Evolutionary computing: examples and trends

5.101 Going beyond Sims

Summary

- Hard body robots → real robots
- Soft body robots
- Soft body robots → real robots
- Anecdotes of artificial evolution’s creativity

Evolving and manufacturing hard body robots 2000

Lipson, H., & Pollack, J. B. (2000). Automatic design and manufacture of robotic lifeforms. Nature, 406(6799), 974-978.

Evolving and manufacturing hard body robots 2000

Population size: 200, evolved for 300-600 generations

Encoding: "A robot was represented by a string of integers and floating-point numbers that describe bars, neurons and their connectivity"

Fitness function0: distance moved in simulation. Eventually fit individuals realised via 3D printing, with stepper motors and a microcontroller added

Evolving and manufacturing soft body robots 2012

J. Hiller and H. Lipson, "Automatic Design and Manufacture of Soft Robots," in IEEE Transactions on Robotics, vol. 28, no. 2, pp. 457-466, April 2012, doi: 10.1109/TRO.2011.2172702.

Evolving soft body robots: 2014

Cheney, N., MacCurdy, R., Clune, J., & Lipson, H. (2014). Unshackling evolution: evolving soft robots with multiple materials and a powerful generative encoding. ACM SIGEVOlution, 7(1), 11-23.

Evolving soft body robots: 2014

Encoding:

Robots made out of deformable voxels using 3 types of material
Material is ‘sprayed’ into a structure by an evolved network (a compositional pattern producing network)

Fitness function:
Robots run in a VoxCAD soft-body physics engine

Evolving and manufacturing shape shifting soft body robots 2021

Shah, D. S., Powers, J. P., Tilton, L. G., Kriegman, S., Bongard, J., & Kramer-Bottiglio, R. (2021). A soft robot that adapts to environments through shape change. Nature Machine Intelligence, 3(1), 51-59.

Arcticle covering many interesting examples of a-life

Lehman, Joel, Jeff Clune, Dusan Misevic, Christoph Adami, Lee Altenberg, Julie Beaulieu, Peter J. Bentley et al. "The surprising creativity of digital evolution: A collection of anecdotes from the evolutionary computation and artificial life research communities." Artificial life 26, no. 2 (2020): 274-306.

Summary

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5.103 State of the art for GAs

Summary

- Evolving neural networks
- Evolving programs
- Trends: benchmarks

GA for neural network design NEAT/ CoDEEPNEAT

Miikkulainen, Risto, et al. "Evolving deep neural networks." Artificial intelligence in the age of neural networks and brain computing. Academic Press, 2019. 293-312.

https://arxiv.org/pdf/1703.00548/

Why automatic design of neural network architectures?

Reaching the limits of human design of networks

Can potentially come up with much simpler (more efficient?) designs

Very computationally expensive to evolve the betwork, but resulting network might be smaller than the human designed one

Encoding and fitness

NEAT:

Chromosones represent neurons in a network

DeepNEAT:

Chromosones represent layers of neurones e.g. fully connected layer,

To assign fitness, generate the neural network, train it for several epochs then test its performance on a specific task (supervised task)

Are the evolved networks competitive to human designs?

“the results show that the approach discovers designs that are comparable to the state of the art, and does it automatically with- out much development effort” – Miikkulainen et al. 2019

Designing software

J. Petke, S. O. Haraldsson, M. Harman, W. B. Langdon, D. R. White and J. R. Woodward, "Genetic Improvement of Software: A Comprehensive Survey," in IEEE Transactions on Evolutionary Computation, vol. 22, no. 3, pp. 415-432, June 2018, doi: 10.1109/TEVC.2017.2693219.

Benchmarks and competitions

Molina, Daniel, Antonio LaTorre, and Francisco Herrera. "An insight into bio-inspired and evolutionary algorithms for global optimization: review, analysis, and lessons learnt over a decade of competitions." Cognitive Computation 10.4 (2018): 517-544.

E.g.

Summary

- Evolving neural networks
- Evolving programs
- Trends: benchmarks