

Evolving robots to study adaptive behavior.

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December 14, 2015

Boston Dynamics: Big Dog (2005)



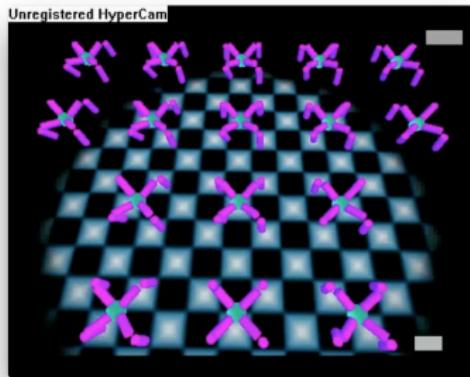
Marc Raibert's 3D Biped (1992)



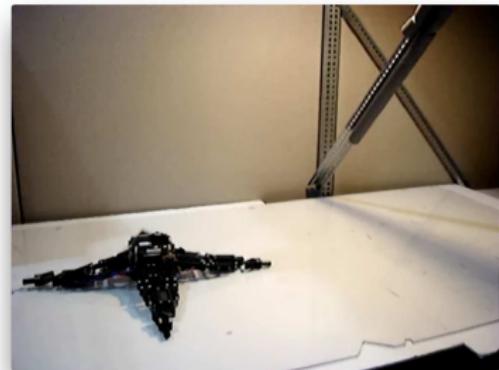
Manufacturing vs. Construction



Evolutionary Robotics

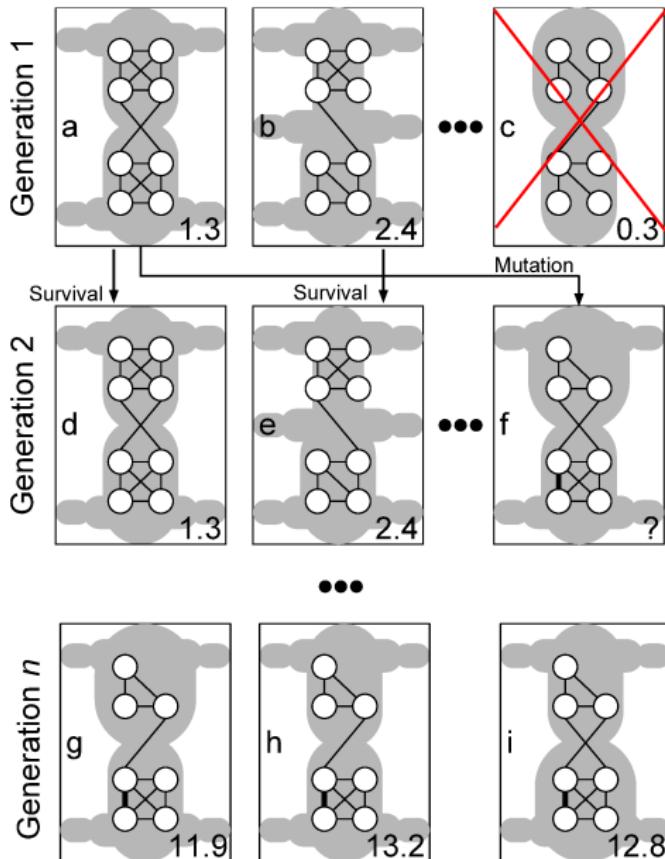


Bongard & Pfeifer, 2002,
Procs of the 7th Intl Conf on the Sim of Adapt Beh



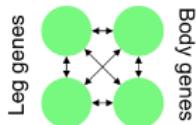
Bongard, Zykov & Lipson, 2006,
Science

Evolutionary Robotics



Modularity can increase evolvability.

Modularity = dense connectivity within modules; sparse connectivity between modules.



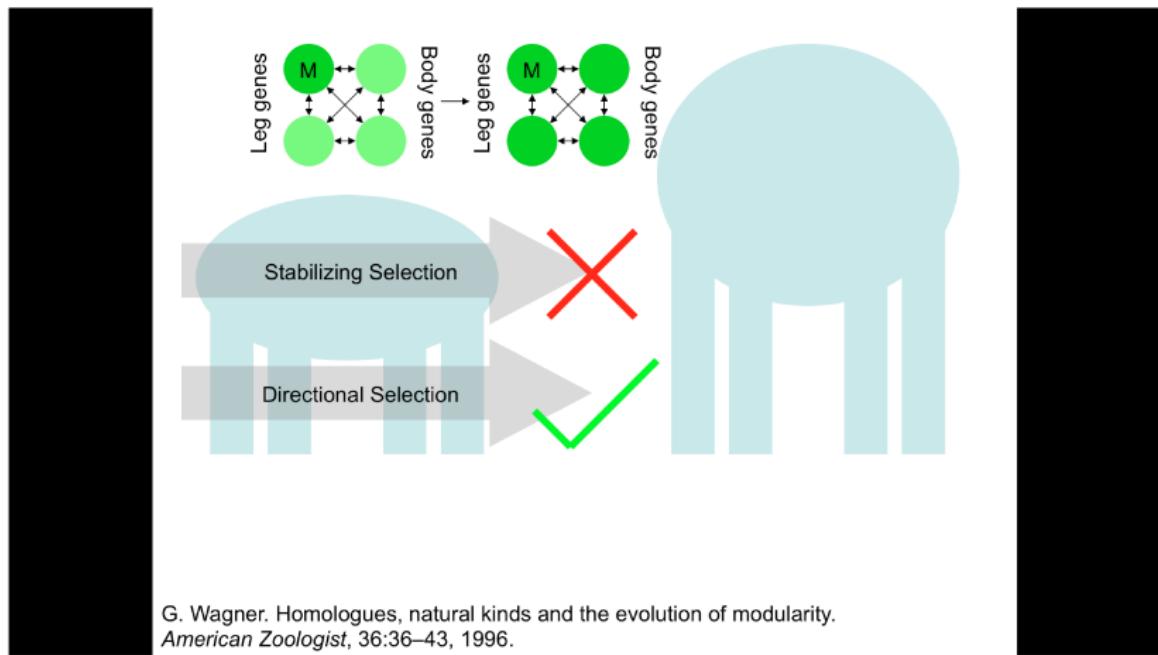
Stabilizing Selection

Directional Selection

G. Wagner. Homologues, natural kinds and the evolution of modularity.
American Zoologist, 36:36–43, 1996.

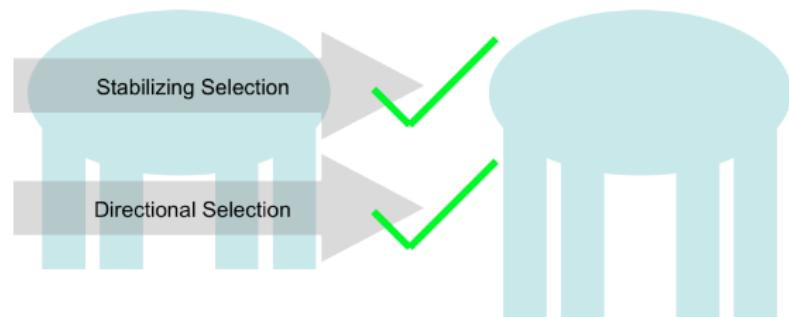
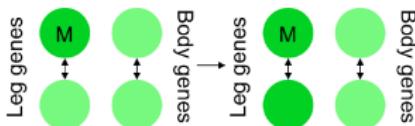
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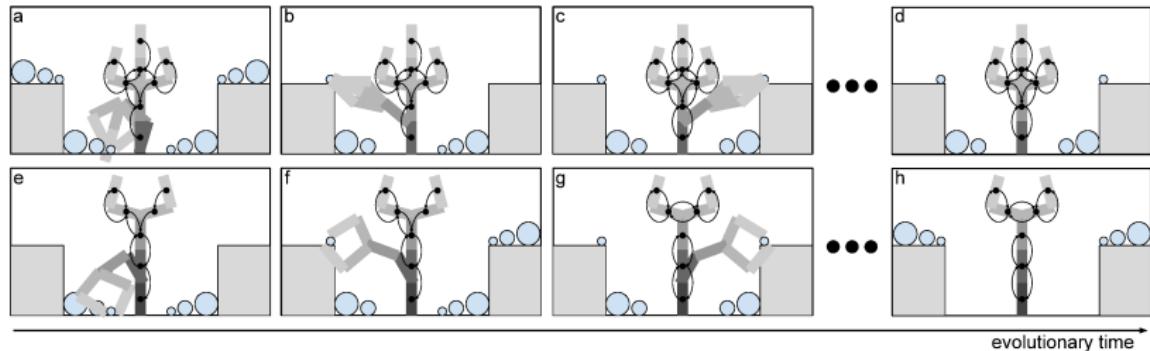
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G. Wagner. Homologues, natural kinds and the evolution of modularity.
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Hypothesis:

- (1) The right morphology increases the probability of evolving neural modularity.
- (2) Neural modularity increases evolvability.
- (3) Thus, evolving robot morphology increases evolvability.



What's Modeled and What Isn't

► Modeled:

- ▶ Heritable genetic variation → differences in reproduction rate
- ▶ Physical impact of the robot on the environment
- ▶ Physical impact of the environment on the robot
- ▶ Point mutation
- ▶ Evolved changes in synaptic strength

► Not Modeled:

- ▶ Sexual recombination
- ▶ Diploidy
- ▶ Evolution of the architecture of the nervous system
- ▶ Evolution of the body plan
- ▶ Evolution of development
- ▶ Epigenetics
- ▶ Sexual selection
- ▶ Neutral mutation
- ▶ ...

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Evolving grasping behavior.

Robot: Four environments; seven degrees of freedom.

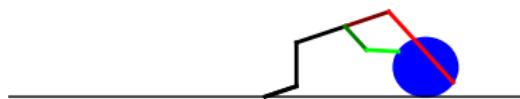
(a): Environment 1



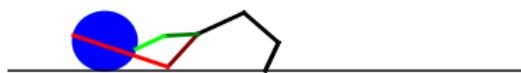
(b): Environment 2



(c): Environment 3

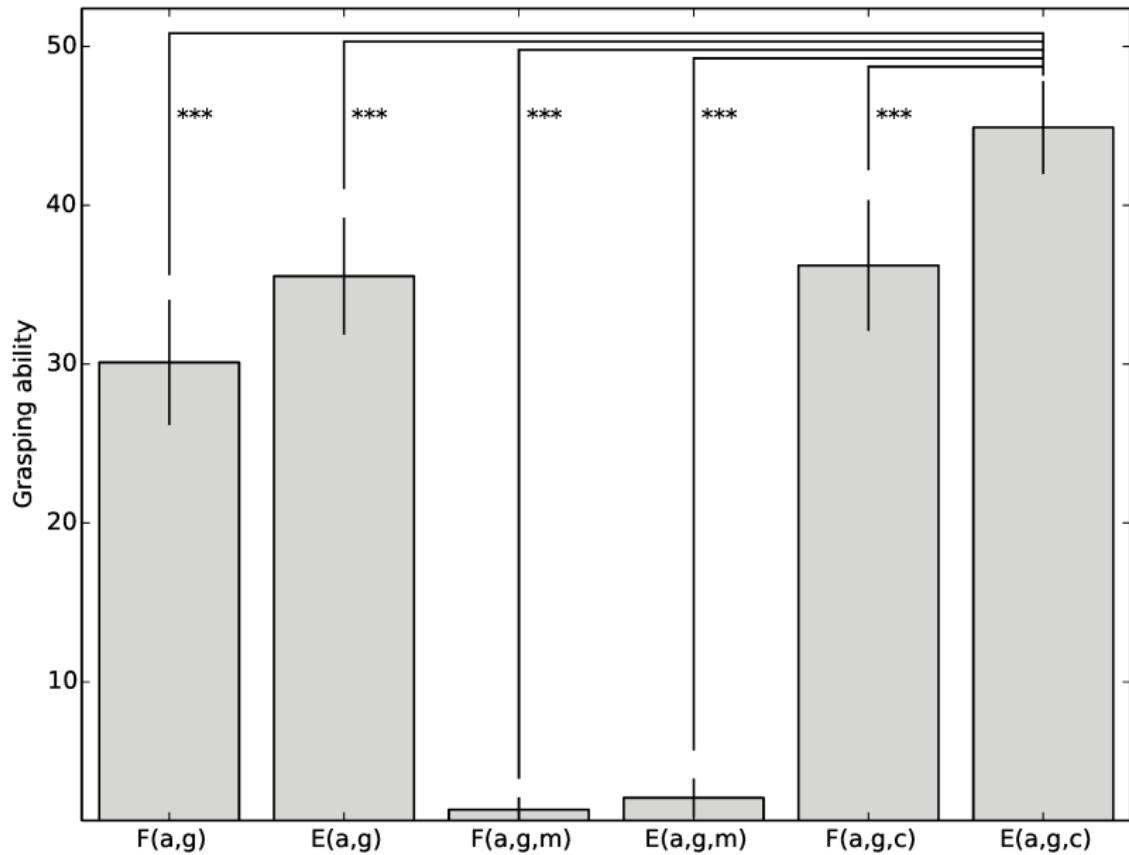


(d): Environment 4



Relative performance

F/E=fix/evolve morphology; a/g/m/c=age/grasping/modularity/conservatism



Non-conservative poses.

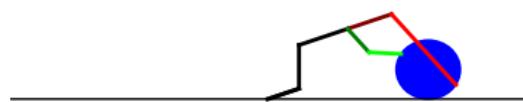
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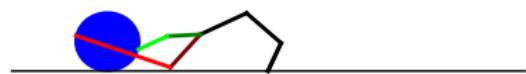
(b): Environment 2



(c): Environment 3

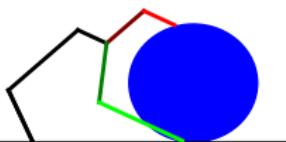


(d): Environment 4

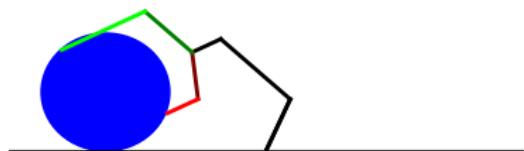


Conservative poses.

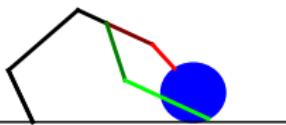
(a): Environment 1



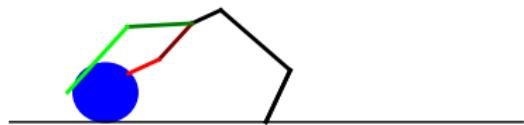
(b): Environment 2



(c): Environment 3



(d): Environment 4



Crowdsourcing robotics: the DotBot Project.

www.uvm.edu/~mwagy/robots/dotbot

Try to design a robot that moves farther!

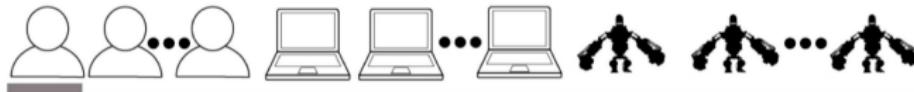
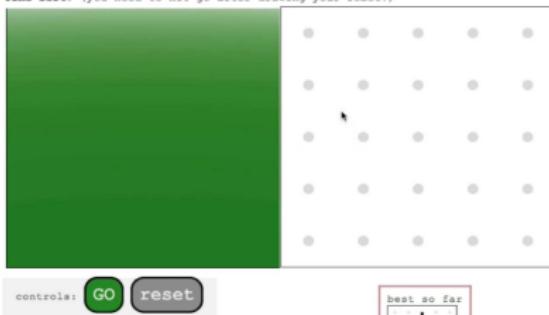
Connect the dots with your mouse to draw a robot then click GO.
If you run the same robot design multiple times, it will learn new behaviors.

Some random past designs:



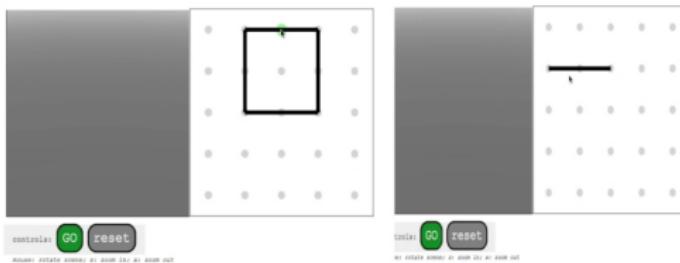
Current distance (from red ball): (you need to draw a robot first!)

Time left: (you need to hit go after drawing your robot!)



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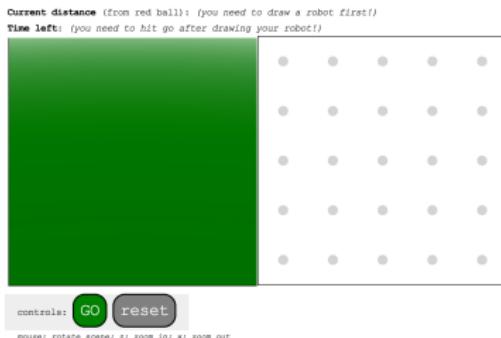
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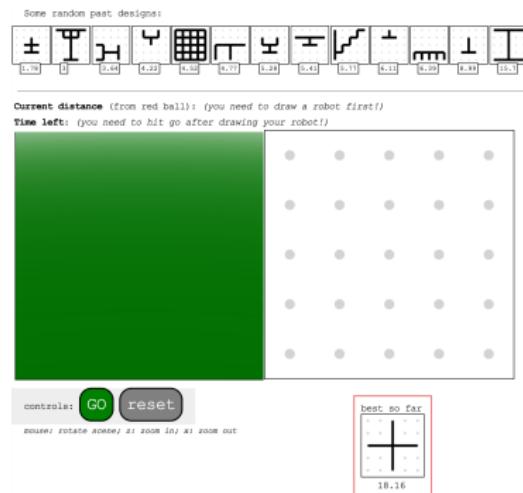
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364 users



1245 designs

398 users



1136 designs

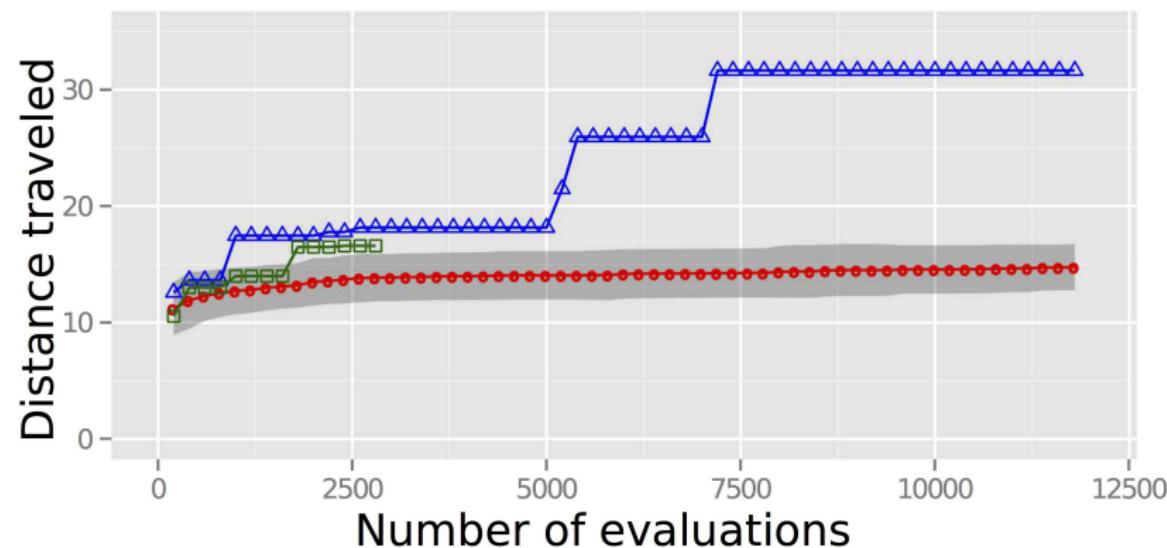
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Blue: Users collaboratively design body plans; computers optimize controllers.

Green: Users independently design body plans; computers optimize controllers.

Red: Computers optimize body plans and controllers.



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Learning evolutionary robotics: Ludobots

www.reddit.com/r/ludobots

