

Automating Algorithm Design through Genetic Programming Hyper-Heuristics

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April 15, 2017
Morris, MN

What does the title mean?

- Reducing the human component in algorithm design



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

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- Reducing the human component in algorithm design
- 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



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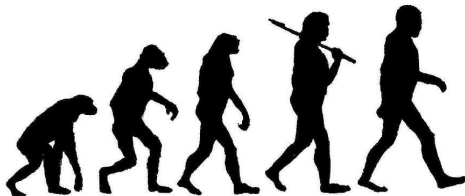
Outline

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

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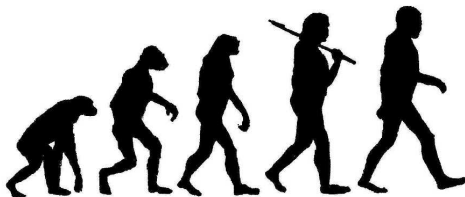
Evolutionary Computation



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

- Subfield of Artificial Intelligence

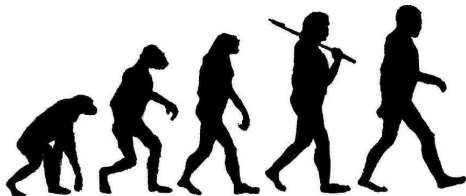
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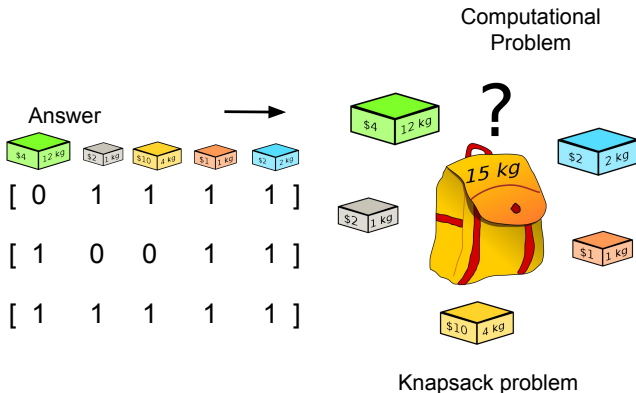
- Subfield of Artificial Intelligence
- Algorithms based on biological evolution

Evolutionary Computation



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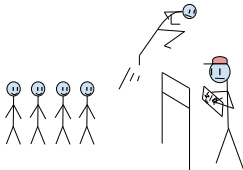
- Subfield of Artificial Intelligence
- Algorithms based on biological evolution
- Uses lots of terminology from biology, doesn't always mean same thing as term means in biology.



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

Evolutionary Computation – Terminology

- **Individual** – a potential solution to a problem (or set of problems)
- **Population** – a group of individuals
- **Fit** – how well suited an individual is at solving a problem
- **Fitness Test** – a set of tests to determine how fit an individual is.



Evolutionary Computation – Terminology

- **Mutation** – an insertion, deletion, or small change in an individual, creating a new individual
- **Sexual reproduction** – when two or more individuals are munged together to create a new individual

Evolutionary Computation – Terminology

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

- **Parent** – Individual A



- **Child** – Individual B



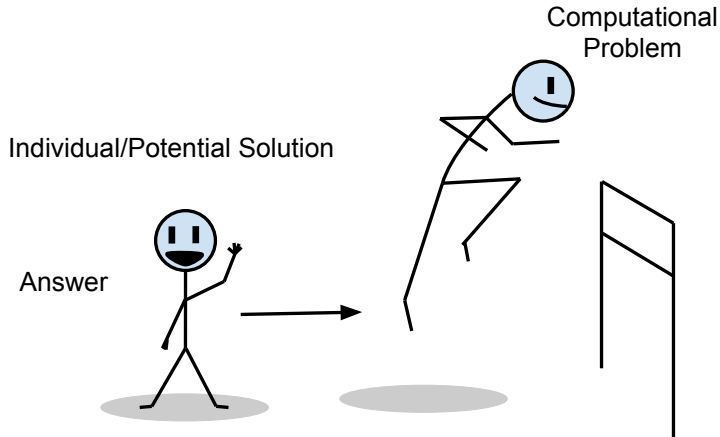
Evolutionary Computation – Terminology

- **Generation** – a population of individuals
- **Global optima** – best solution (or solutions) possible
- **Stopping point** – time limit, or generation limit.

Genetic Programming

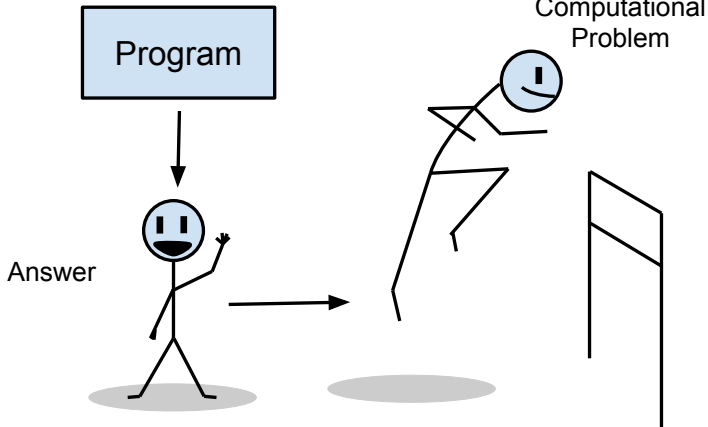
A family of algorithms in Evolutionary Computation that uses biological techniques to create programs to solve computational problems.

Genetic Programming



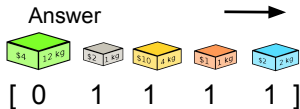
Genetic Programming

Individual/Potential Solution

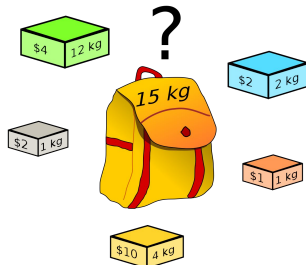


Genetic Programming

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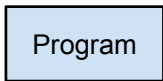
Computational Problem



Knapsack problem

Genetic Programming

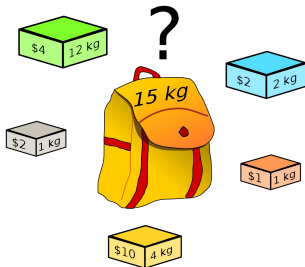
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Answer



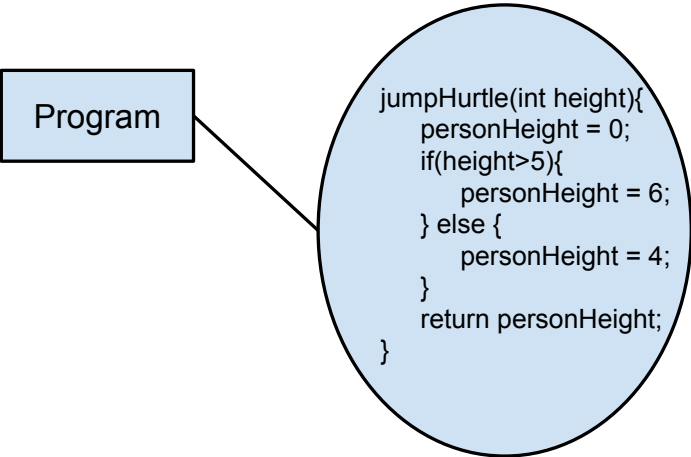
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Knapsack problem

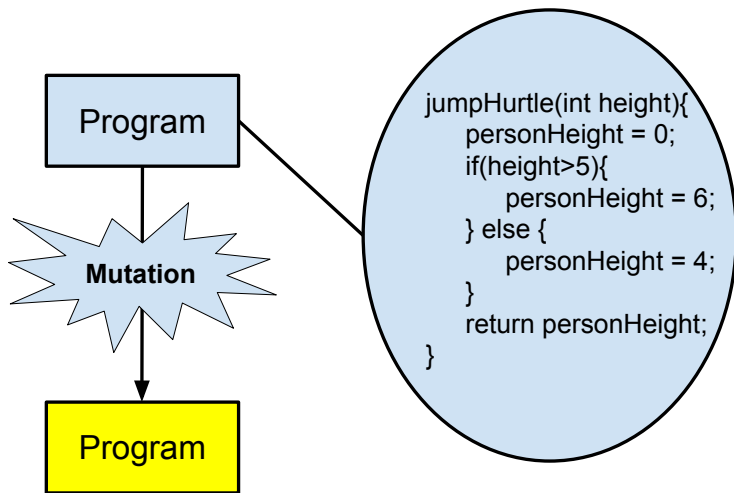
Genetic Programming

Program

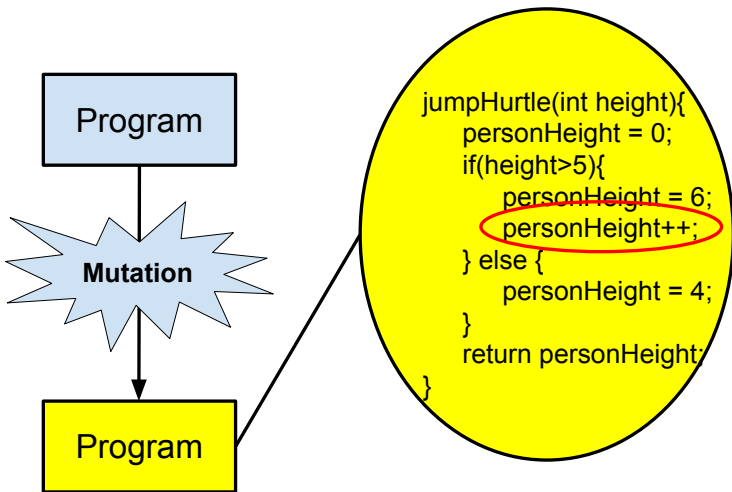


```
jumpHurtle(int height){  
    personHeight = 0;  
    if(height>5){  
        personHeight = 6;  
    } else {  
        personHeight = 4;  
    }  
    return personHeight;  
}
```

Genetic Programming



Genetic Programming



Outline

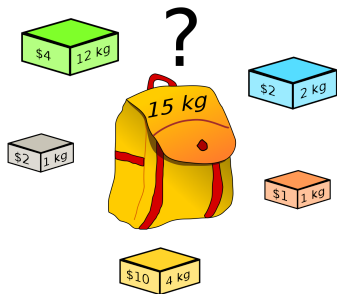
- 1 Background
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 - Heuristics
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Heuristics

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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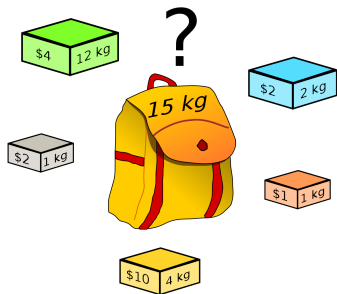


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Heuristics

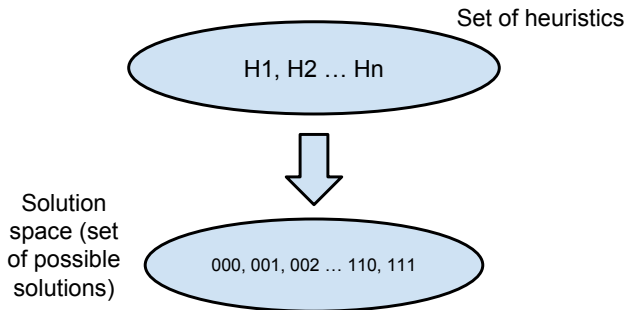
Heuristics – a function that ranks alternatives in a search algorithm at each branching step and uses that information to choose which branch to follow.

Example: “Select highest valued item and put into knapsack. If item puts knapsack overweight, select next highest value instead. Repeat until all items are gone or until the knapsack is full”

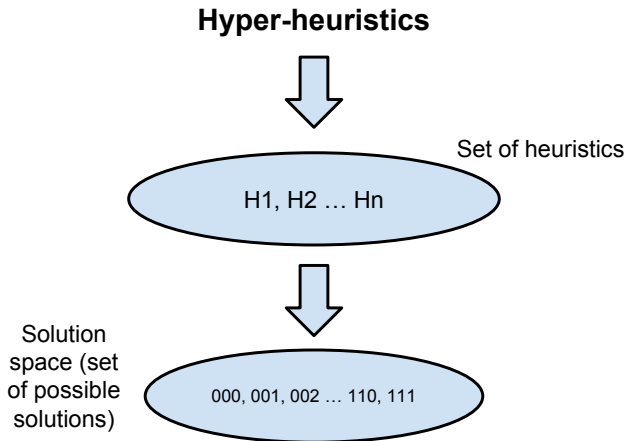


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Heuristics



Hyper-heuristics



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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 - 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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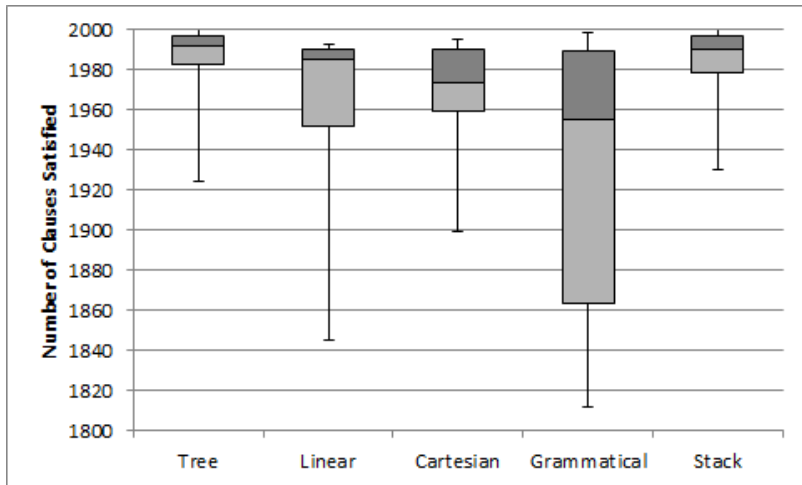
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GP variants tested:

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

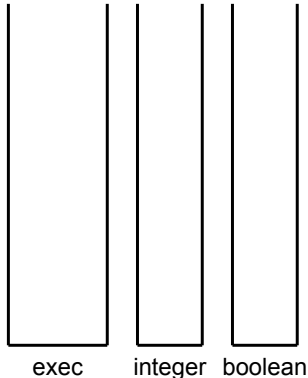
Why should we care?



Graph taken from Harris et al. [1]

Stack-based genetic programming

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

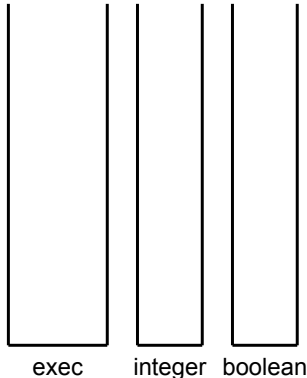


Stack-based genetic programming

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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 integer_add 2 integer_equal)
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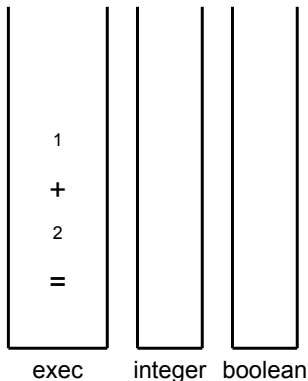


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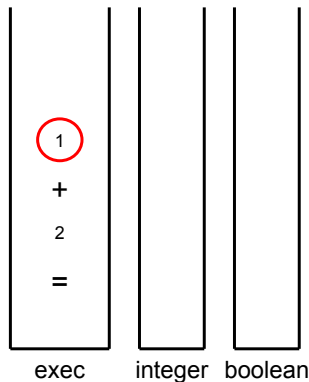


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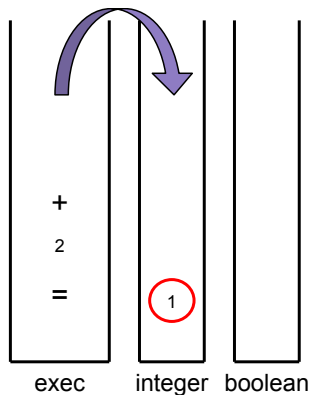


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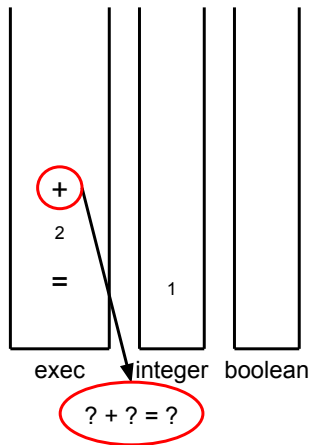


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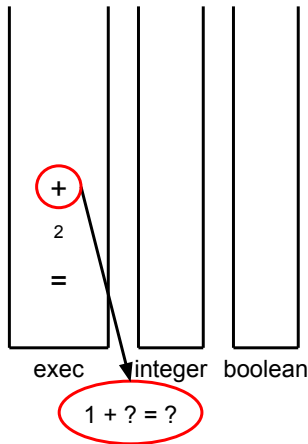


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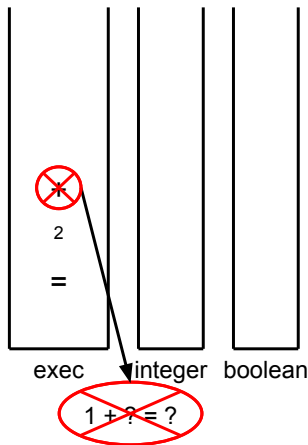


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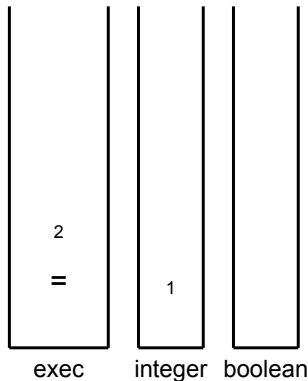


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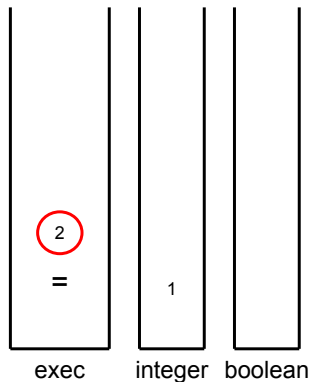


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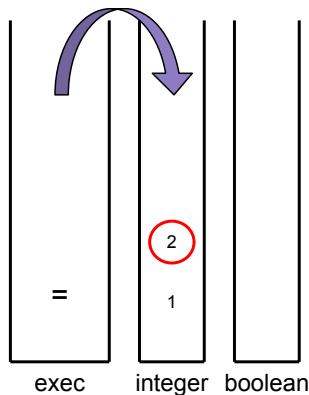


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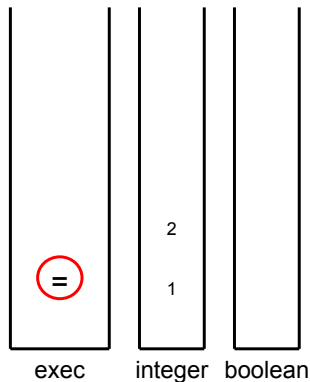


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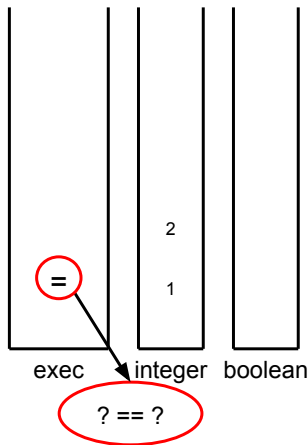


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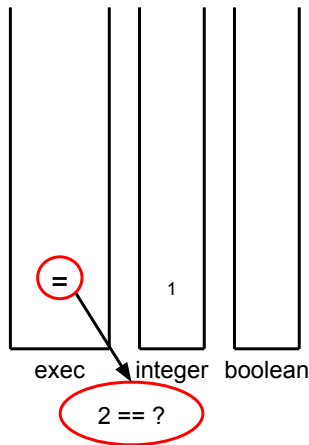


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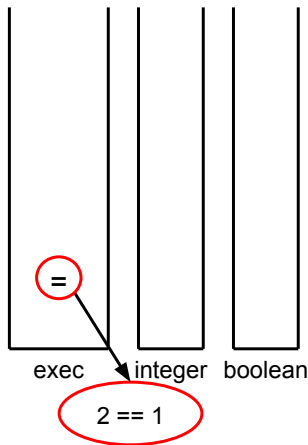


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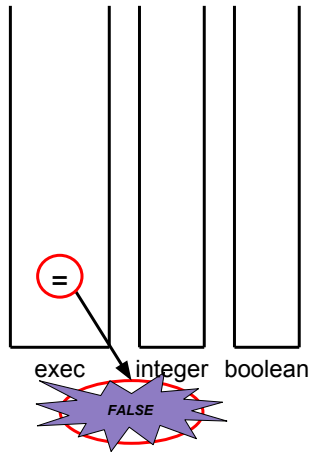


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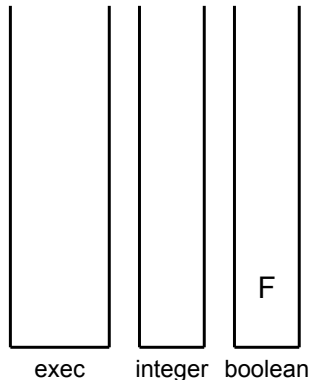


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 - What is it?
 - AutoDoG
 - Results of AutoDoG
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What is Autoconstruction?

- Autoconstruction is a type of genetic programming hyper-heuristic (GPHH)

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- In most GPHH, the individual programs are evolving, but everything else is specified by the engineer; in autoconstruction, evolution is evolving as well.

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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 constructing their offspring.

AutoDoG

- A system designed by Spector et al. [2] that uses autoconstruction to evolve programs.

AutoDoG

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- Uses the Push programming language

AutoDoG

- A system designed by Spector et al. [2] that uses autoconstruction to evolve programs.
- Uses the Push programming language
- Uses Plush, a linear genome format for Push

AutoDoG – reproduction

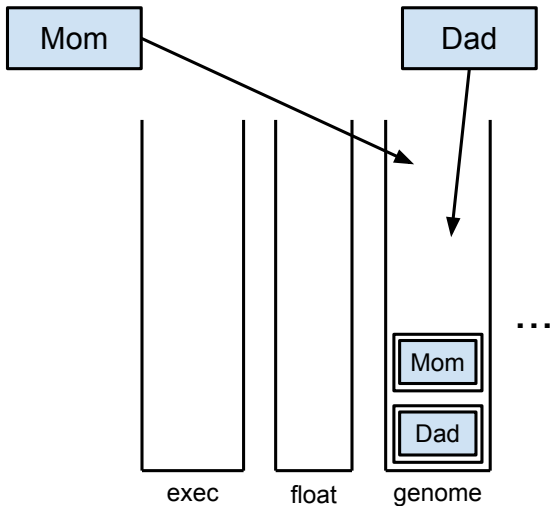
Mom

AutoDoG – reproduction

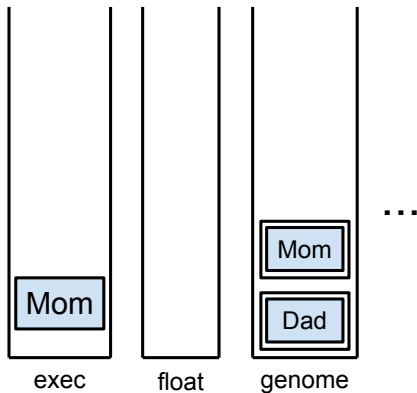
Mom

Dad

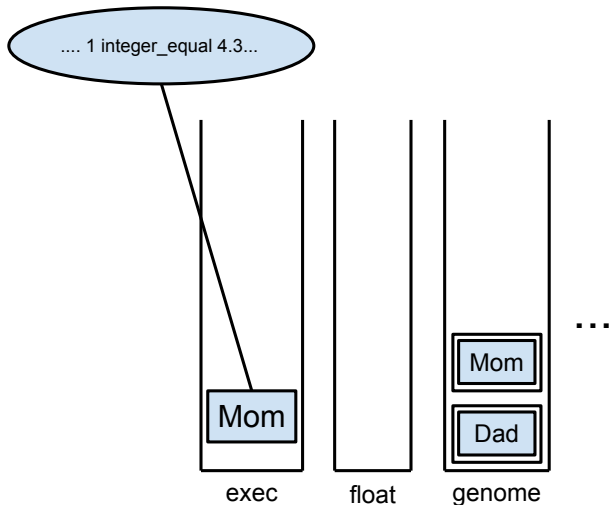
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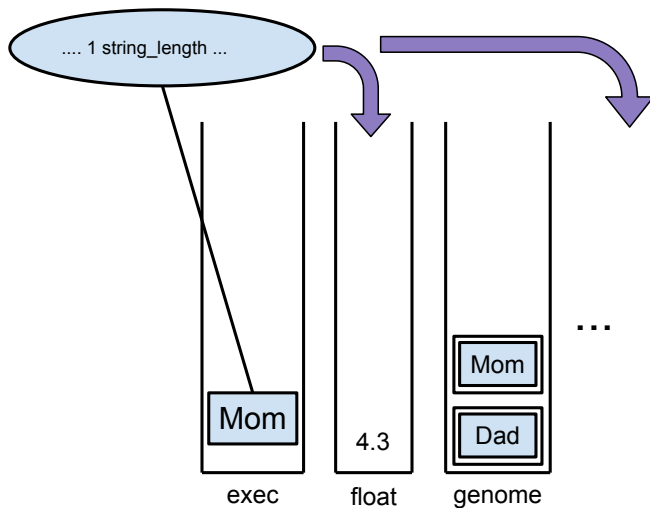
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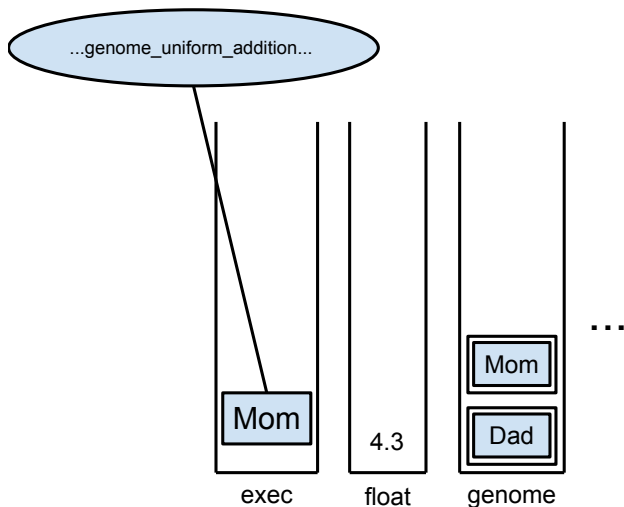
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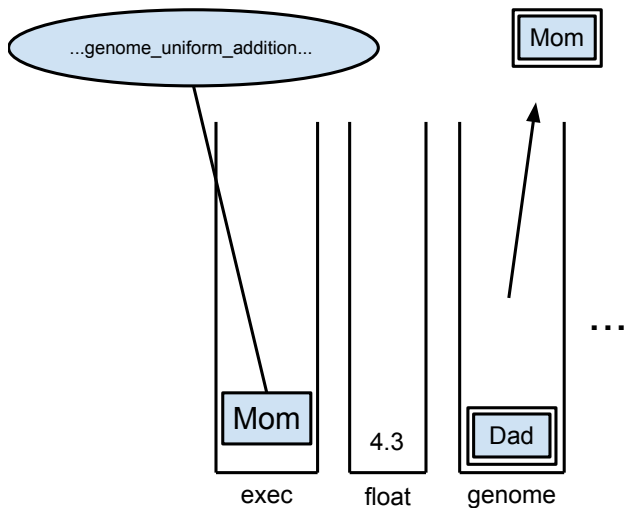
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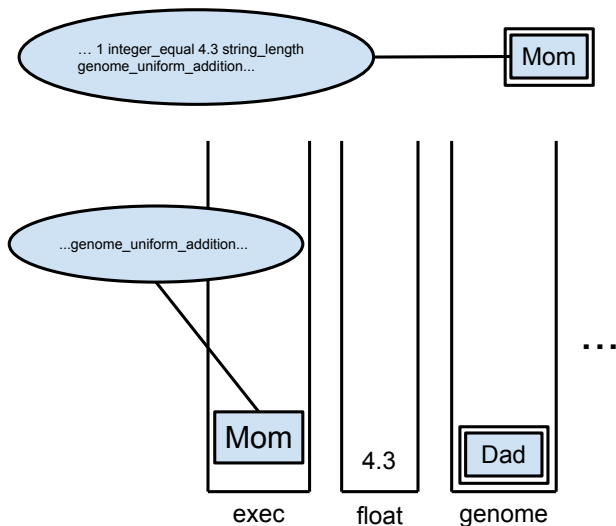
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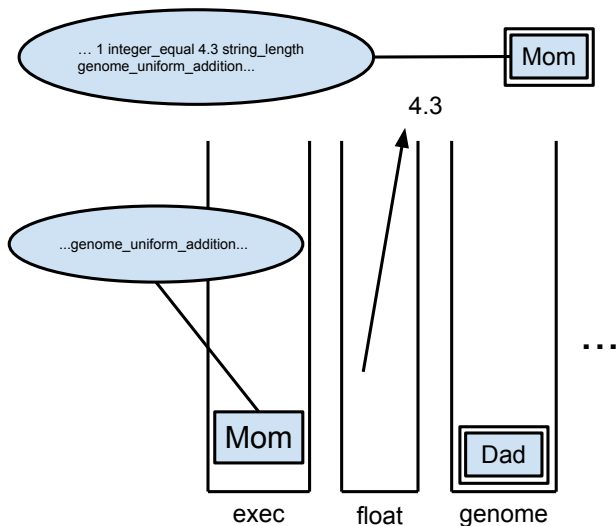
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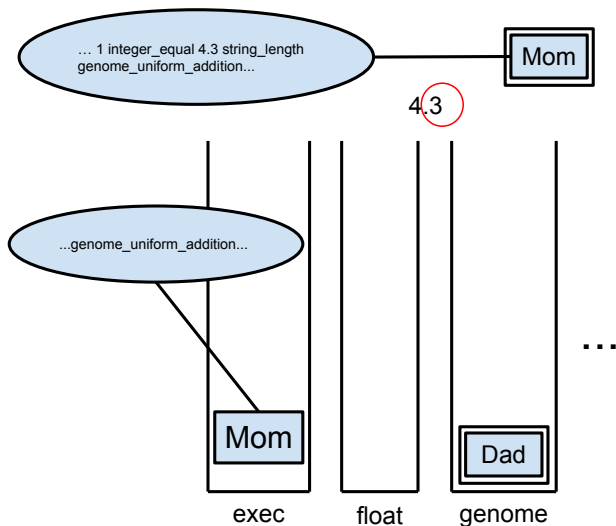
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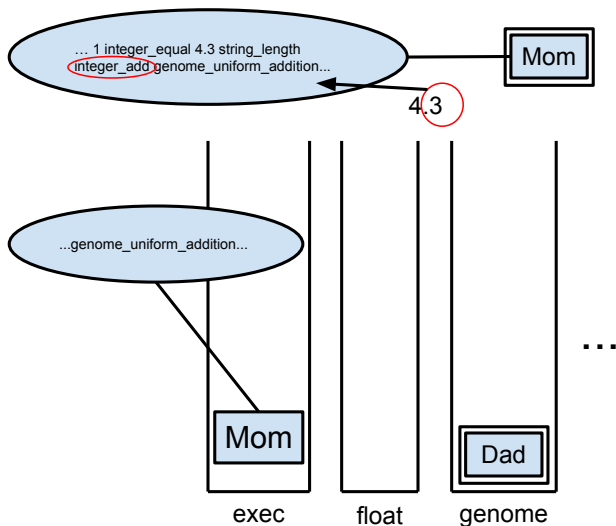
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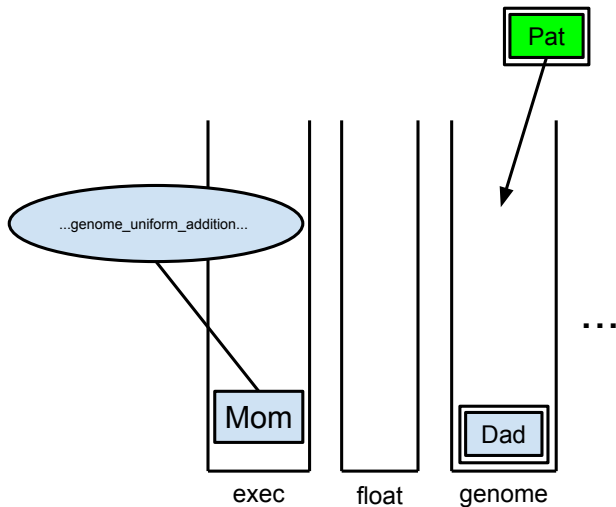
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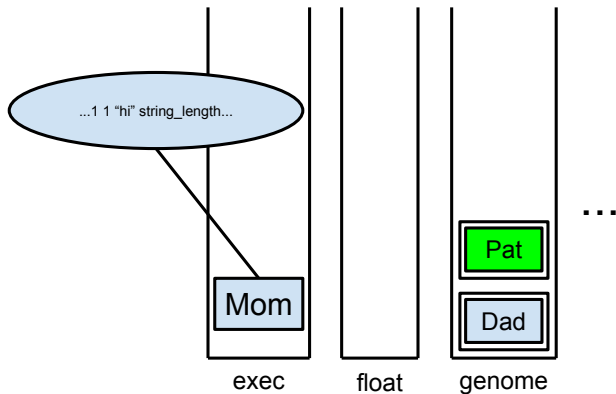
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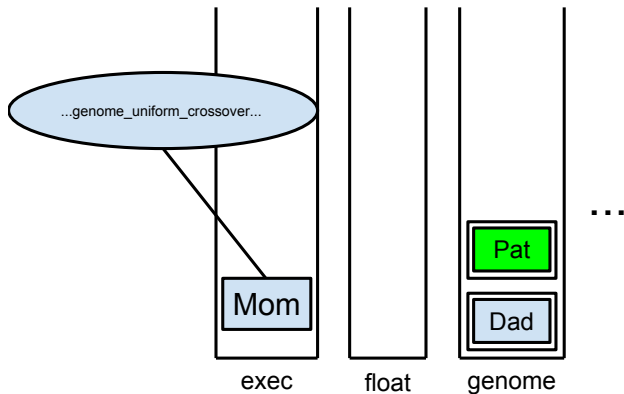
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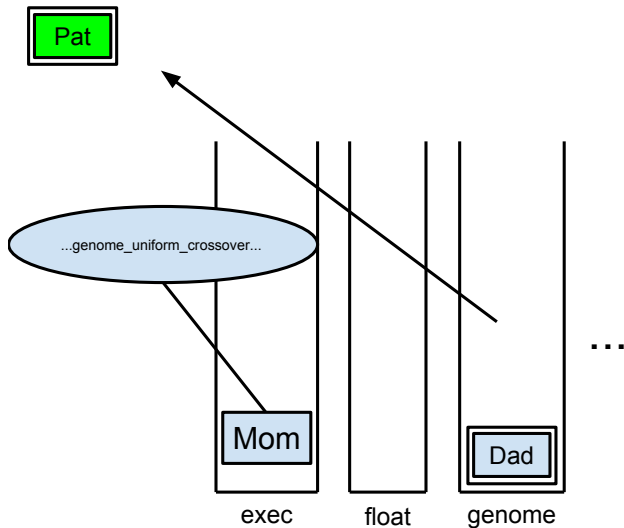
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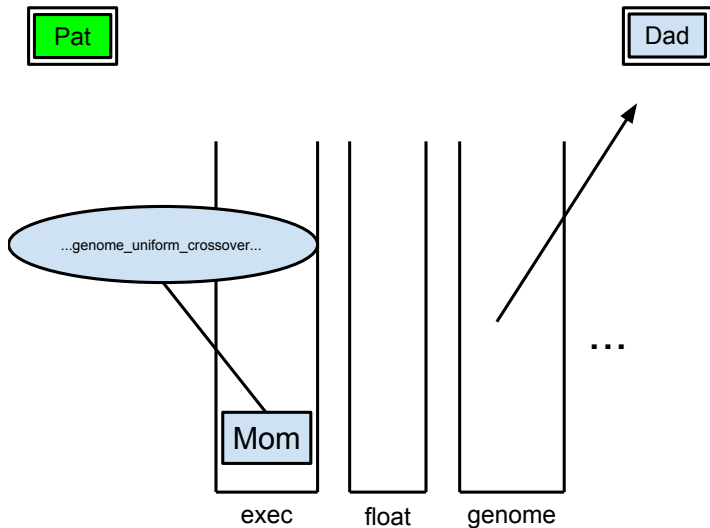
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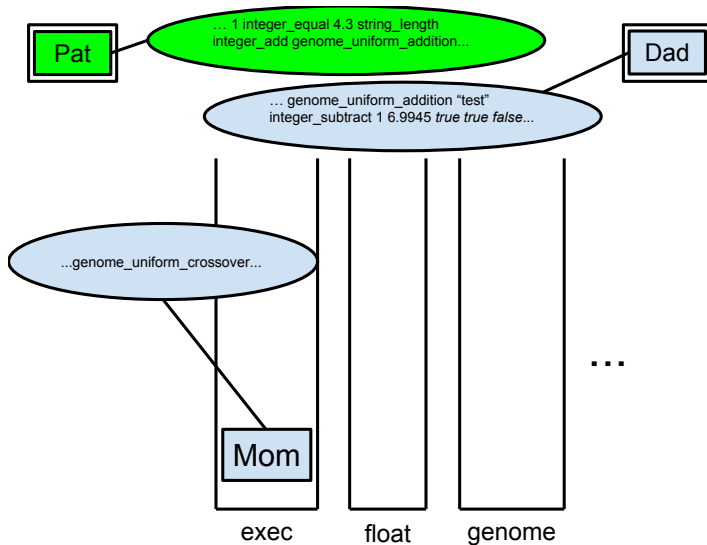
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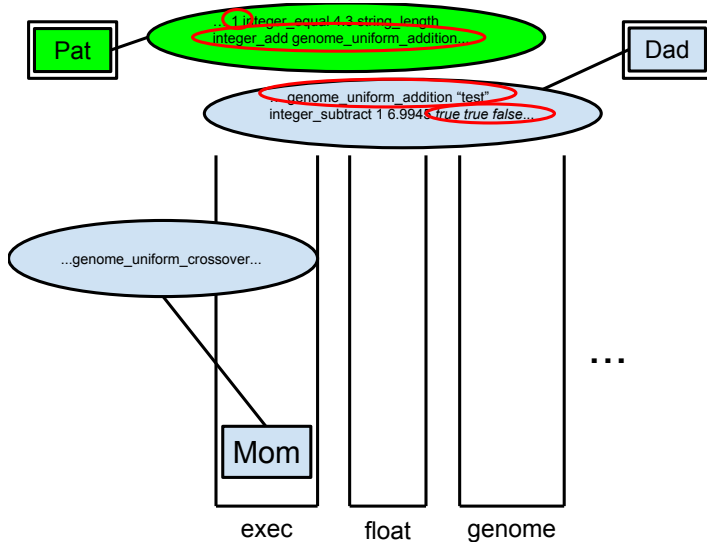
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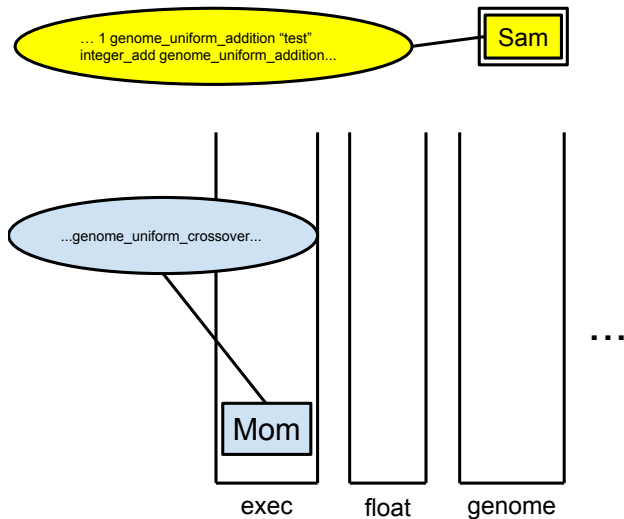
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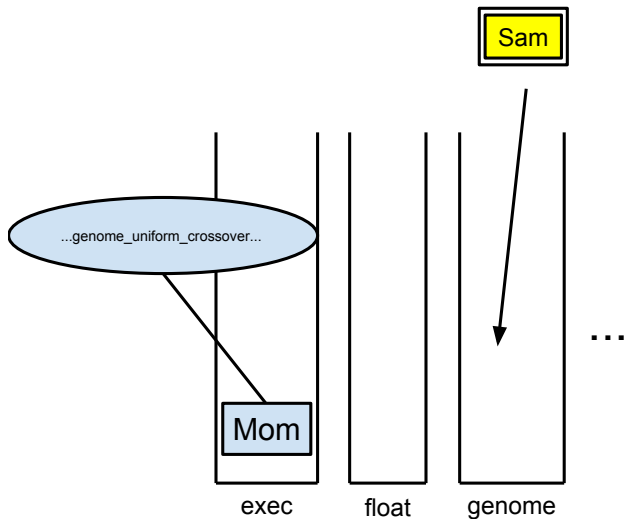
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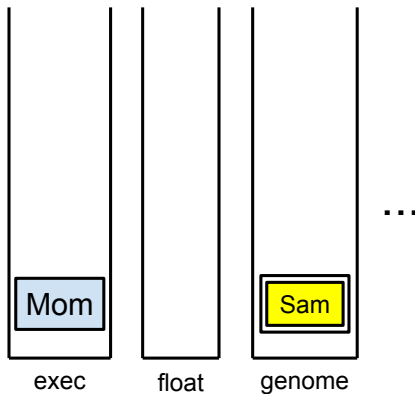
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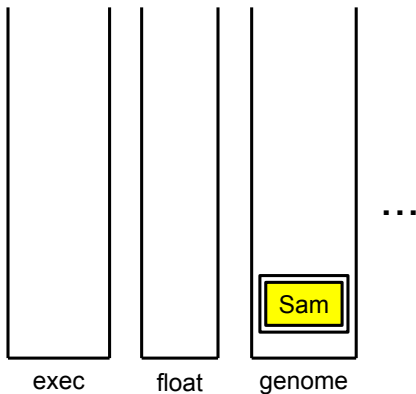
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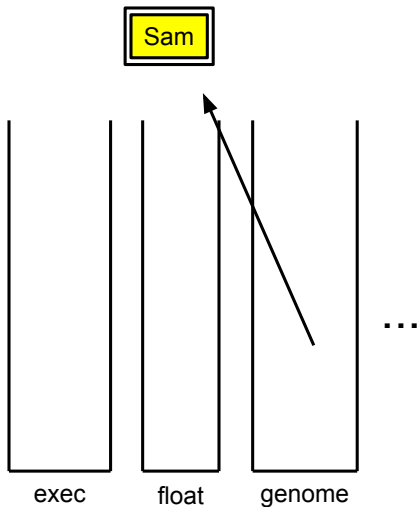
AutoDoG – reproduction



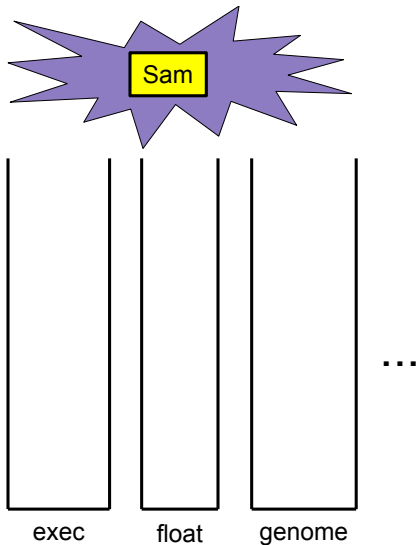
AutoDoG – reproduction



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AutoDoG – reproduction



AutoDoG – reproduction

Now Sam moves on to the next generation, right?

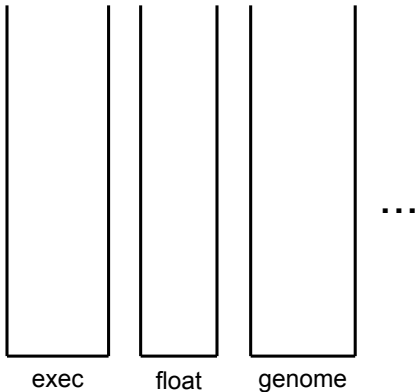
AutoDoG – reproduction

Now Sam moves on to the next generation, right?

WRONG!

AutoDoG – diversification test

Sam



AutoDoG – diversification test

Sam

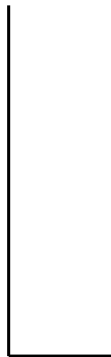
Sam



exec



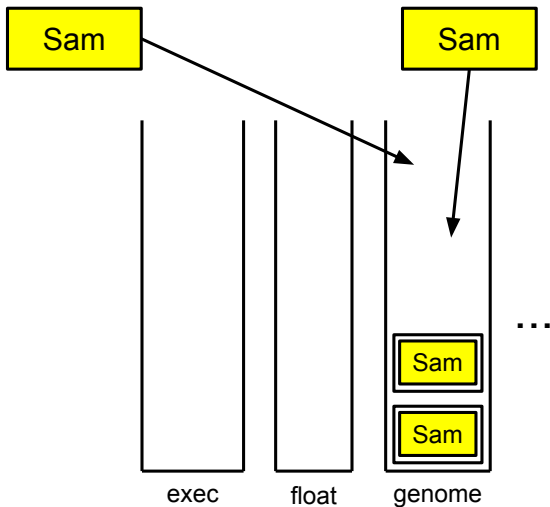
float



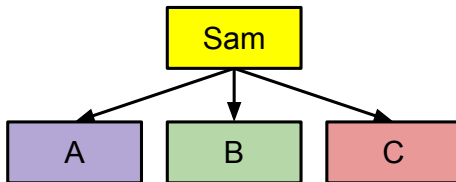
genome

...

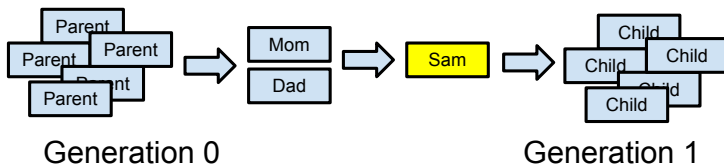
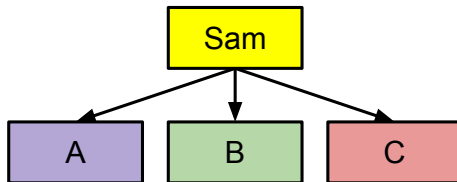
AutoDoG – diversification test



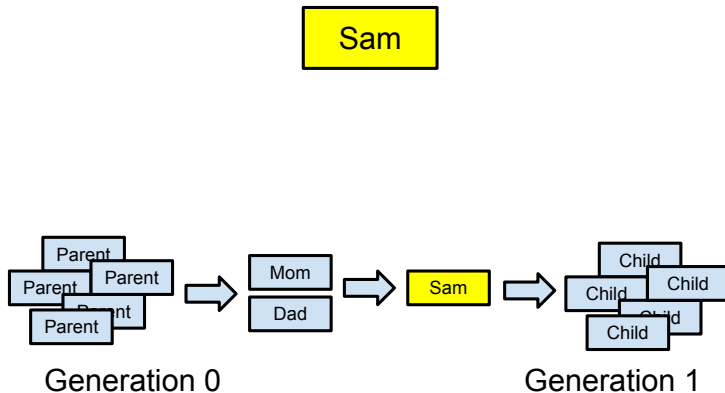
AutoDoG – diversification test



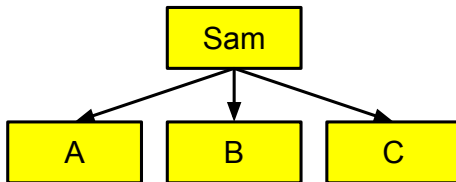
AutoDoG – diversification test



AutoDoG – diversification test



AutoDoG – diversification test



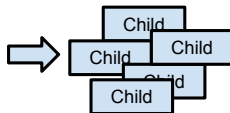
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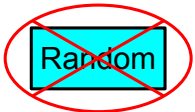


Random

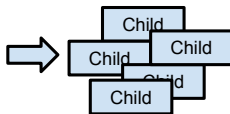
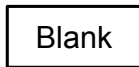


Generation 1

AutoDoG – diversification test



AutoDoG – diversification test



Generation 1

Results of AutoDoG

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

Results of AutoDoG

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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

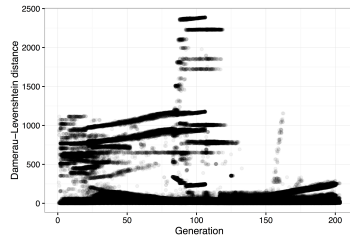
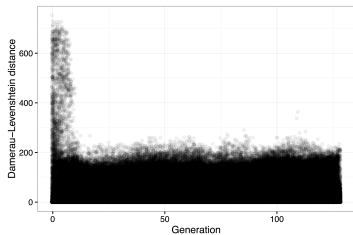
AutoDoG solves RSWN 5–10% of the time, where PushGP solves this problem 50% of the time.

Results of AutoDoG

AutoDoG solves RSWN 5–10% of the time, where PushGP solves this problem 50% of the time.

This is actually really impressive!

Results of AutoDoG



Graphs taken from Spector et al. [2]

Outline

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

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Summary

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- Autoconstruction is a type of GP HH
- 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!

Acknowledgments

Special thanks to Nic McPhee and Elena Machkasova for their feedback and constructive comments.

Thanks for coming!

Questions?

If your question was not answered during the presentation today, feel free to contact me: <brow3924@morris.umn.edu>

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See my paper for additional references.