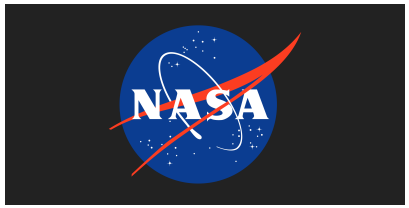
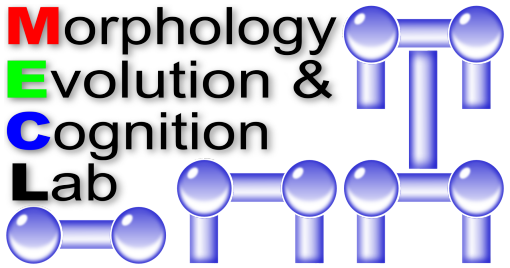
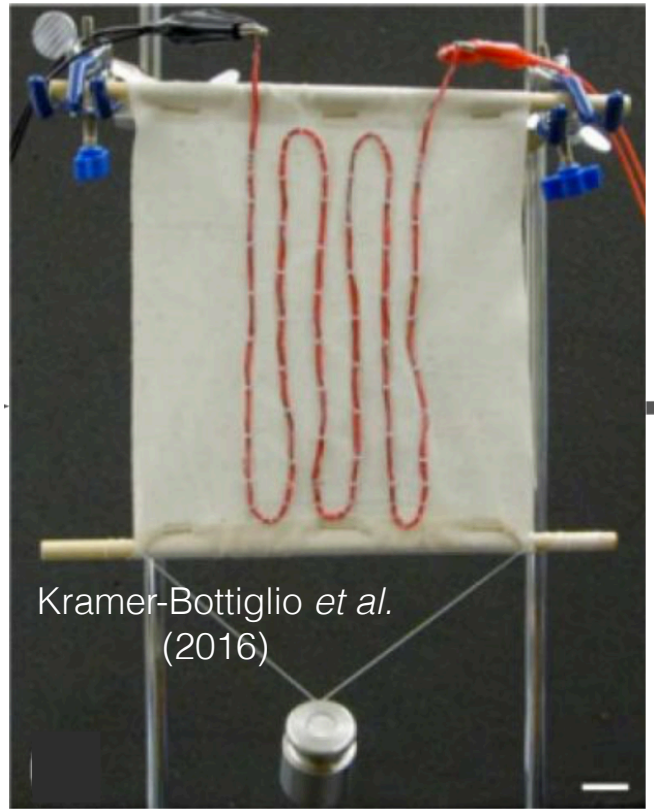
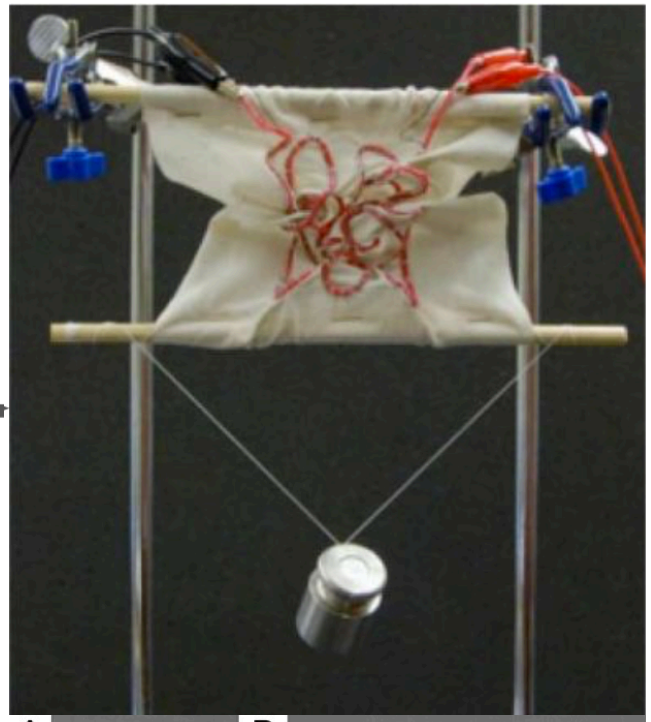


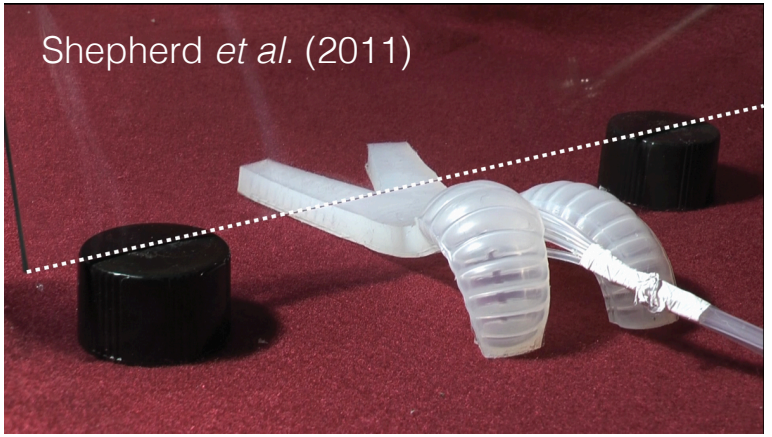
Soft robots that evolve and develop.

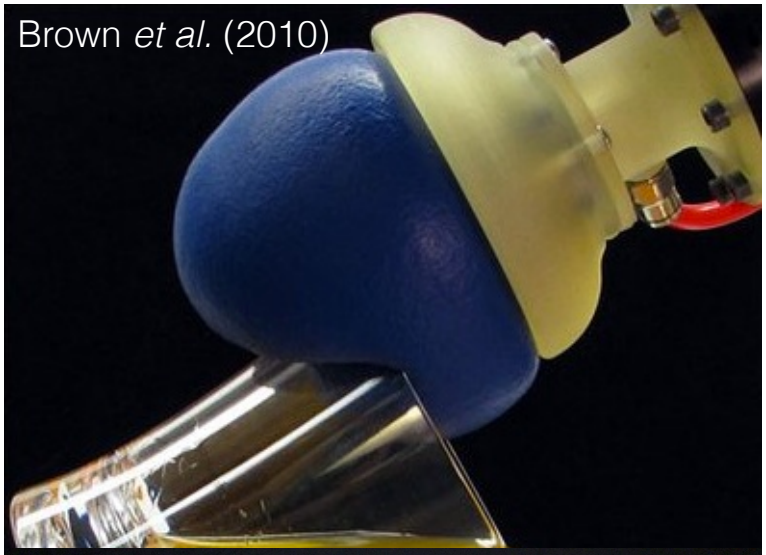
Josh Bongard
Morphology, Evolution & Cognition Laboratory
Vermont Complex Systems Center
University of Vermont

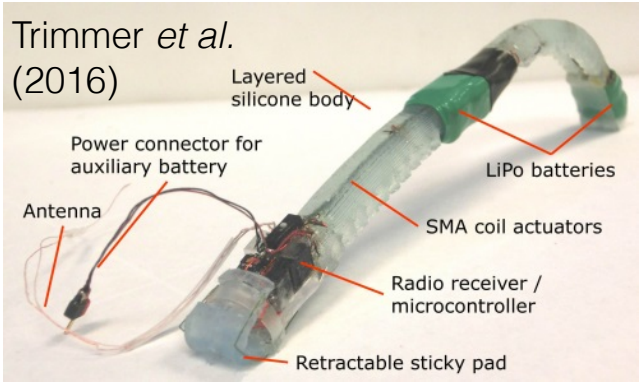


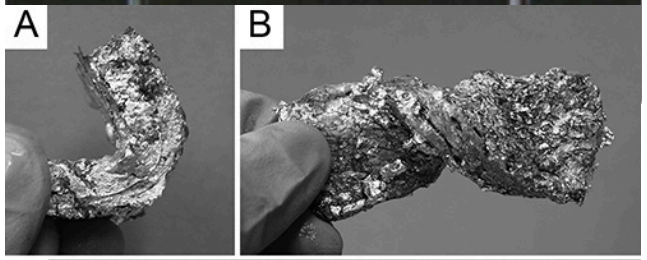

Kramer-Bottiglio *et al.*
(2016)

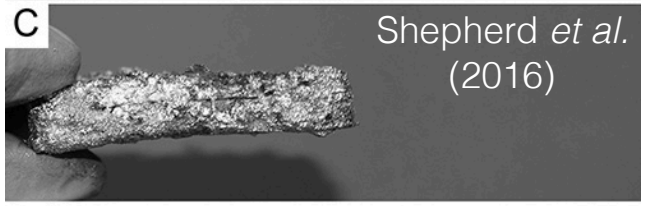


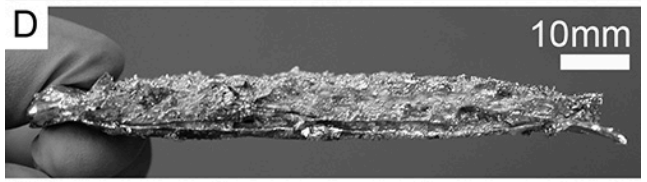

Shepherd *et al.* (2011)

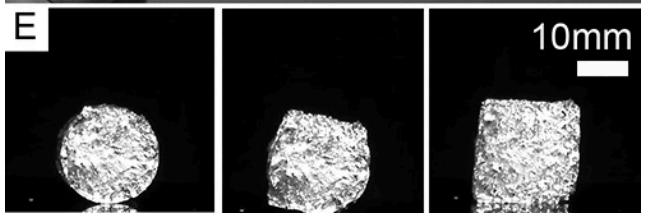

Brown *et al.* (2010)


Trimmer *et al.*
(2016)
Layered silicone body
Power connector for auxiliary battery
LiPo batteries
Antenna
SMA coil actuators
Radio receiver / microcontroller
Retractable sticky pad


A
B

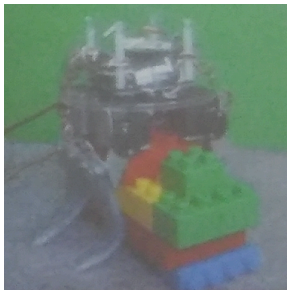

C
Shepherd *et al.*
(2016)


D
10mm

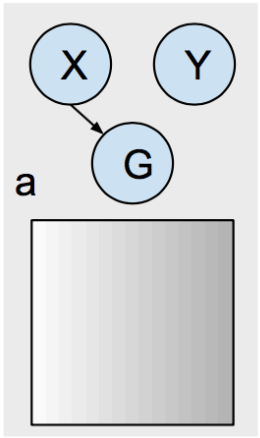

E
10mm


Wood *et al.*
(2014)

Inaba (2000)



Cheney, MacCurdy, Clune, & Lipson. 2013. *Procs. of GECCO Conf.*

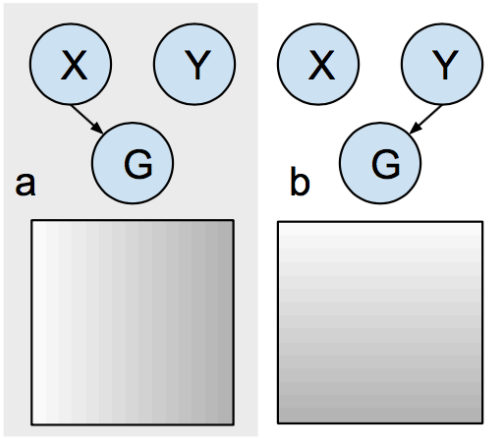


Stanley (2007).

Compositional pattern producing networks:

A novel abstraction of development.

Procs. of the GECCO Conf.



Stanley (2007).

Compositional pattern producing networks:

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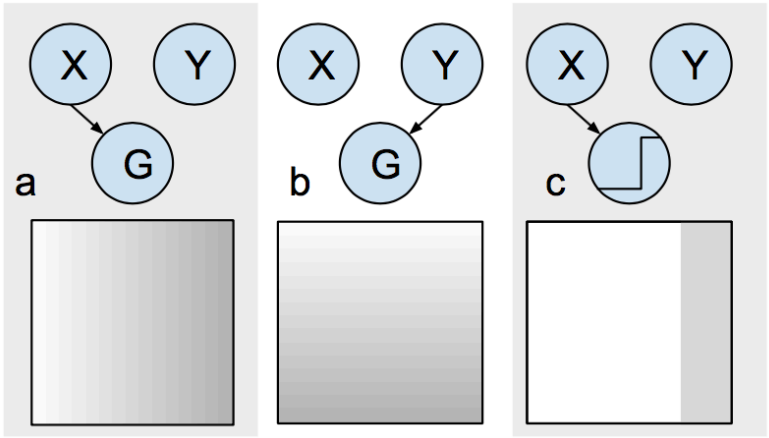
Procs. of the GECCO Conf.



Stanley (2007).

Compositional pattern producing networks:

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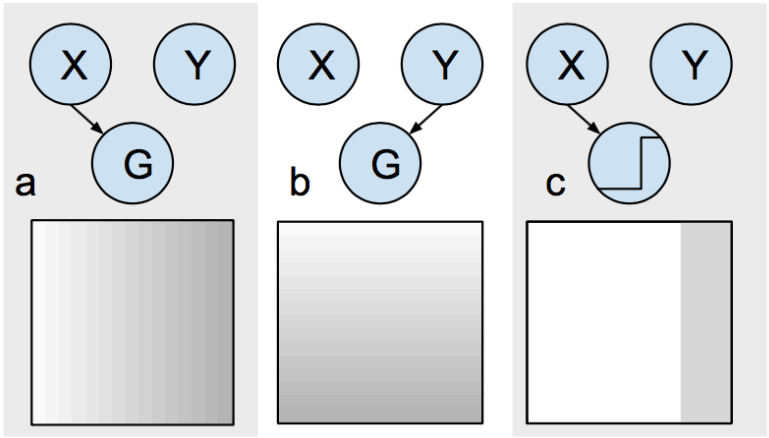
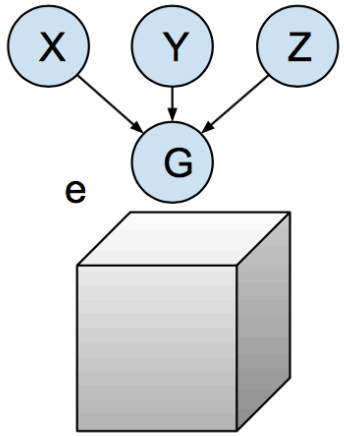
Procs. of the GECCO Conf.





Stanley (2007).

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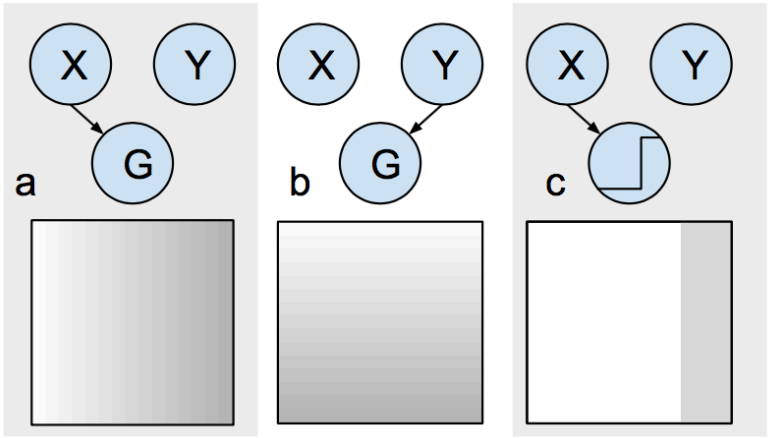
Procs. of the GECCO Conf.



Stanley (2007).

Compositional pattern producing networks:

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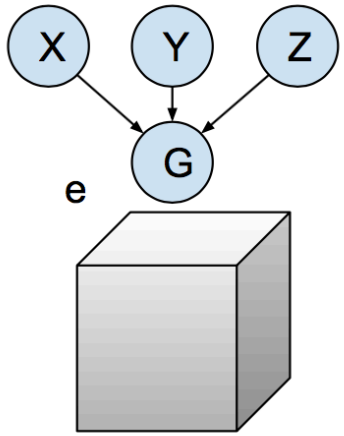
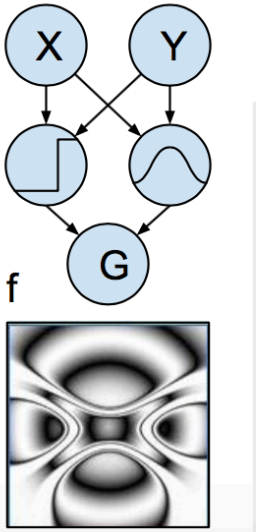
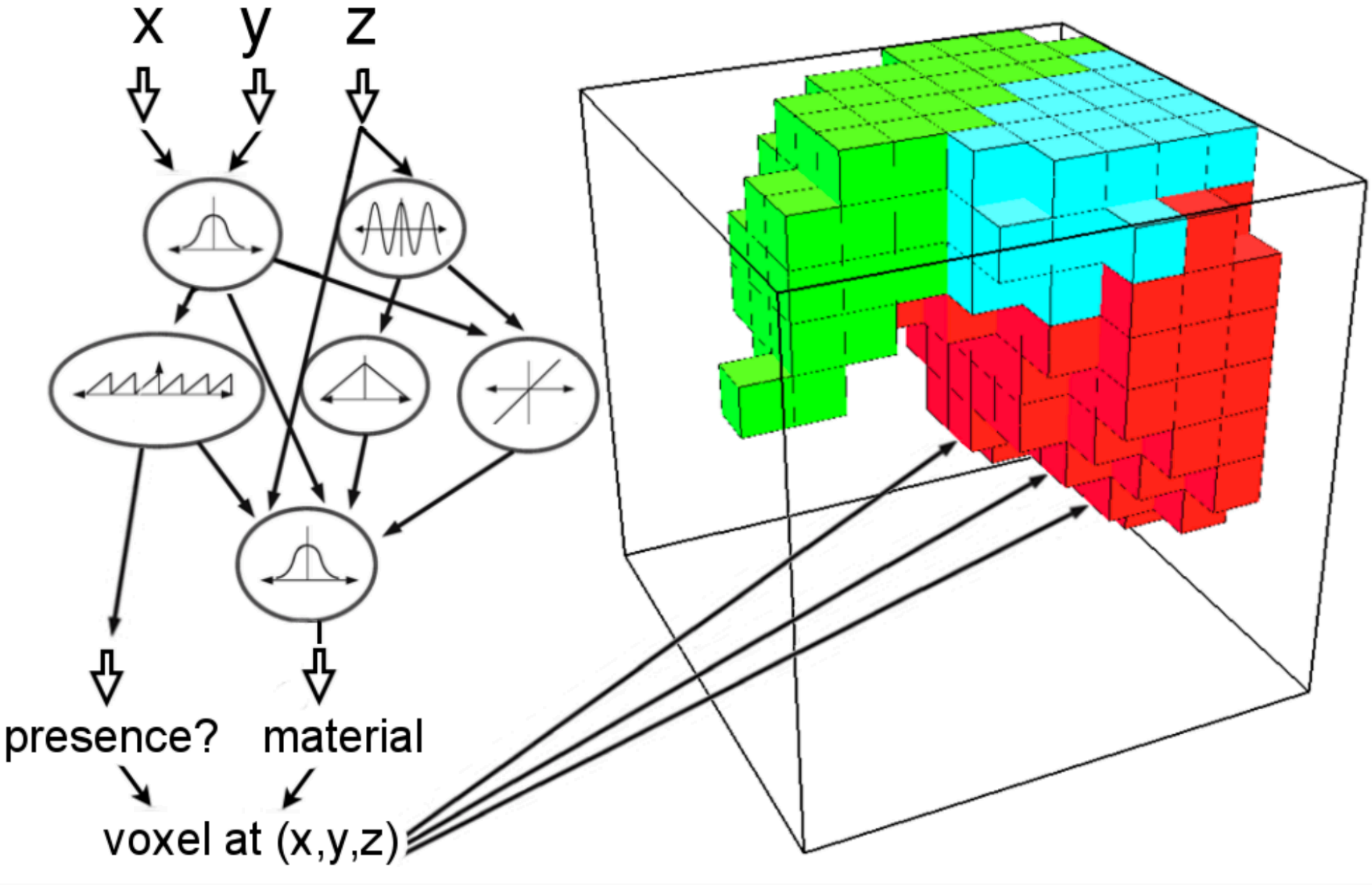
Procs. of the GECCO Conf.

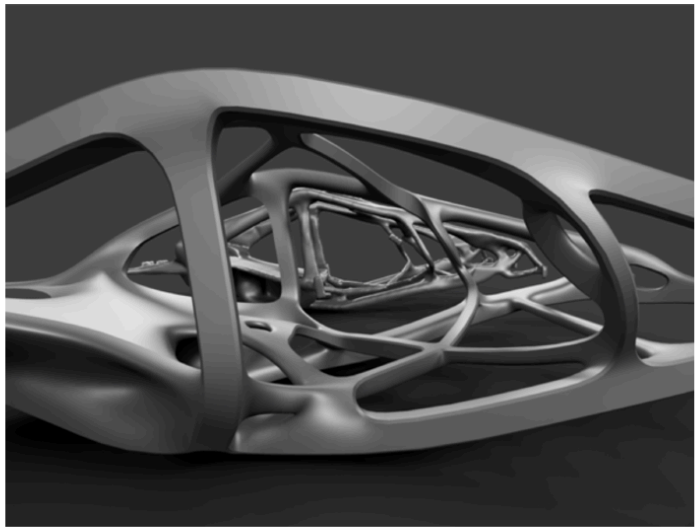




Cheney, MacCurdy, Clune, & Lipson. (2013). *Procs. of GECCO Conf.*



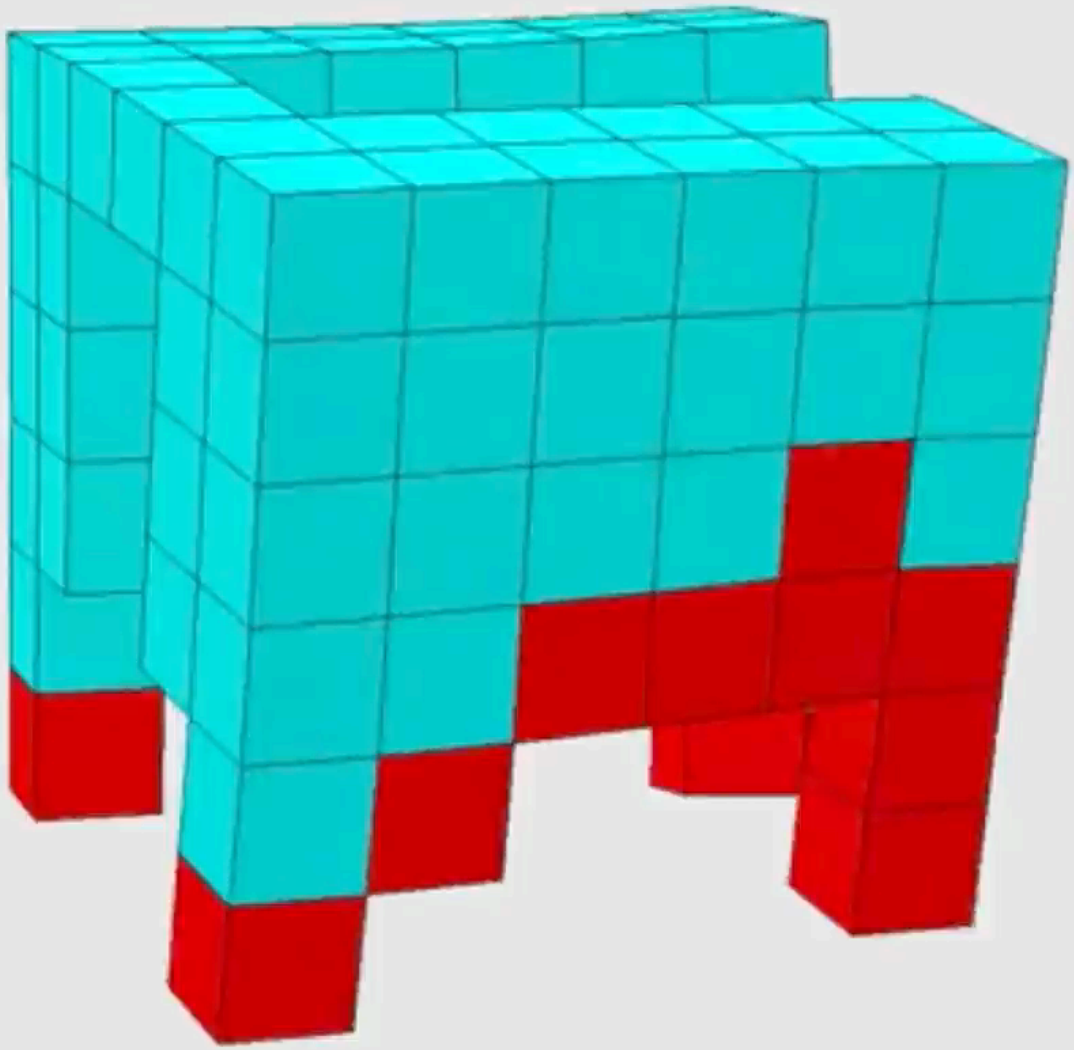
Project Dreamcatcher



What if a CAD system could generate thousands of design options that all meet your specified goals? It's no longer what if: it's Project Dreamcatcher, the next generation of CAD. Dreamcatcher is a generative design system that enables designers to craft a definition of their design problem through goals and constraints. This information is used to synthesize alternative design solutions that meet the objectives. Designers are able to explore trade-offs between many alternative approaches and select design solutions for manufacture.

GROUPS

Design Research, Computational Science Research

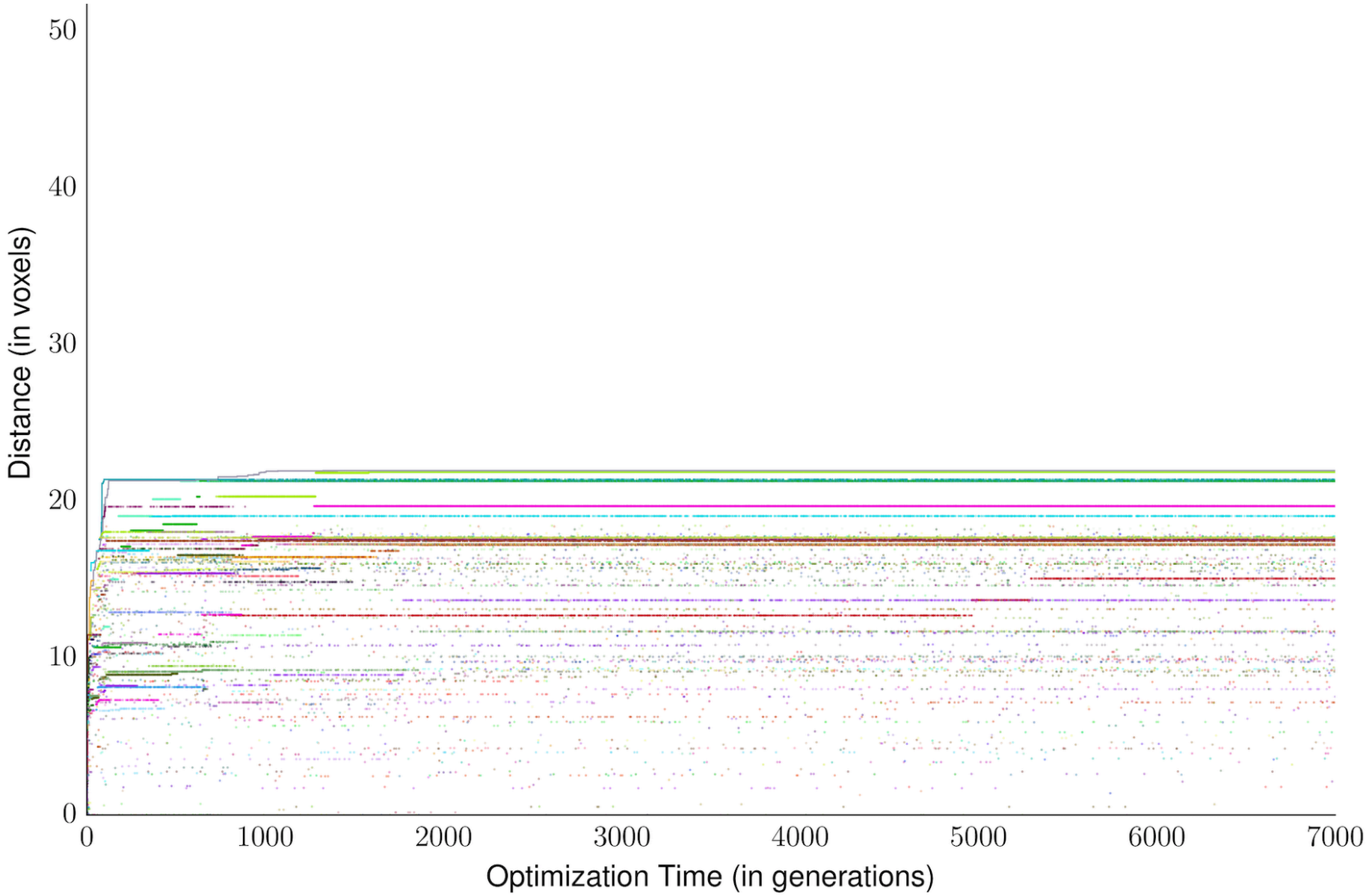


Corucci, *et al.* (2017) *Soft Robotics.* In review.

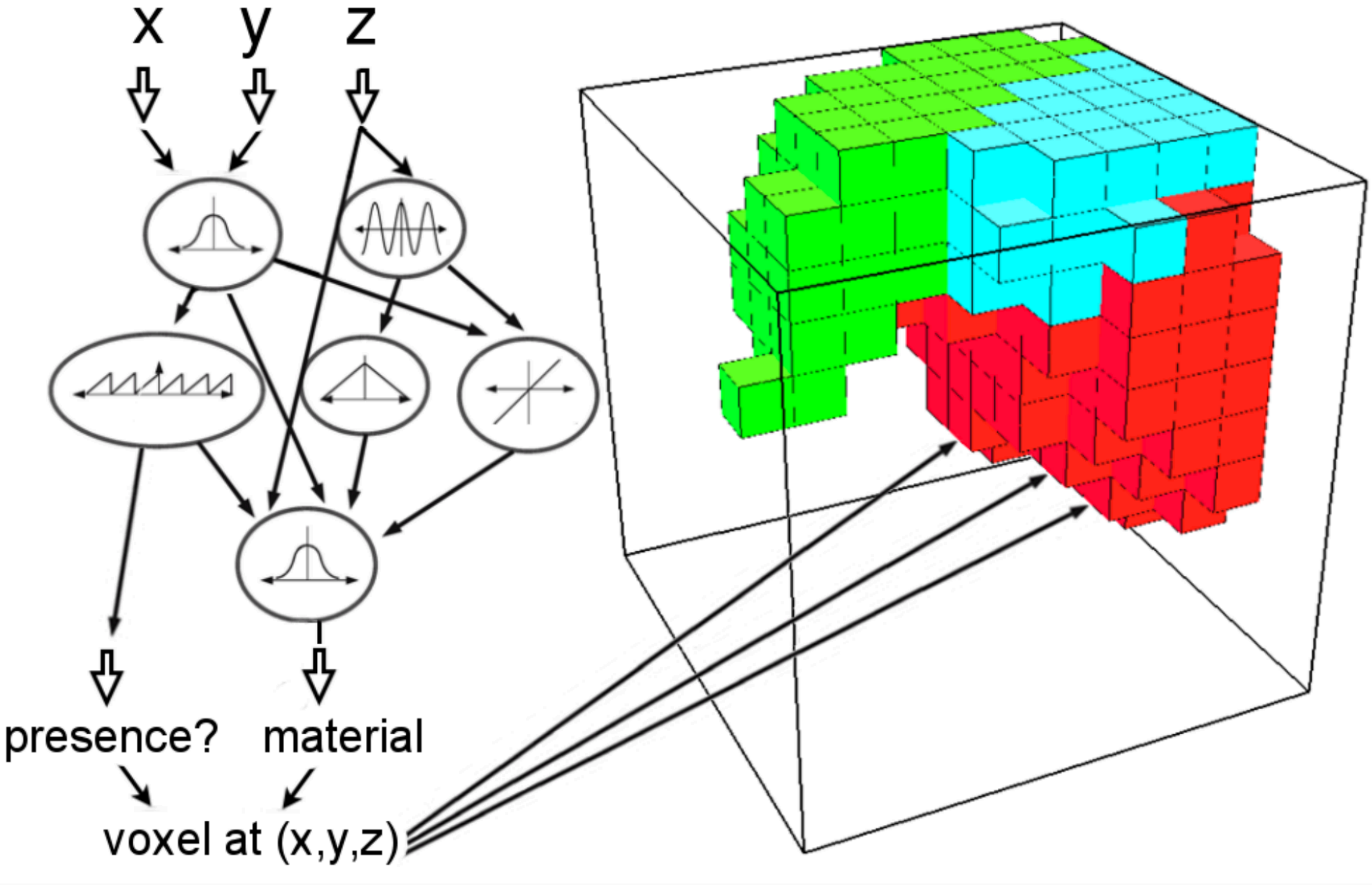
Cheney,
Bongard,
SunSpiral &
Lipson

(2017)

arXiv.



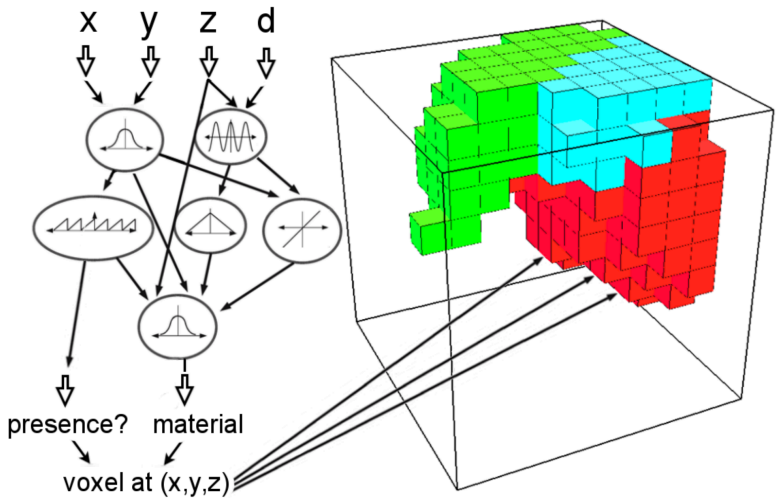
Cheney, MacCurdy, Clune, & Lipson. (2013). *Procs. of GECCO Conf.*



Cheney, Bongard, SunSpiral & Lipson

(2017)

arXiv.



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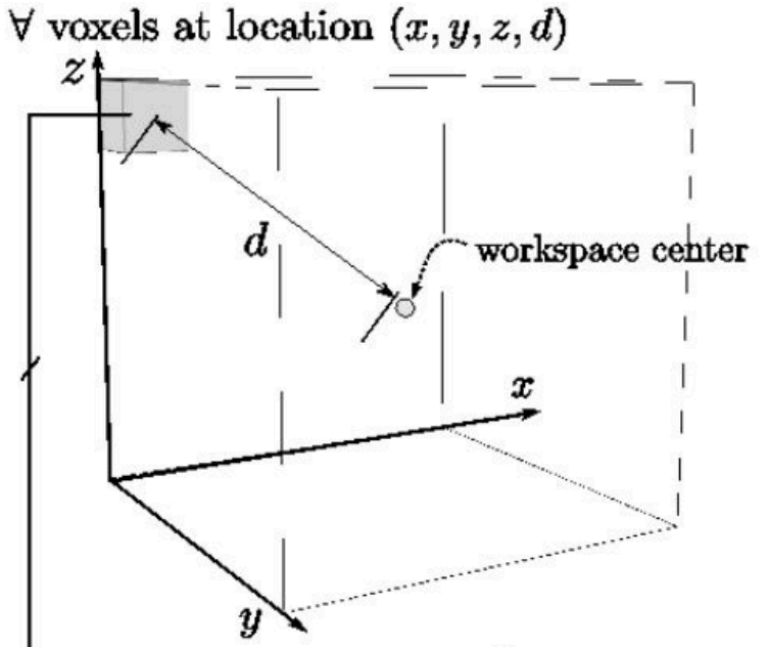

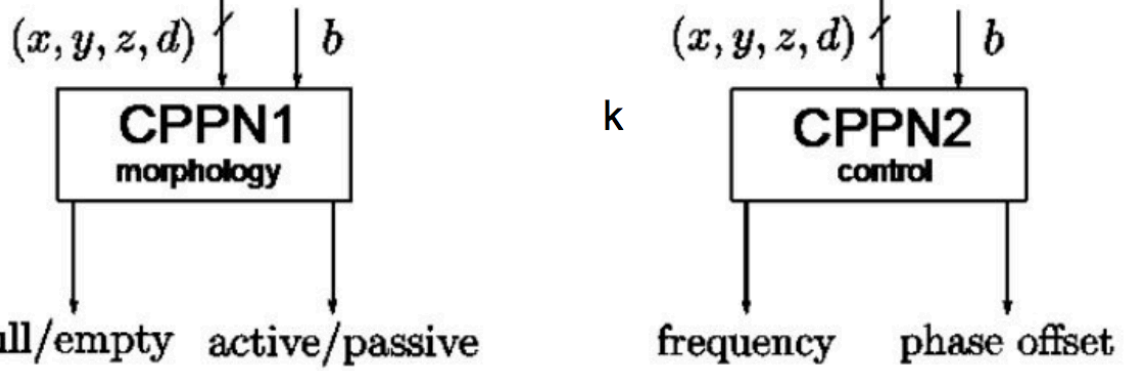

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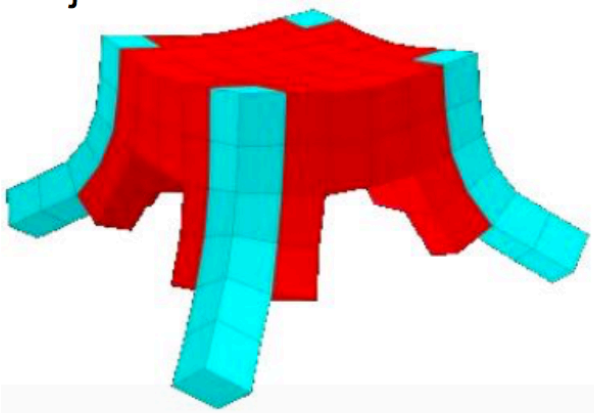

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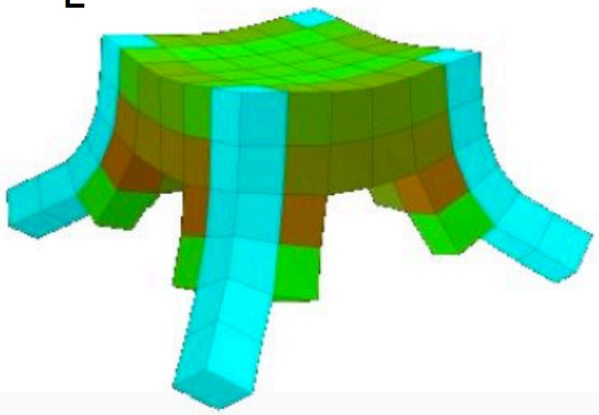
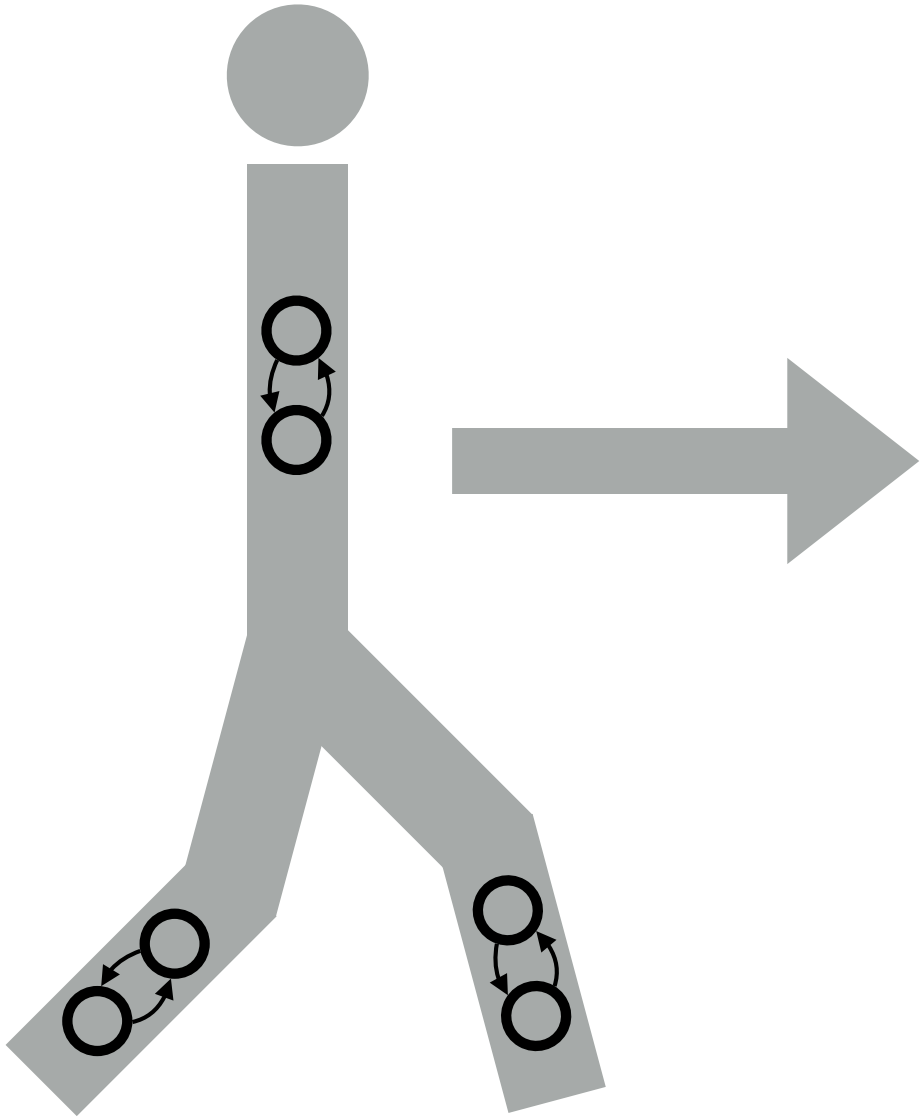


Protecting morphological innovations.

Cheney, Bongard, SunSpiral & Lipson

(2017)

arXiv.



Protecting morphological innovations.

Cheney, Bongard, SunSpiral & Lipson

(2017)

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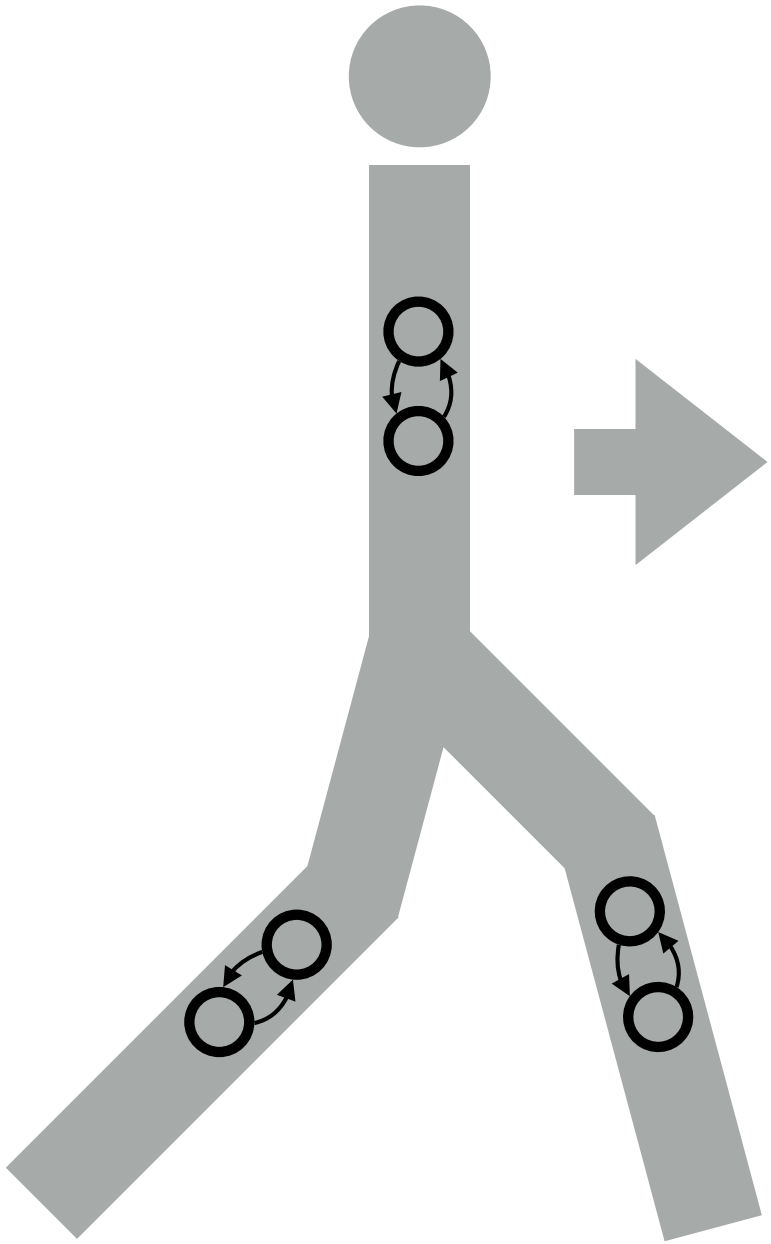

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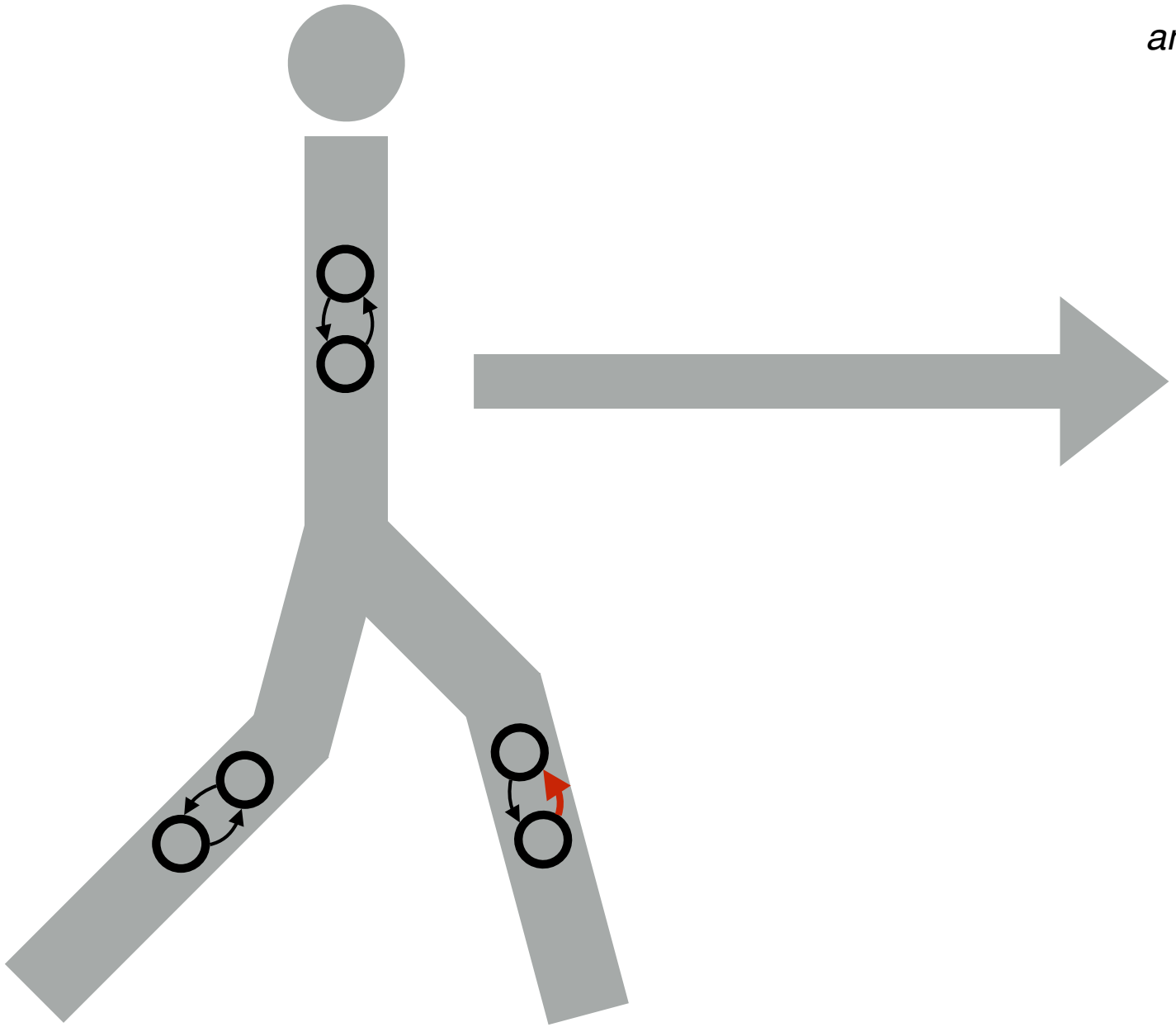
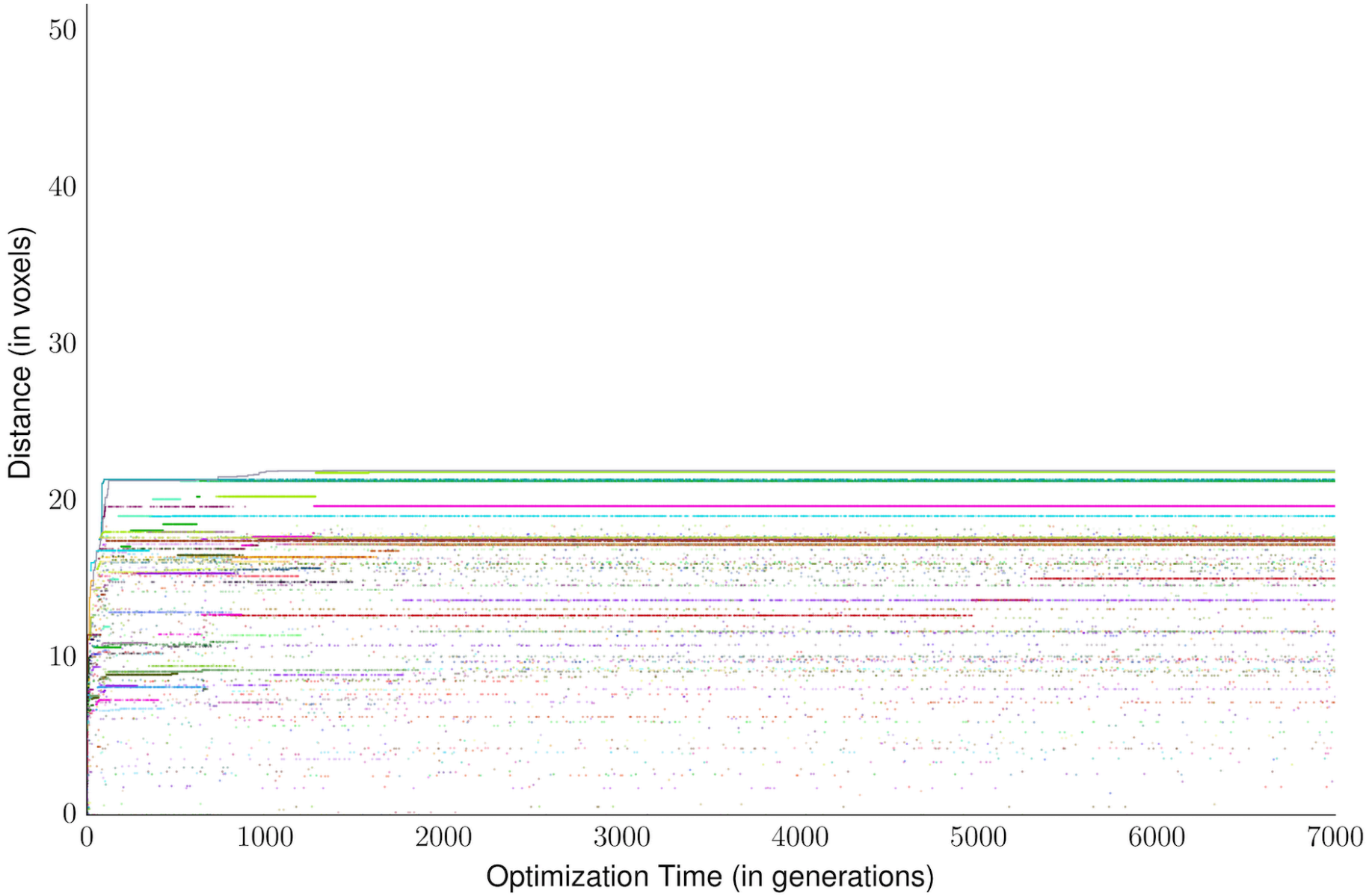
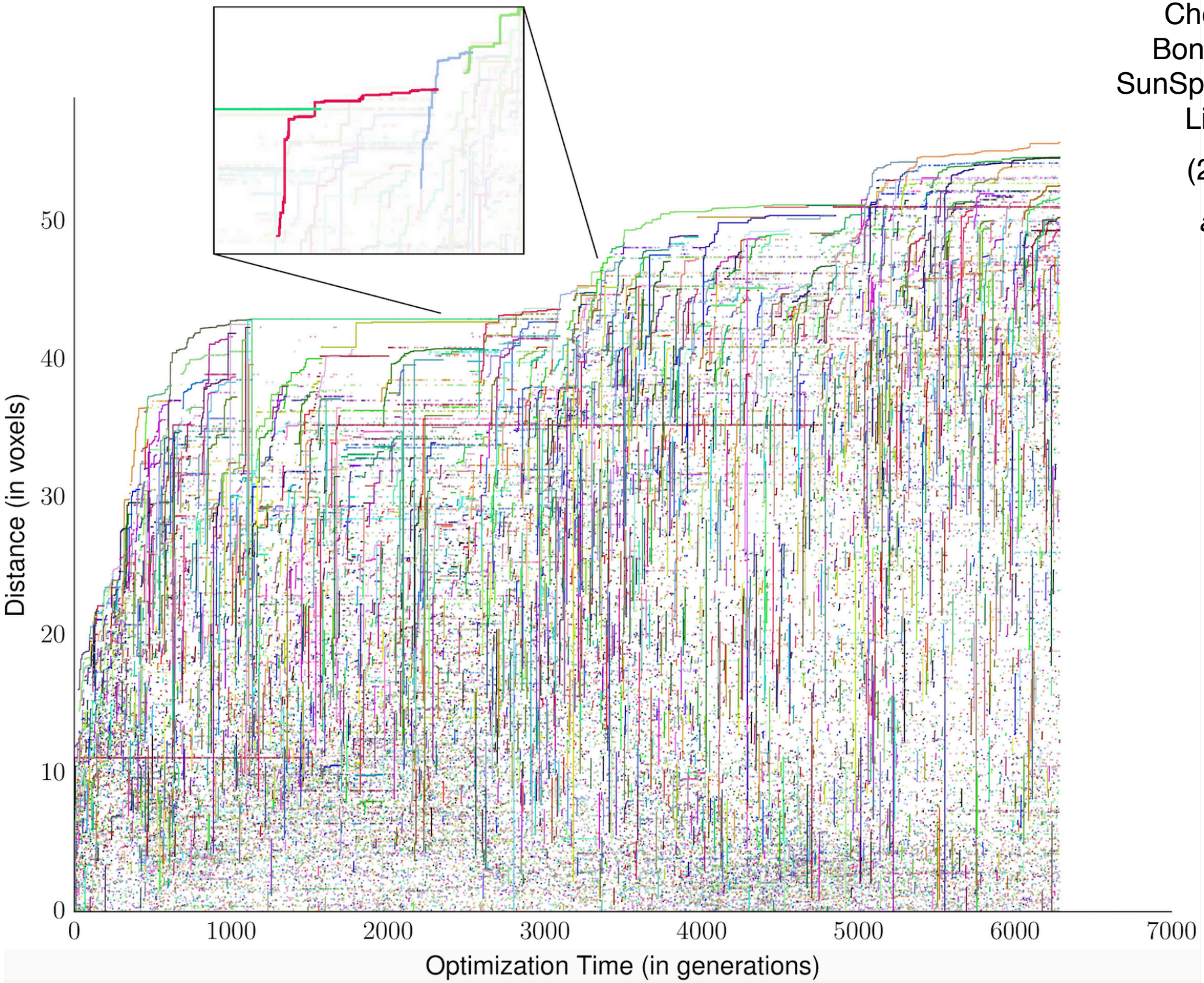


Cheney,
Bongard,
SunSpiral &
Lipson

(2017)

arXiv.

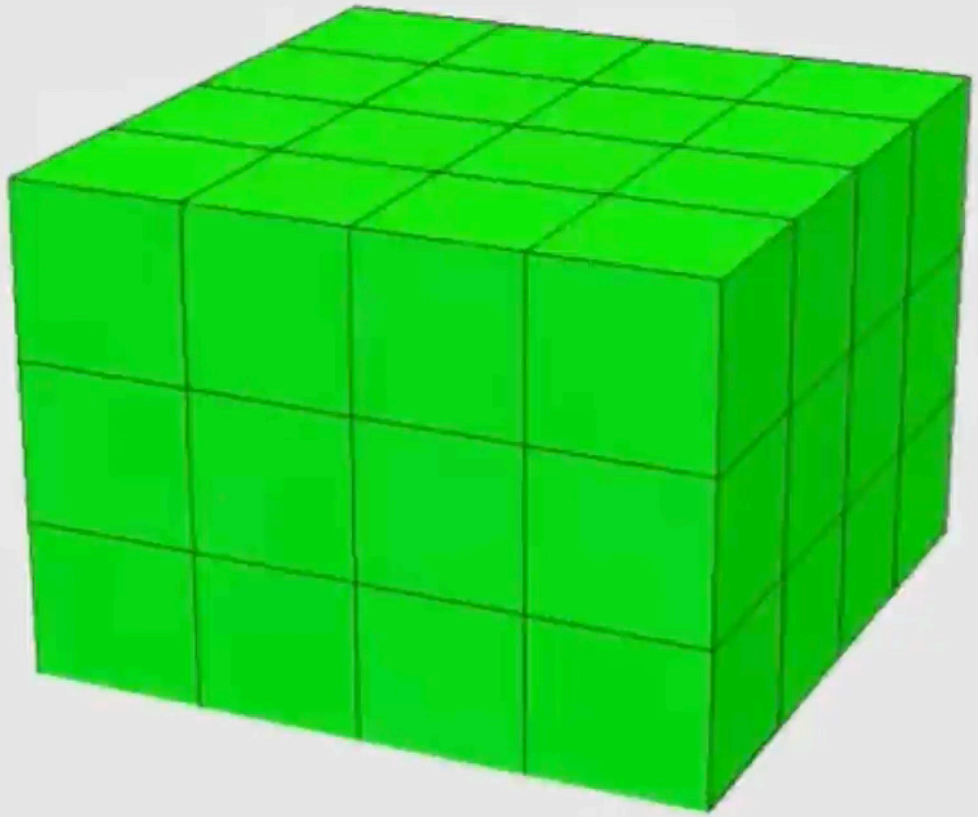




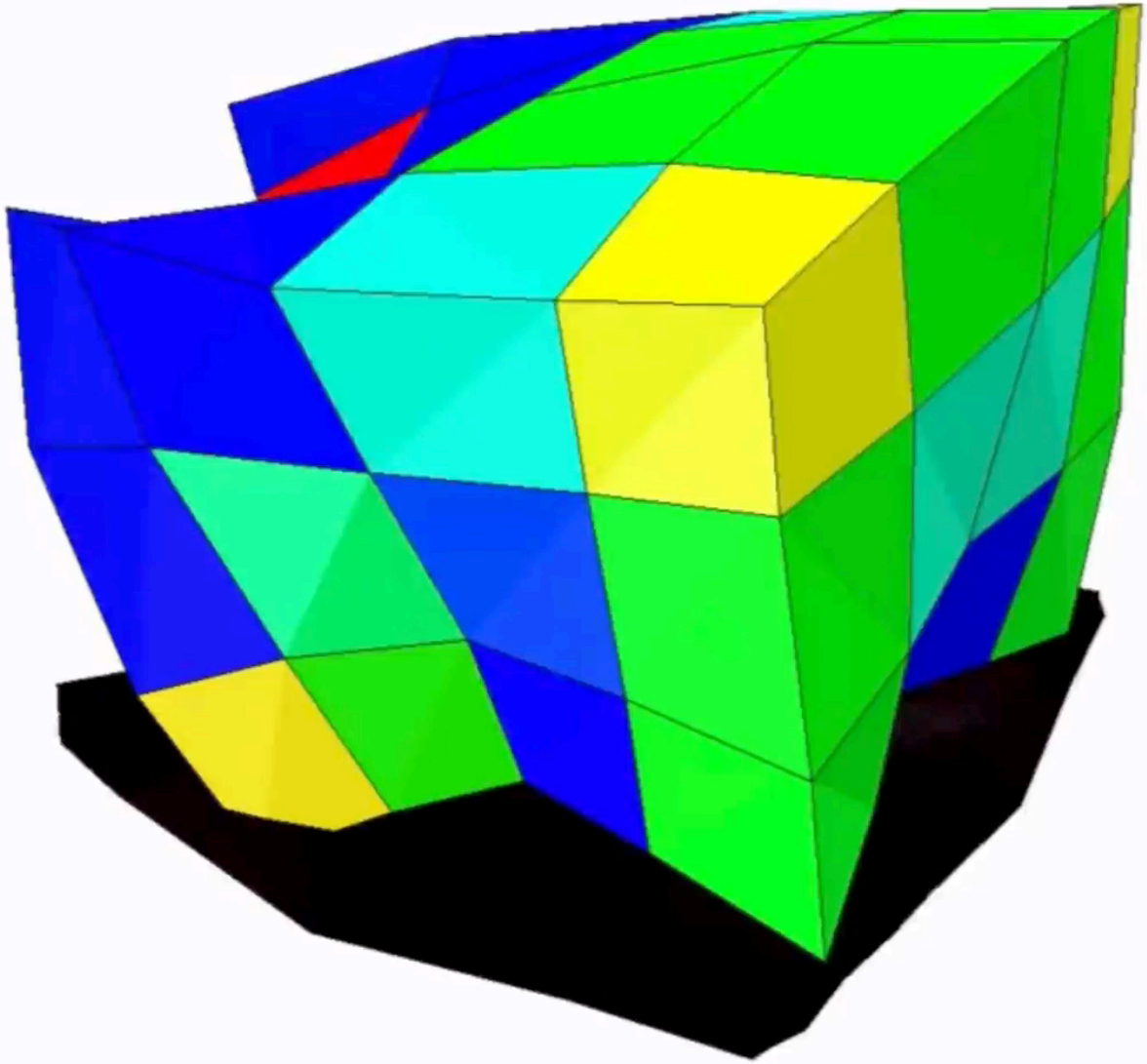
Cheney, Bongard, SunSpiral & Lipson

(2017)

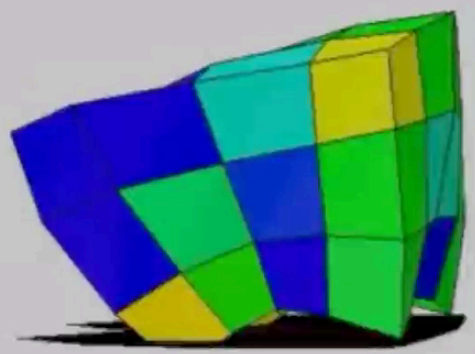
arXiv.

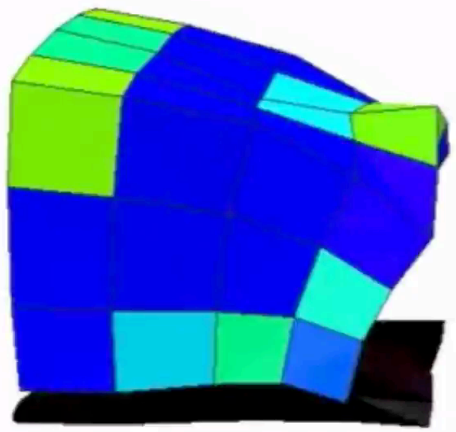


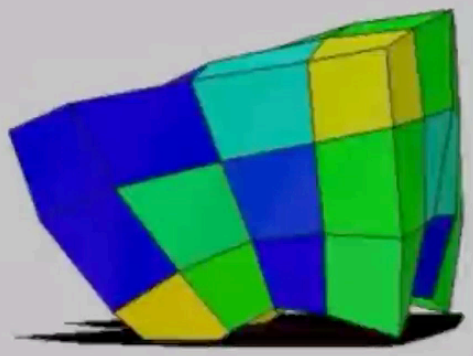
Kriegman et. al. 2017. A Minimal Developmental Model Can Increase Evolvability in Soft Robots. In *Proceedings of GECCO '17.*

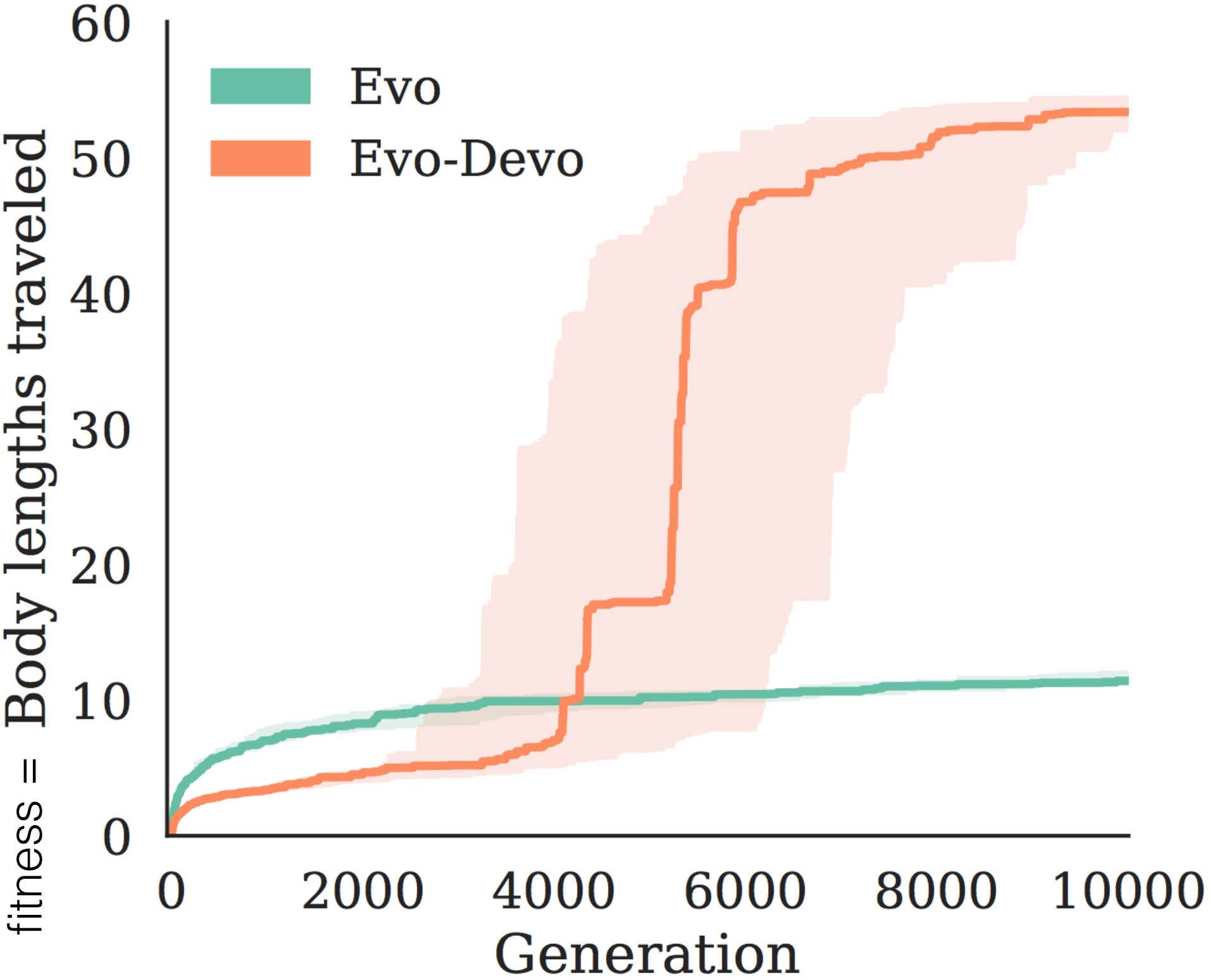


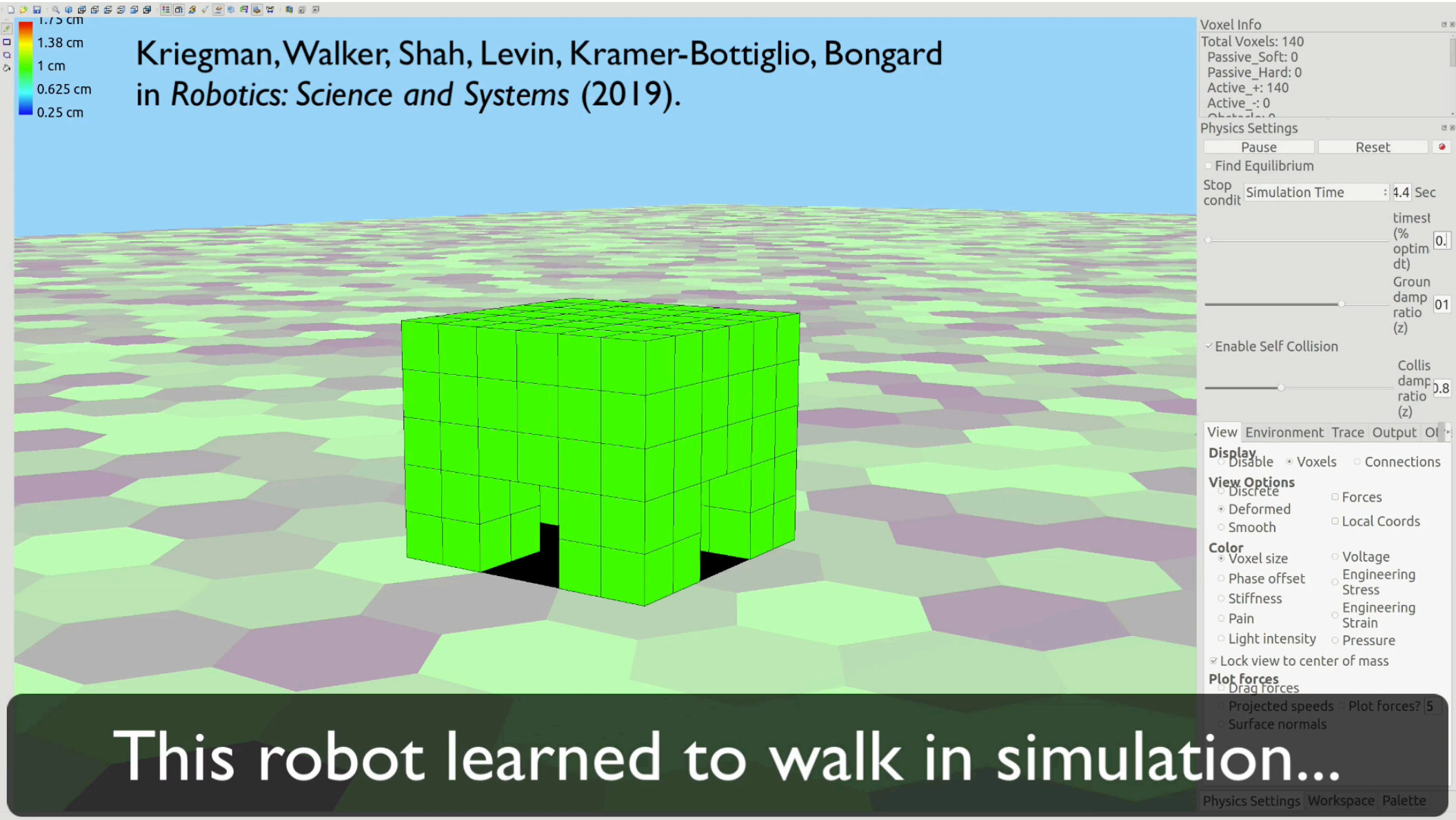
Kriegman et. al. 2017. A Minimal Developmental Model Can Increase Evolvability in Soft Robots. In *Proceedings of GECCO '17.*








Evo
Evo-Devo
fitness = Body lengths traveled
0
10
20
30
40
50
60
0
2000
4000
6000
8000
10000
Generation


1.38 cm
1 cm
0.625 cm
0.25 cm
Kriegman, Walker, Shah, Levin, Kramer-Bottiglio, Bongard
in *Robotics: Science and Systems* (2019).
Voxel Info
Total Voxels: 140
Passive_Soft: 0
Passive_Hard: 0
Active_+: 140
Active_-: 0
Physics Settings
Pause
Reset
Find Equilibrium
Stop condit
Simulation Time
4.4
Sec
timest (% optim dt)
Groun damp ratio (z)
Enable Self Collision
Collis damp ratio (z)
View
Environment
Trace
Output
Display
Disable
Voxels
Connections
View Options
Discrete
Deformed
Smooth
Forces
Local Coords
Color
Voxel size
Phase offset
Stiffness
Pain
Light intensity
Voltage
Engineering Stress
Engineering Strain
Pressure
Lock view to center of mass
Plot forces
Drag forces
Projected speeds
Plot forces?
Surface normals
Physics Settings
Workspace
Palette
This robot learned to walk in simulation...

Automated design: Evolving soft robots. (“Evo SoRo”)

Cheney, MacCurdy, Clune, & Lipson. (2013). *Procs. of the GECCO Conference.*

Automated design: Evolving soft robots. (“Evo SoRo”)

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Evolving regular patterns in space: CPPNs

Stanley (2007). *Procs. of the GECCO Conf*.

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Evolving morphology and control independently.

Cheney, Bongard, SunSpiral, Lipson (2017). *arXiv.*

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Evolving regular patterns in time: Evolving soft robots that develop (“Evo Devo SoRo”).

Kriegman *et al.* (2017). *Procs of the GECCO Conference*.

meclab.org

Automated design: Evolving soft robots. (“Evo SoRo”)

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Evolving regular patterns in time: Evolving soft robots that develop (“Evo Devo SoRo”).

Kriegman *et al.* (2017). *Procs of the GECCO Conference.*

Robots that shapeshift to recover from damage.

Kriegman et al. (2019). Procs of Robotics: Science and Systems Conf.