

“Evo Devo So Ro”: Evolving soft robots that develop over their lifetime.

Josh Bongard

Morphology, Evolution and Cognition Laboratory
University of Vermont
www.meclab.org

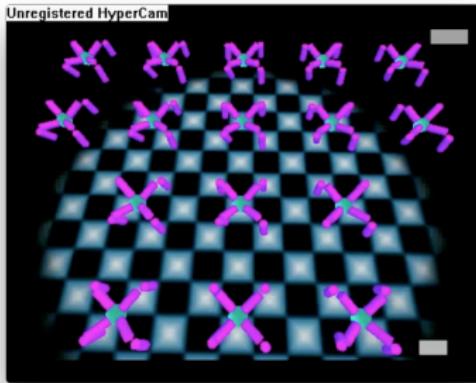
December 26, 2016

Robo.

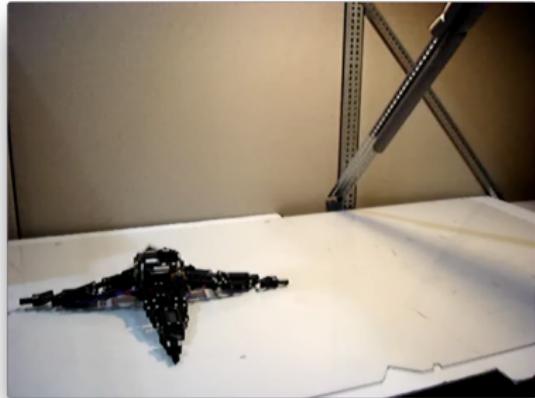
DARPA Robotics Grand Challenge.



Evo robo.



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



Bongard, Zykov & Lipson, 2006,
Science

Evo robo.

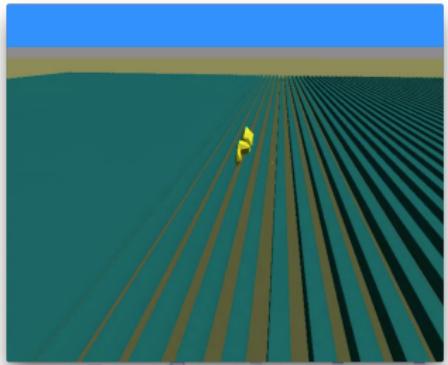
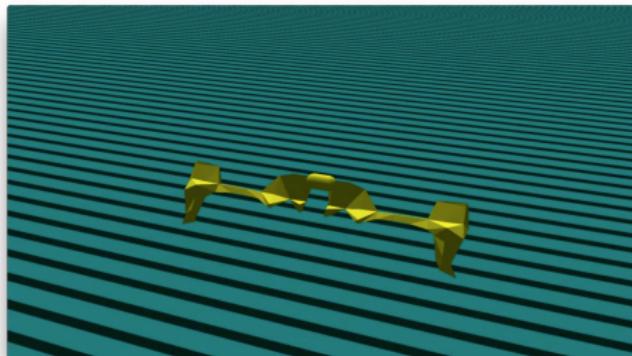
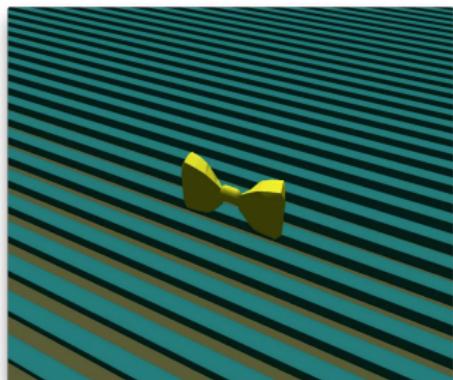
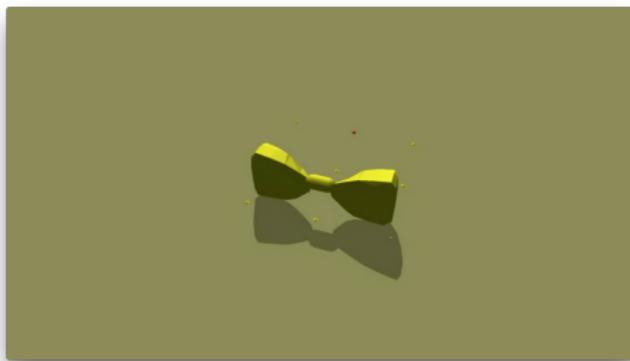
- ▶ Sims (1994), *Artificial Life*.



- ▶ Eggenberger (1997), *Procs of the 4th Euro Conf on Artificial Life*.
- ▶ Lipson & Pollack (2000), *Nature*.
- ▶ Bongard & Pfeifer (2001), *Procs of the Genetic and Evolutionary Computation Conf.*
- ▶ Hornby & Pollack (2002). *Artificial Life*.
- ▶ Bongard, Zykov & Lipson (2006), *Science*.
- ▶ Bongard (2011), *PNAS*.
- ▶ Cheney, MacCurdy, Clune & Lipson (2013), *Procs of the Genetic and Evolutionary Computation Conf.*
- ▶ Auerbach & Bongard (2013), *PLoS Comp Bio*.

Evo robo.

Auerbach & Bongard. (2013). *PLoS Computational Biology*.



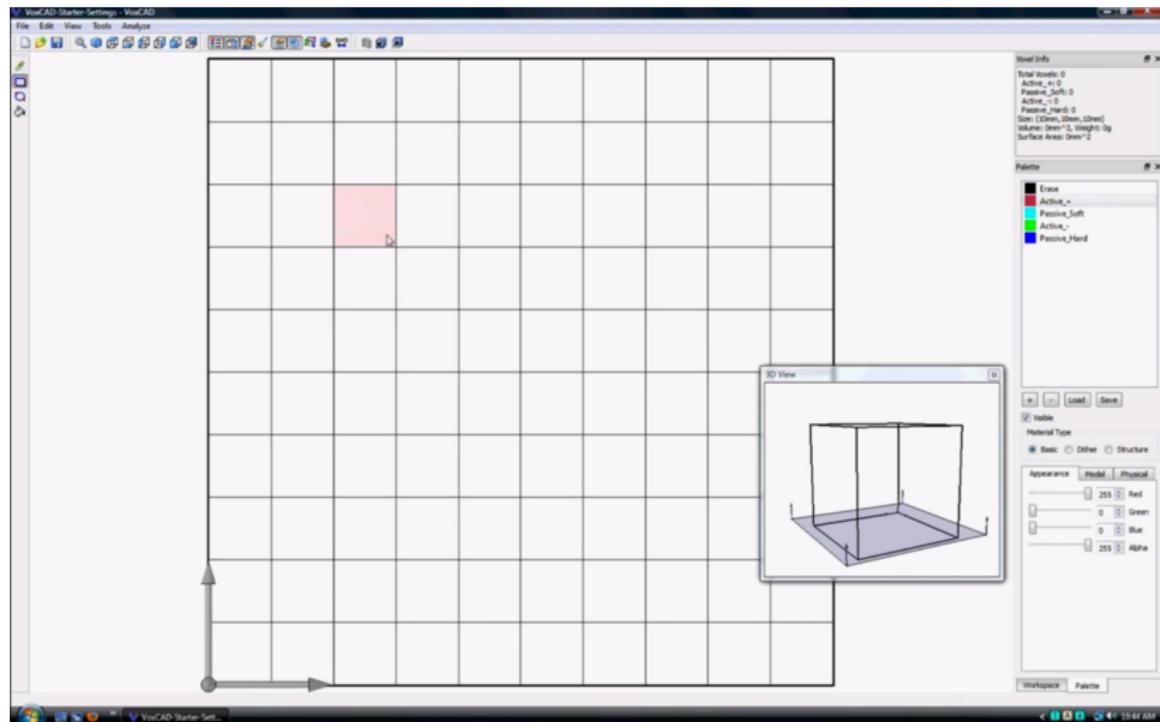
So ro.

Shepherd, Whitesides *et al.* (2011), PNAS.



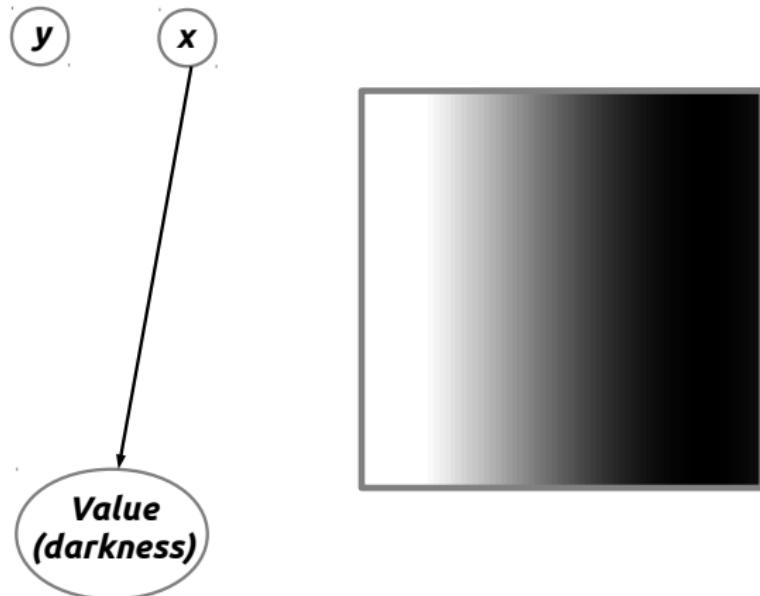
VoxCAD: Soft robotics modeling tool.

github.com/jonhiller/VoxCAD



Compositional Pattern Producing Networks (CPPNs)

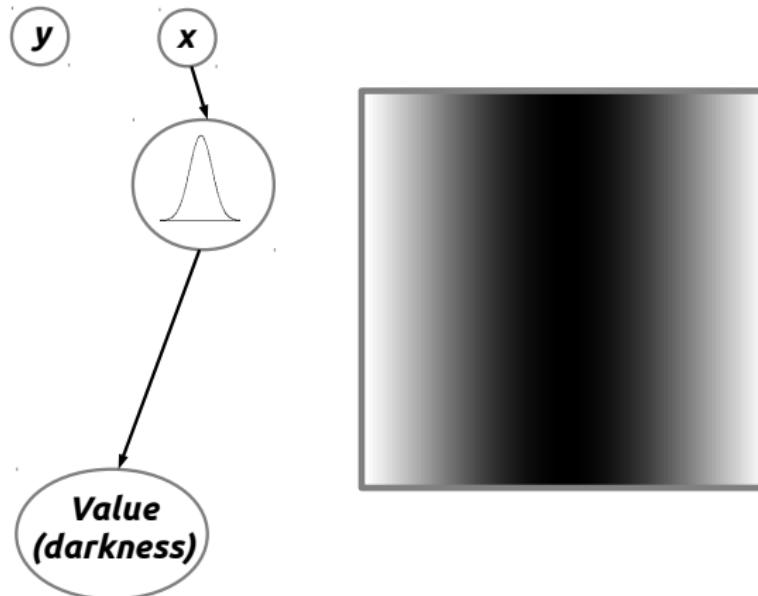
KO Stanley, *Genetic programming and evolvable machines* 8(2), 131-162



(Image courtesy of Nicholas Cheney)

Compositional Pattern Producing Networks (CPPNs)

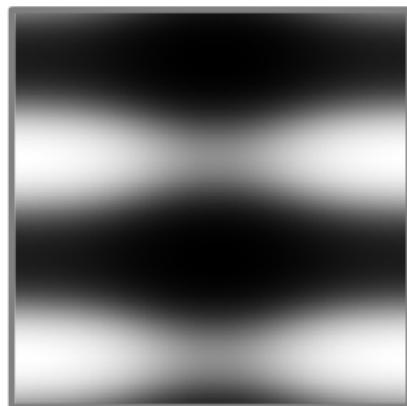
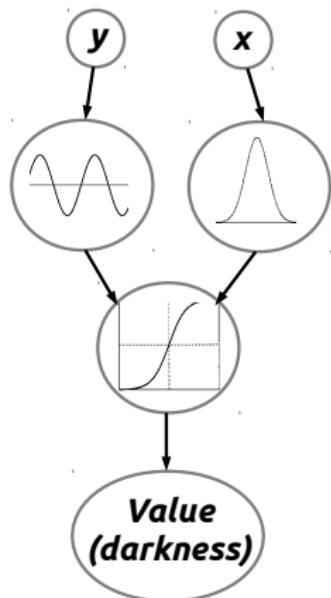
KO Stanley, *Genetic programming and evolvable machines* 8(2), 131-162



(Image courtesy of Nicholas Cheney)

Compositional Pattern Producing Networks (CPPNs)

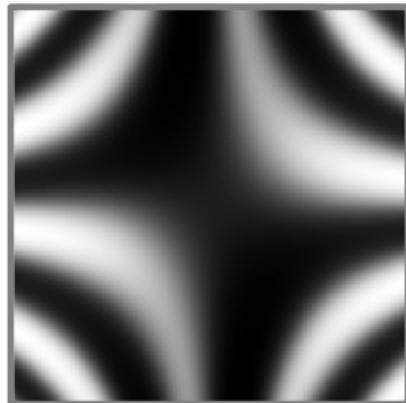
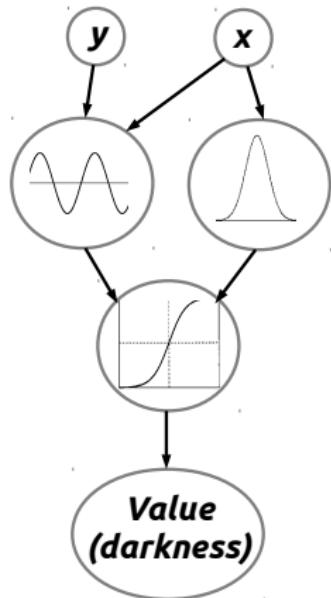
KO Stanley, *Genetic programming and evolvable machines* 8(2), 131-162



(Image courtesy of Nicholas Cheney)

Compositional Pattern Producing Networks (CPPNs)

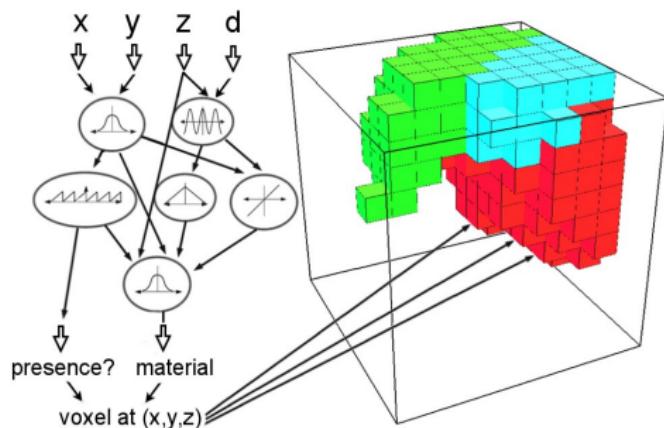
KO Stanley, *Genetic programming and evolvable machines* 8(2), 131-162



(Image courtesy of Nicholas Cheney)

Evo so ro.

Cheney, MacCurdy, Clune & Lipson (2013). *Procs Genetic Evolutionary Comp Conf*



(Image courtesy of Nicholas Cheney)

Evo so ro.

Cheney, MacCurdy, Clune & Lipson (2013). *Procs Genetic Evolutionary Comp Conf*

We gave evolution four materials:

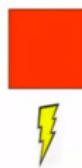
- █ Muscle: contract then expand
- █ Tissue: soft support
- █ Muscle2: expand then contract
- █ Bone: hard support



Evo so ro.

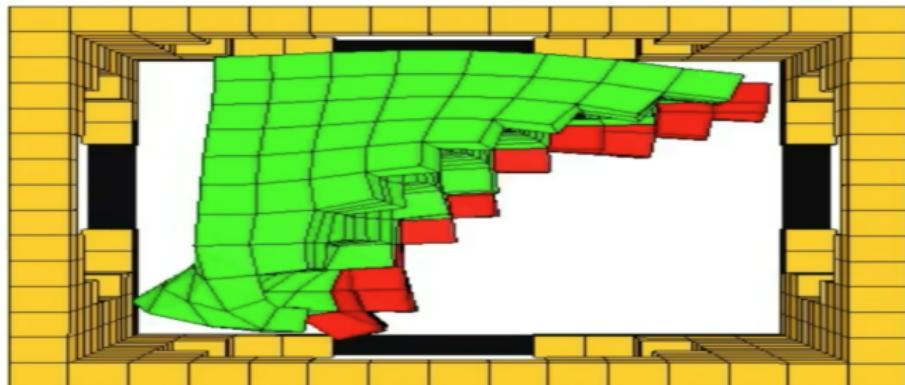
Cheney, Clune & Lipson. (2014). Procs of the GECCO Conference.

In this model, the red cells act as pacemakers,
producing a regular spike of electricity.



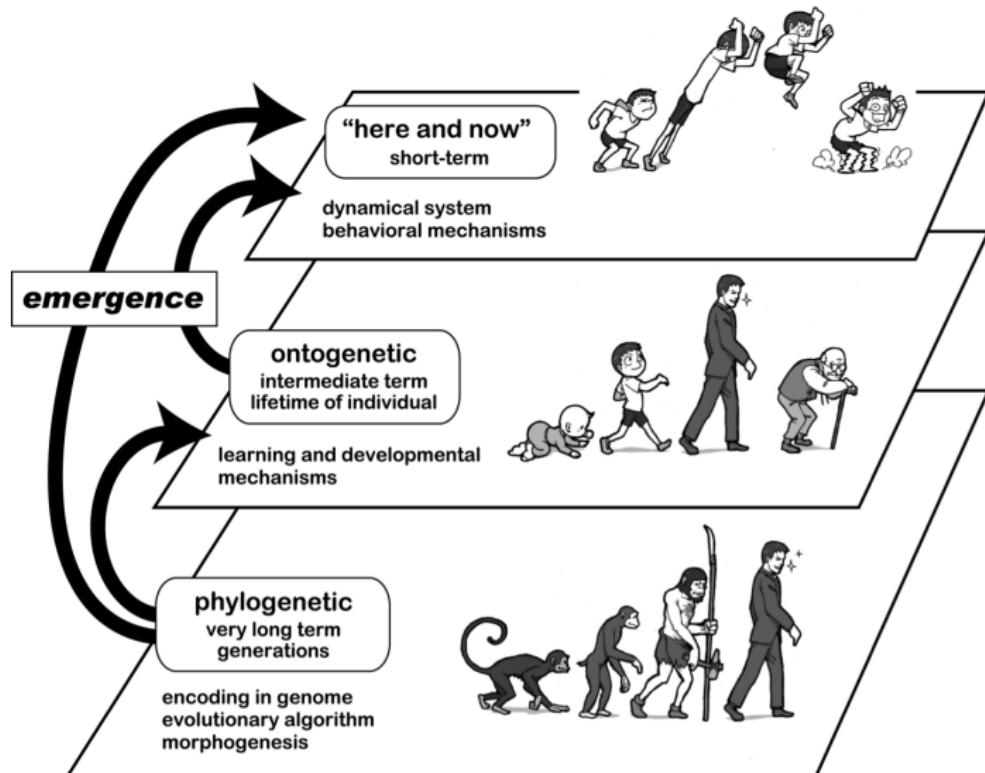
Evo so ro.

Cheney, Clune & Lipson. (2015). Procs of the GECCO Conference.



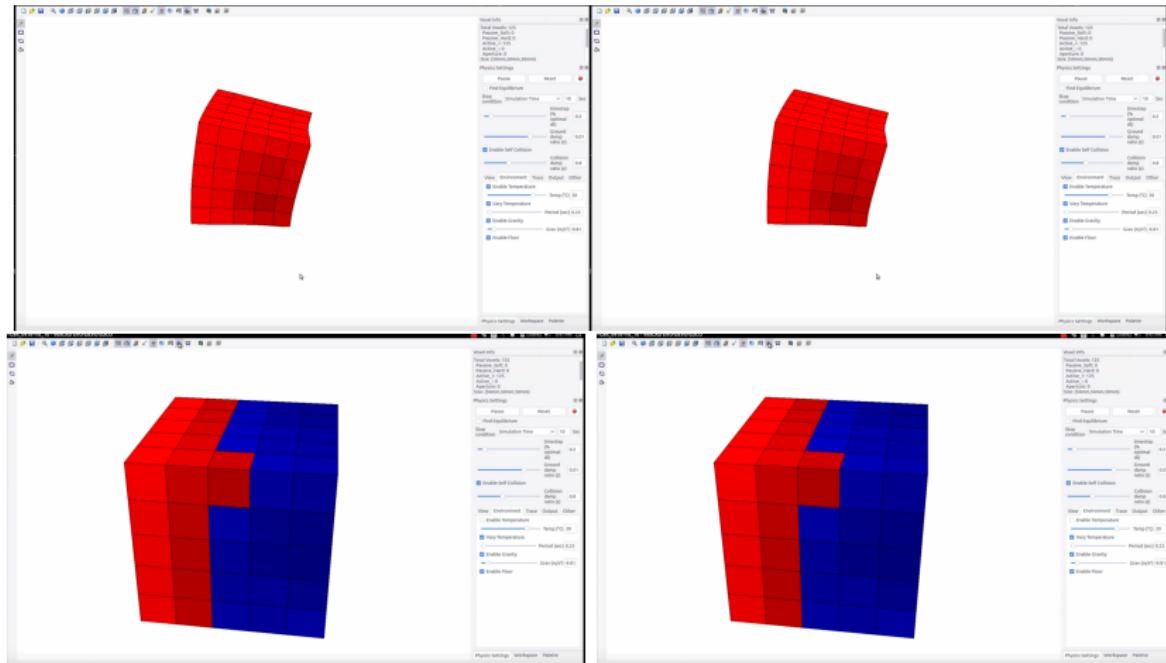
Evo devo.

(From Pfeifer & Bongard (2006). *How the Body Shapes the Way We Think.*)



Evo devo so ro.

Kriegman, Cheney, Corucci & Bongard. In preparation.



Evo devo so ro.

Corucci, Cheney, Kriegman & Bongard. In preparation.

Slow change in color:

developmental change...

...in stiffness

...in response to pressure.

Fast change in color:

local pressure.

