Automating Algorithm Design through Genetic Programming Hyper-Heuristicss

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What does the title mean?

- Reducing the human component in algorithm design

https://scratch.mit.edu/discuss/m/topic/200574/

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- More work at the beginning, more possibilities

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What does the title mean?

- Reducing the human component in algorithm design
- More work at the beginning, more possibilities
- Genetic programming hyper-heuristics as a method to the madness

https://scratch.mit.edu/discuss/m/topic/200574/

Outline

1. Background
2. Hyper-heuristics
3. Genetic Programming Variants
4. Autoconstruction
5. Summary

Outline

1. **Background**
   - Evolutionary Computation
   - Genetic Programming
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Evolutionary Computation

https://www.spigotmc.org/attachments/evolution-jpg.137048/

- Subfield of Artificial Intelligence

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- Subfield of Artificial Intelligence
- Algorithms based on biological evolution

Evolutionary Computation

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- Subfield of Artificial Intelligence
- Algorithms based on biological evolution
- Uses lots of terminology from biology, doesn't always mean same thing as term means in biology.

Evolutionary Computation – Terminology

- **Individual** – a potential solution to a problem (or set of problems)

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- **Fit** – how well suited an individual is at solving a problem

- **Fitness Test** – a set of tests to determine how fit an individual is.

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- **Generation** – a population of individuals
- **Global optima** – best solution (or solutions) possible

Evolutionary Computation – Terminology

If individual A experiences a mutation to create individual B, then:

Evolutionary Computation – Terminology

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- **Parent** – Individual A

Evolutionary Computation – Terminology

If individual A experiences a mutation to create individual B, then:

- **Parent** – Individual A
- **Child** – Individual B

Genetic Programming

A family of algorithms in Evolutionary Computation that uses biological techniques to create programs to solve computational problems.

Genetic Programming

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2. Hyper-heuristics
   - Heuristics
   - Metaheuristics
   - Hyper-heuristics
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Heuristics

Heuristics – a function that ranks alternatives in a search algorithm at each branching step and uses that information to choose which branch to follow.

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https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

Metaheuristic

Metaheuristic – a heuristic that does not require knowledge about the problem and is not problem specific

Heuristics and Metaheuristics

Hyper-heuristics

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Genetic programming hyper-heuristics – hyper-heuristics that use genetic programming for the process of selecting, generating, or adapting several simpler heuristics.

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3. **Genetic Programming Variants**
   - What are they?
   - Why should we care?
   - Stack-based genetic programming
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Genetic programming variants

GP variants – variations on the structure and setup of a genetic programming system.

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GP variants tested:

- Cartesian GP
- Linear GP
- Stack-based GP
- Tree-based GP
- Grammatical Evolution

Why should we care?

Graph taken from Harris et al. [1]

Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

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Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

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(1 2 integer_equal)
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4. **Autoconstruction**
   - What is it?
   - AutoDoG
   - Results of AutoDoG
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What is Autoconstruction?

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- Autoconstruction is a type of genetic programming hyper-heuristic (GPHH)
- In most GPHH, the individual programs are evolving, but everything else is specified by the engineer; in autoconstruction, evolution is evolving as well.
- Programs are responsible for evolving solutions *and* responsible for evolving their offspring.

AutoDoG

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- Uses Plush, a linear genome format for Push

AutoDoG – reproduction

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Mom

Dad

AutoDoG – reproduction

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Now Child moves on to the next generation, right?

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WRONG!

AutoDoG – diversification test

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Results of AutoDoG

AutoDoG has solved Replace Space with New Line (RSWN).

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RSWN: given a string S, print S with all spaces replaced with new lines and return the integer count of all non-whitespace characters.

Results of AutoDoG

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This is actually really impressive!

Results of AutoDoG

Graphs taken from Spector et al. [2]

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Summary

- Genetic programming hyper-heuristics (GPHH) for heuristic/program evolution
- There are many types of GP variants, and the variant chosen may affect the success of the hyper-heuristic
- Autoconstruction is a type of GPHH
- AutoDoG is a newer autoconstructive system that uses stack-based GP and has had recent success in the field of automating algorithm design
- AutoDoG/autoconstruction is special because evolution is evolving

Summary

This may drastically change the way we program in the future!

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See my paper for additional references.

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Thanks for coming!