgait is a redirect to http://creativemachines.cornell.edu, and I am unable to find the videos related to this paper on that website, and so I am unable to view these videos or look at the source code. It would be very useful to be able to view these videos, so a corrected url should be included. Why did the parameterized gaits not move the center hip motor at all? I found it curious that this joint was included (and could be actuated by the HyperNEAT controllers) but was not used at all with the paremeterized gaits. Does this not put those gaits at a disadvantage? The description of the Nelder-Mead simplex method is incredibly vague. Yes, a reference is provided for reading more about this method, but it would be helpful if some more space was devoted to giving a better description of that method in this paper. It seems that the HyperNEAT setup was for the most part copied from Clune's previous work. A few questions about this: all parameters except for max generations and population size were kept the same as in Clune's work, however with these smaller population sizes those parameters may not be appropriate (especially those relating to speciation). The authors do not seem to consider this. Some justification for why the same parameters will still work with these smaller population sizes would be helpful. Additionally recent work has demonstrated that a seperate output for the presence/absence of connections is useful in addition to the output that determines connection weights, was this considered at all?

There appears to be large differences in the performance of any single gait. Obviously this is one of the challenges when evolving on real, noisy, hardware. Because of this it is difficult to judge how well any single gait will perform in future evaluations. In extending this work with combining physical and simulated evaluations it would be useful to select for robustness to noise as opposed to the ability to perform really well by chance which is what is done here.

Minor points:
In the introduction it is stated that "An additional motivation is to test whether gaits evolved in simulaiton tranfer to reality well," but this is never tested here as all gaits are evolved on the real robots.

Why was the gait interpolated between command gai and stationary pose for 1 second at the beginning, but 2 seconds at the end? Why not use the same amount of time at either end? A sentence motivating this design decision would be helpful.

On page 4 it is stated "For future studies we will use a 2 x 2 array of Wii remotes to double the size of the measurment arena." Wouldn't using a 2 x 2 array quadruple the size of the arena not double it?

Review 3

Overall rating:	**3** (strong accept)
Confidence:	**3** (high)
Novelty	4 (good)
Quality of introduction	4 (good)
Quality of state of the art description	4 (good)
Quality of method description	4 (good)
Quality of results description	4 (good)
[Article only] Has the capacity to produce an important Alife journal publication (after extension)	3 (maybe)
[Abstract only] Did the authors properly refer to the prior publication	1 (yes)
Presentation form	3 (oral)
Review:	This work deals with evolving gait on a real robot with HyperNEAT approach. This is the well written paper and is worth to be accepted. There are several open questions, which can be addressed in the final version of the paper: 1) Can motor-feedback sensors be used in the gait generation? Can they improve the ANN-based control?

2) How it would improve the fitness evaluation, when IR LED would be installed on each of the legs?
3) It would make sense to compare this approach with rhythmic gain generator based on CPGs, which used analytical approaches for gait generation.
4) What is the number of trials (see discussion on the page 8)?