CS254: Genetic Programming

Lee Spector

Agenda

- Introductions: you and me
- Genetic Programming
- Syllabus (course description, assignments, etc.)
- Homework

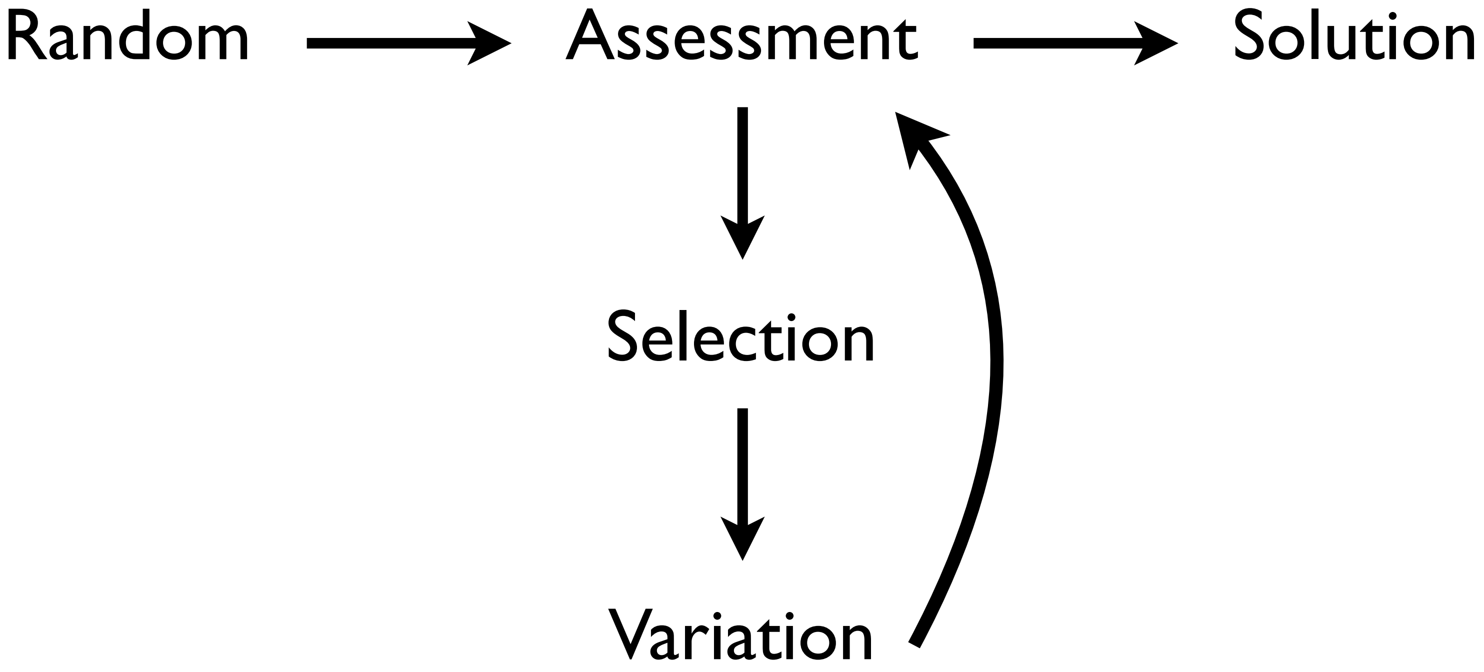
You

- Name
- Pronouns
- Institution, year
- Registration status
- Computer science experience
- Evolutionary biology experience

Me

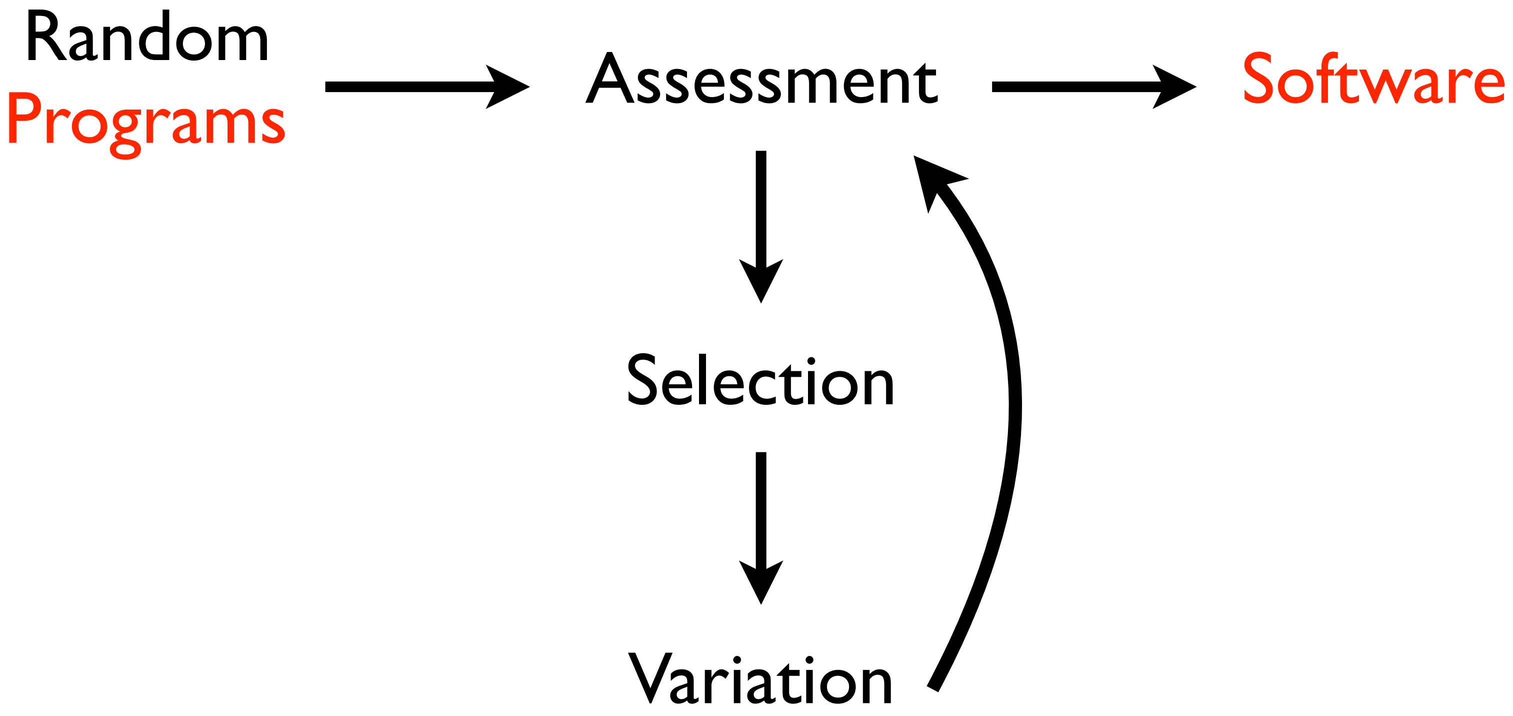
- B.A. Oberlin philosophy, TIMARA
- Ph.D. UMD computer science, artificial intelligence
- NIH/NINDS planning in the brain
- Hampshire:
  - Cognitive Science
  - DART: Design, Art & Technology
  - Quantum computing
  - Computational Intelligence Lab
  - High-Performance Computing Cluster
- Adjunct Prof @ UMass
- Executive committee of ACM SIGEVO
- Editor of *Genetic Programming and Evolvable Machines*

Evolutionary Computation



Evolving Lego Bridges

Genetic Programming



Random Programs

Assessment

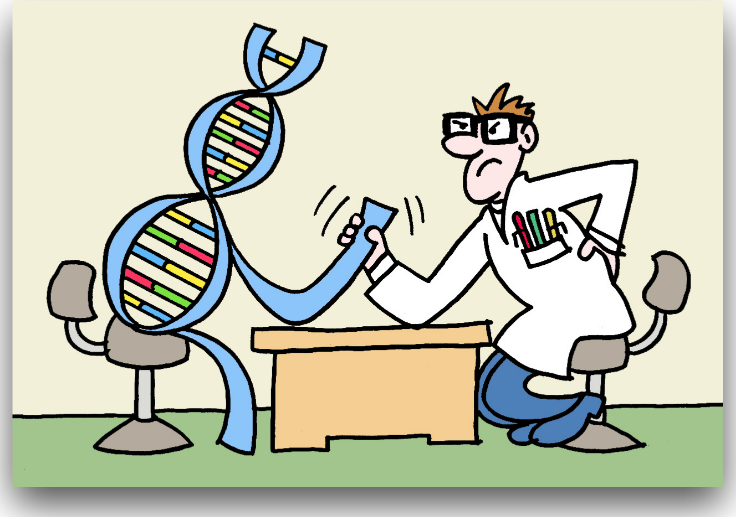
Software

Selection

Variation

Analyzing a Decade of Human-Competitive (“HUMIE”) Winners: What Can We Learn?

Karthik Kannappan, Lee Spector, Moshe Sipper, Thomas Helmuth, William Lacava, Jake Wisdom, Omri Bernstein



- Competition for evolutionary computation results
- Up to $10,000 in cash prizes
- Held annually since 2004

Humies Criteria

- The result was **patented as an invention** in the past is an improvement over a patented invention or would qualify today as a patentable new invention.
- The result is equal to or better than a result that was accepted as a **new scientific result** at the time when it was published in a peer-reviewed scientific journal.
- The result is equal to or better than a result that was placed into a database or archive of results maintained by an **internationally recognized panel of scientific experts**.
- The result is **publishable in its own right** as a new scientific result independent of the fact that the result was mechanically created.
- The result is equal to or better than the **most recent human-created** solution to a long-standing problem for which there has been a succession of increasingly better human-created solutions.
- The result is equal to or better than a result that was considered an **achievement in its field** at the time it was first discovered.
- The result solves a problem of **indisputable difficulty** in its field.
- The result holds its own or wins a regulated **competition involving human contestants** (in the form of either live human players or human-written computer programs).

Humies Winners

- Application areas: antennas, biology, chemistry, computer vision, electrical engineering, electronics, games, image processing, mathematics, mechanical engineering, medicine, operations research, optics, optimization, photonics, physics, planning, polymers, quantum computing, security, software engineering
- Winningest technique: genetic programming
- Winningest problem type: design

Yavalath

Yavalath is an abstract board game for two or three players, invented by a computer program called Ludi. It has an easy rule set that any player can pick up immediately, but which produces surprisingly tricky emergent play.

Yavalath is available from nestorgames, making it the first — and still only — computer-generated game to be commercially published, together with its sister game Pentalath.

In October 2011, Yavalath was ranked in the top #100 abstract board games ever invented on the BoardGameGeek database. This helped it win the GECCO "Humies" gold medal for human-competitive results in evolutionary computation for 2012.

Here is a Yavalath article in the November 2013 issue of Bitcoin magazine.

Rules

The board starts empty.

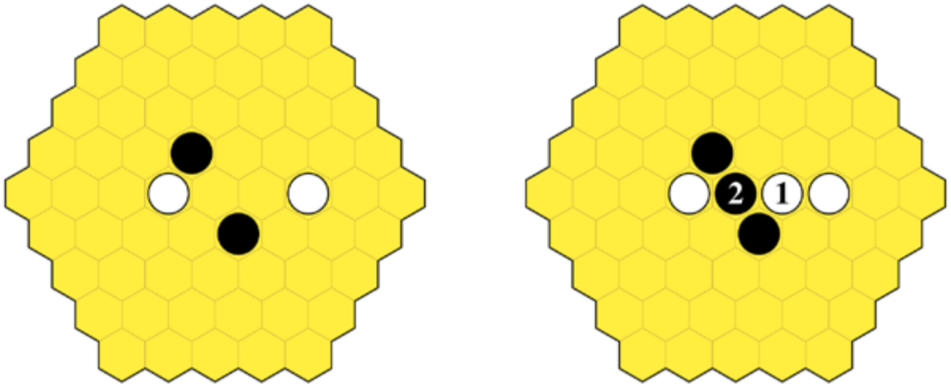
Two players take turns adding a piece of their colour to an empty cell.

Win by making a line-of-4 (or more) pieces of your colour.
Lose by making a line-of-3 pieces of your colour beforehand.
Draw if the board otherwise fills up.

No, players are not allowed to pass.

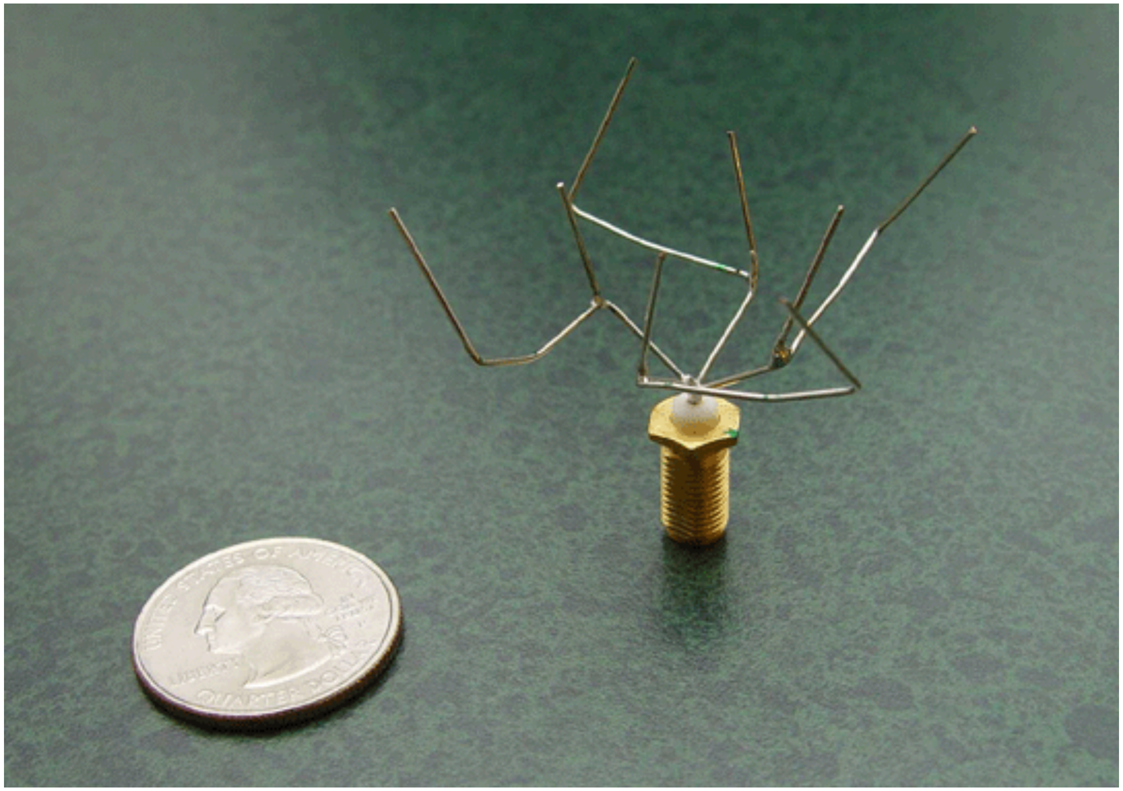
Tactics and Strategy

The key tactical play in Yavalath is the *forcing move*, as shown below. White move **1** forces Black to lose with the blocking move **2**.



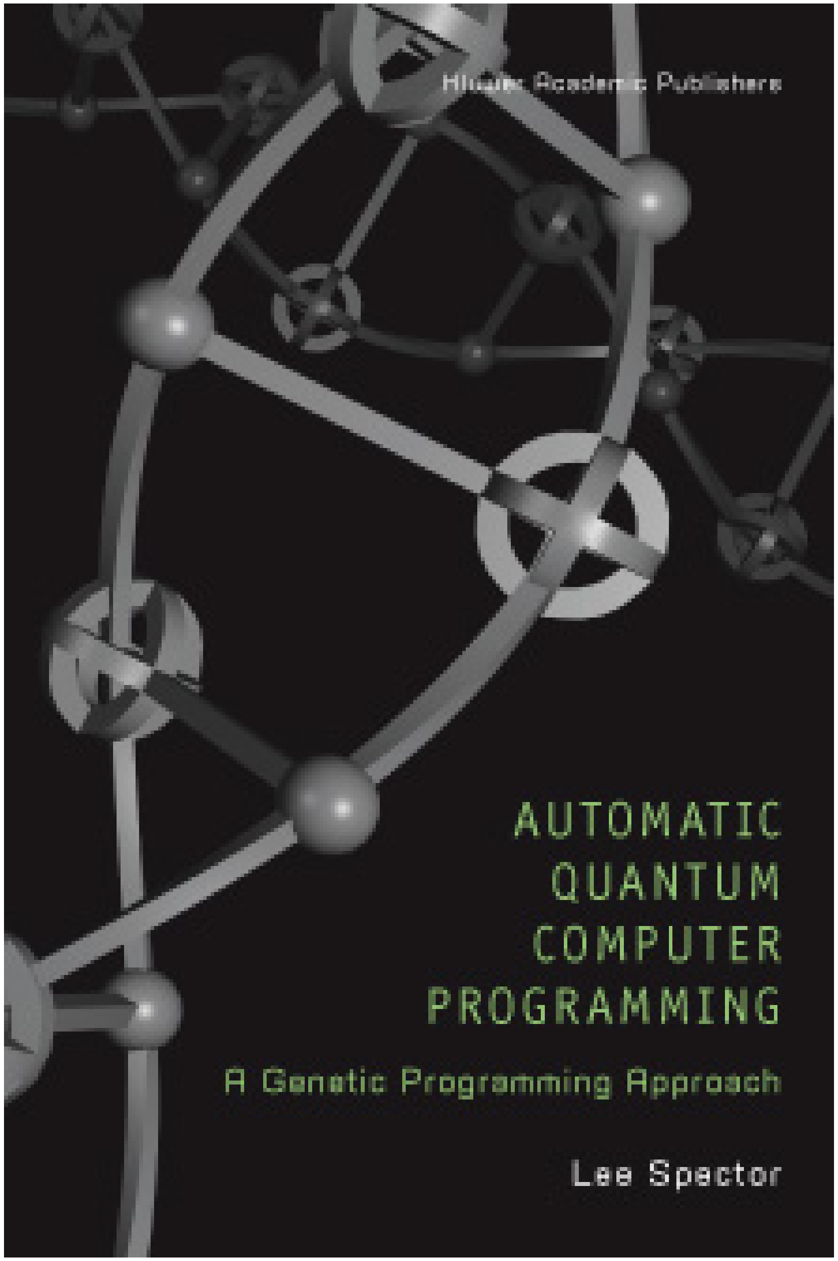
Humies Gold Medal, 2012

Evolved Antenna



NASA Space Technology 5 Mission, Lohn, Hornby, and Linden

Humies Gold Medal, 2004



Kluwer Academic Publishers

AUTOMATIC QUANTUM COMPUTER PROGRAMMING

A Genetic Programming Approach

Lee Spector

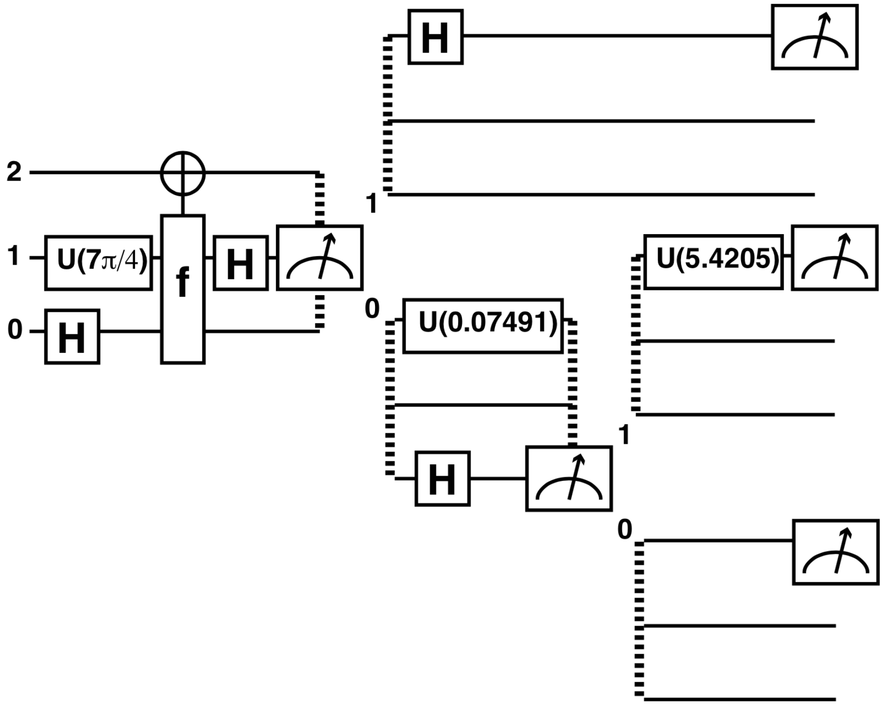


Figure 8.11. A gate array diagram for an evolved solution to the AND/OR oracle problem. The gate marked "f" is the oracle. The sub-diagrams on the right represent the possible execution paths following the intermediate measurements.

Humies Gold Medal, 2004

Genetic Programming for Finite Algebras

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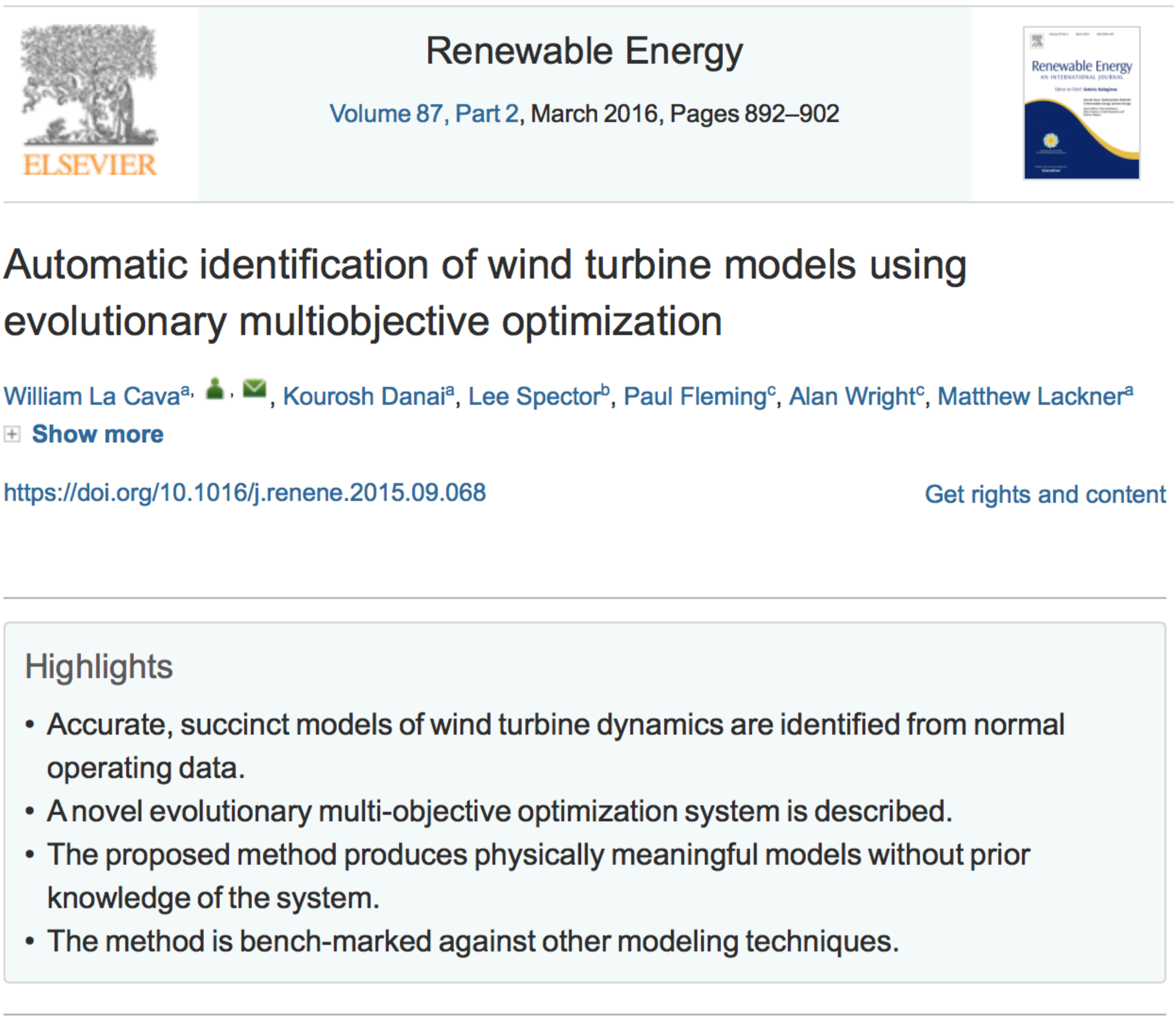
$$((((((((x*(y*x))*x)*z)*(z*x))*((x*(z*(x*(z*y))))*z))*$$
$$z)*z)*(z*((((x*(((z*z)*x)*(z*x)))*x)*y)*(((y*(z*(z*$$
$$y)))*(((y*y)*x)*z))*(x*(((z*z)*x)*(z*(x*(z*y)))))))))$$

Humies Gold Medal, 2008



Renewable Energy

Volume 87, Part 2, March 2016, Pages 892–902

Automatic identification of wind turbine models using evolutionary multiobjective optimization

William La Cava[a], Kourosh Danai[a], Lee Spector[b], Paul Fleming[c], Alan Wright[c], Matthew Lackner[a]

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https://doi.org/10.1016/j.renene.2015.09.068

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Highlights

- Accurate, succinct models of wind turbine dynamics are identified from normal operating data.
- A novel evolutionary multi-objective optimization system is described.
- The proposed method produces physically meaningful models without prior knowledge of the system.
- The method is bench-marked against other modeling techniques.

Genetic programming representations for multi-dimensional feature learning in biomedical classification

William La Cava[1], Sara Silva[2,3], Leonardo Vanneschi[4], Lee Spector[5], and Jason Moore[1]

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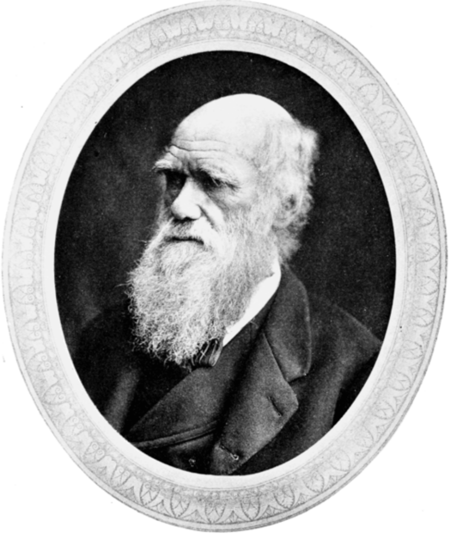
Abstract. We present a new classification method that uses genetic programming (GP) to evolve feature transformations for a deterministic, distanced-based classifier. This method, called M4GP, differs from common approaches to classifier representation in GP in that it does not enforce arbitrary decision boundaries and it allows individuals to produce multiple outputs via a stack-based GP system. In comparison to typical methods of classification, M4GP can be advantageous in its ability to produce readable models. We conduct a comprehensive study of M4GP, first in comparison to other GP classifiers, and then in comparison to six common machine learning classifiers. We conduct full hyper-parameter optimization for all of the methods on a suite of 16 biomedical data sets, ranging in size and difficulty. The results indicate that M4GP outperforms other GP methods for classification. M4GP performs competitively with other machine learning methods in terms of the accuracy of the produced models for most problems. M4GP also exhibits the ability to detect epistatic interactions better than the other methods.

Keywords: genetic programming, feature learning, classification

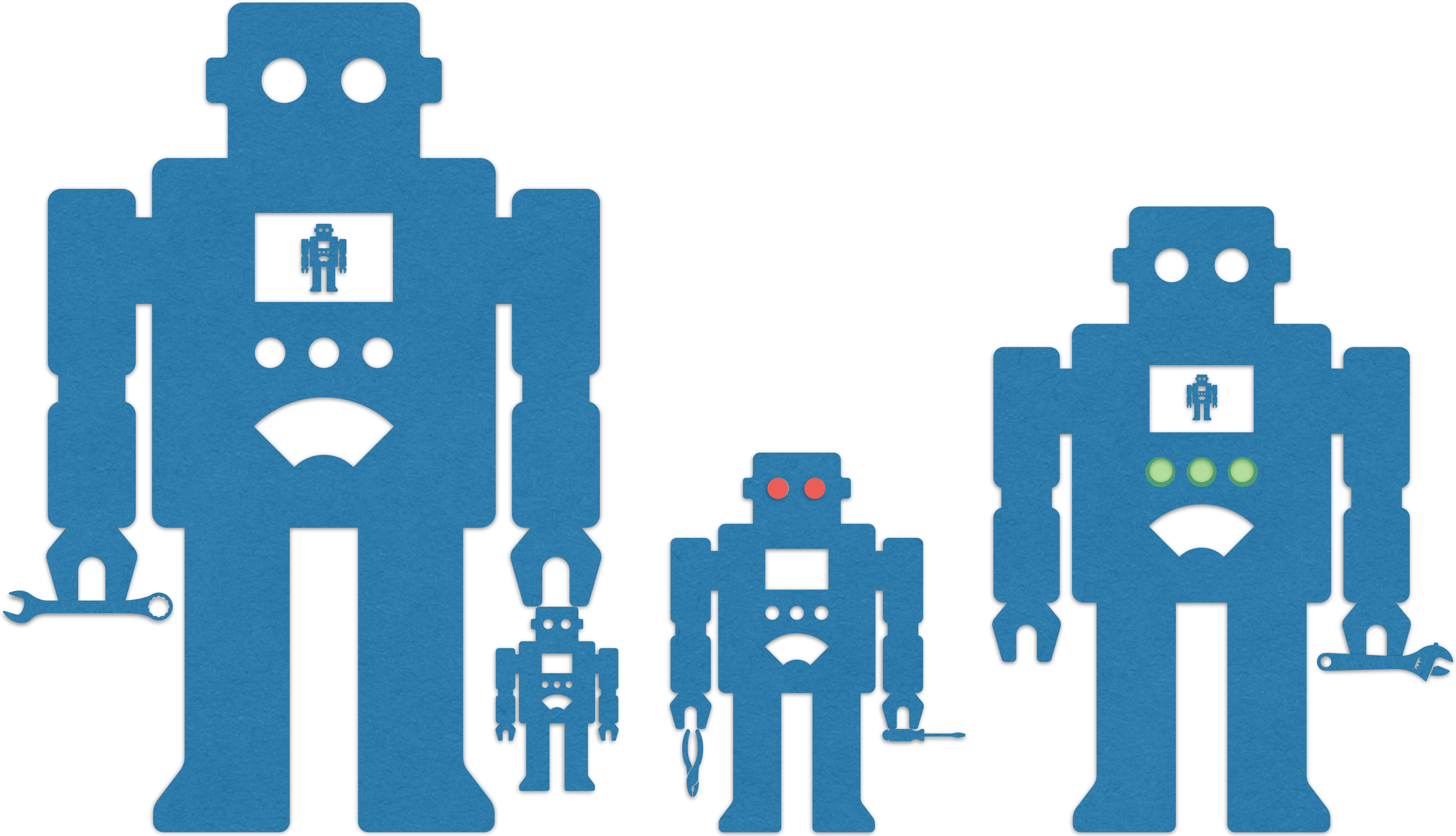
Intro Programming

Number IO, Small or Large, For Loop Index, Compare String Lengths, Double Letters, Collatz Numbers, Replace Space with Newline, String Differences, Even Squares, Wallis Pi, String Lengths Backwards, Last Index of Zero, Vector Average, Count Odds, Mirror Image, Super Anagrams, Sum of Squares, Vectors Summed, X-Word Lines, Pig Latin, Negative to Zero, Scrabble Score, Word Stats, Checksum, Digits, Grade, Median, Smallest, Syllables

Tests

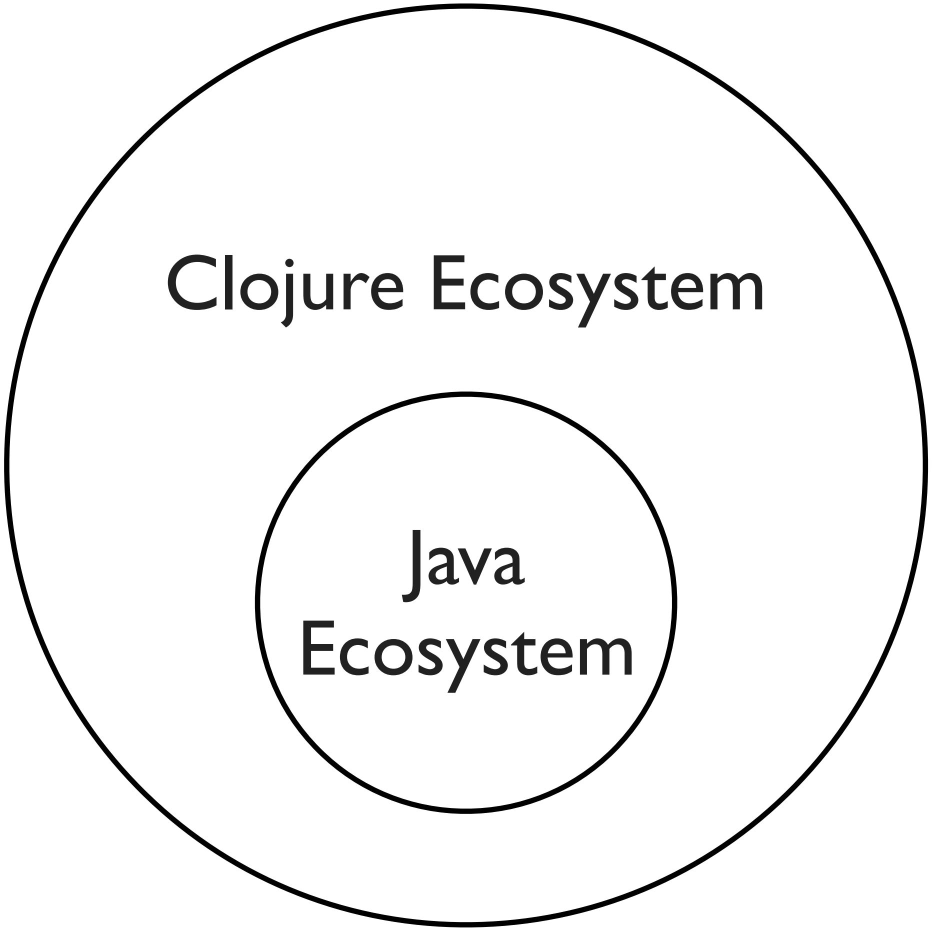


Software



Clojure

- Modern, growing, practical, jobs
- Functional, flexible, powerful, concise
- Lisp's history/tools/concepts re: AI



Syllabus/Homework

moodle