Automating Algorithm Design through Genetic Programming Hyper-Heuristicss

Elsa Browning

Division of Science and Mathematics
University of Minnesota, Morris
Morris, Minnesota, USA

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/

What does the title mean?

- Reducing the human component in algorithm design
- More work at the beginning, more possibilities

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

What does the title mean?

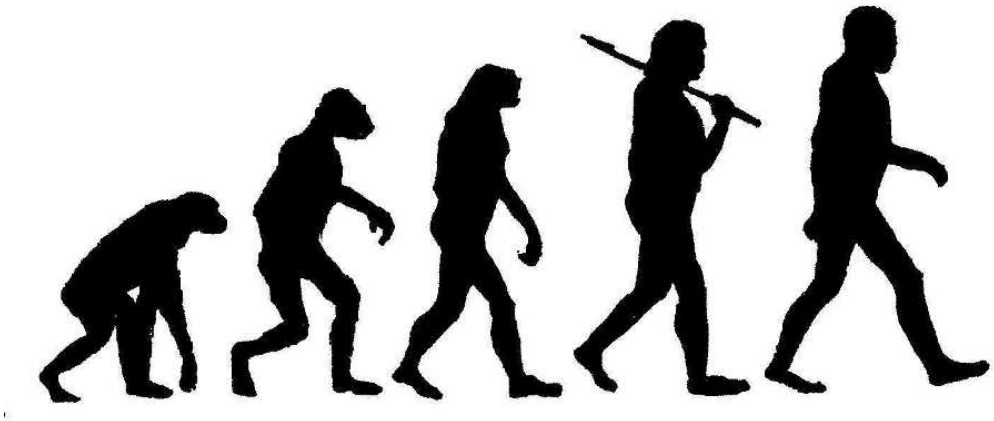
- Reducing the human component in algorithm design
- More work at the beginning, more possibilities
- Genetic programming hyper-heuristics as a method to the madness

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

Outline

Outline

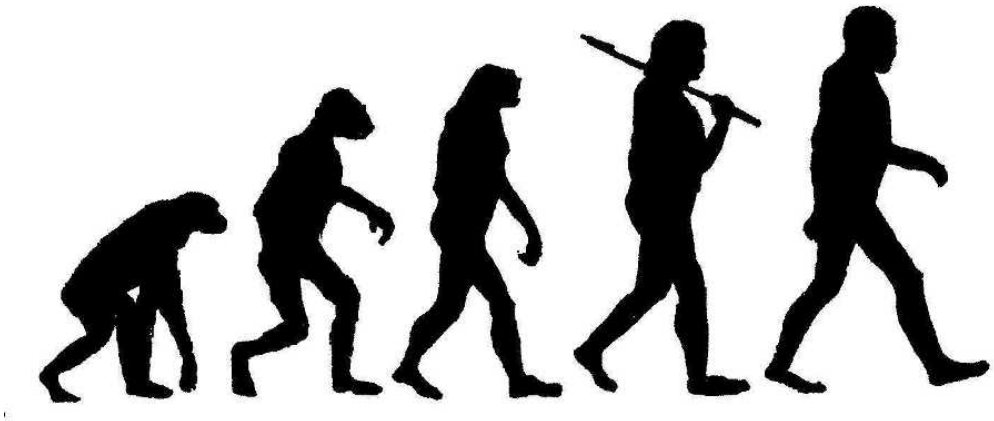
Evolutionary Computation



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

- Subfield of Artificial Intelligence

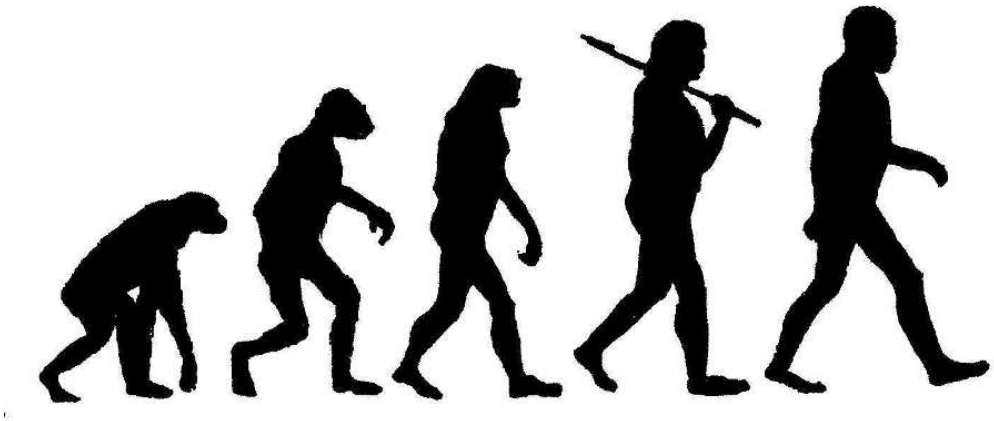
Evolutionary Computation



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

- Subfield of Artificial Intelligence
- Algorithms based on biological evolution

Evolutionary Computation

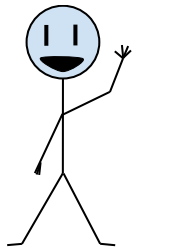


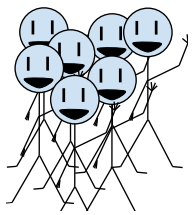
https://www.spigotmc.org/attachments/evolution-jpg.137048/

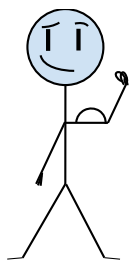
- Subfield of Artificial Intelligence
- Algorithms based on biological evolution
- Uses lots of terminology from biology, doesn't always mean same thing as term means in biology.

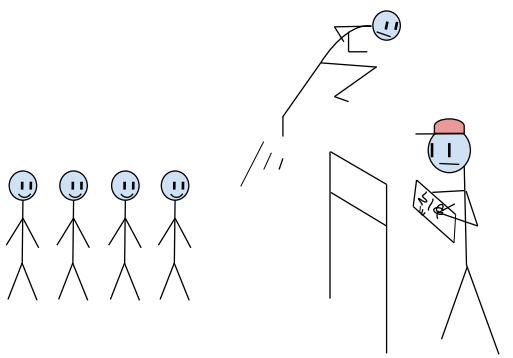
Evolutionary Computation – Terminology

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

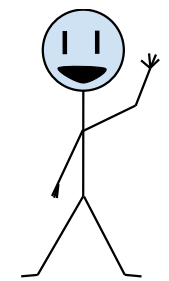
- **Mutation** – an insertion, deletion, or small change in the code of an individual, creating a new individual
- **Sexual reproduction** – when two or more individuals are munged together to create a new individual

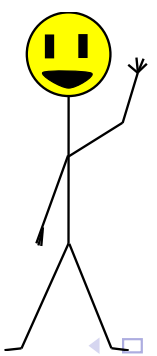
Evolutionary Computation – Terminology

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

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

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





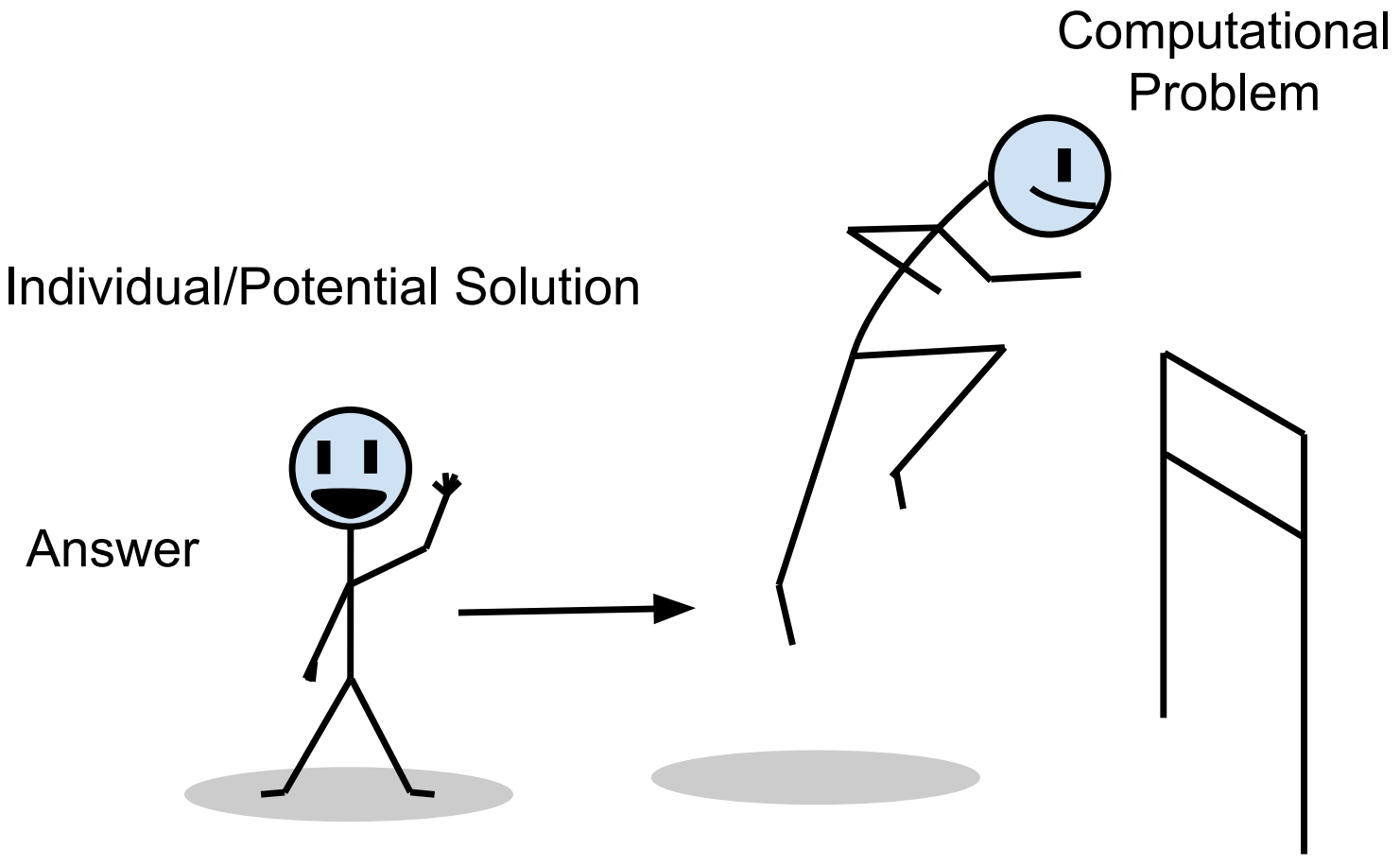
Evolutionary Computation – Terminology

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

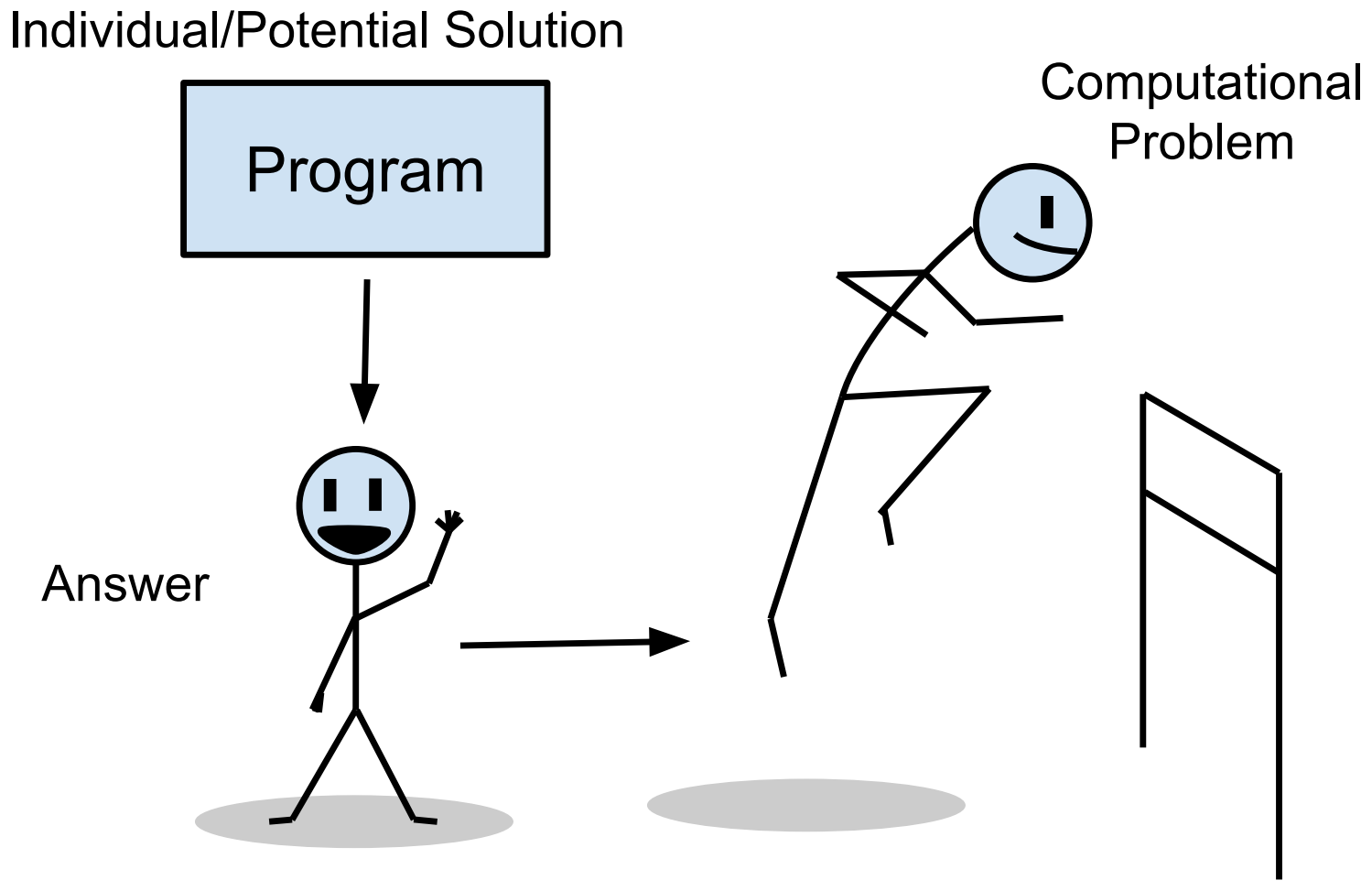
Genetic Programming

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

Genetic Programming



Genetic Programming



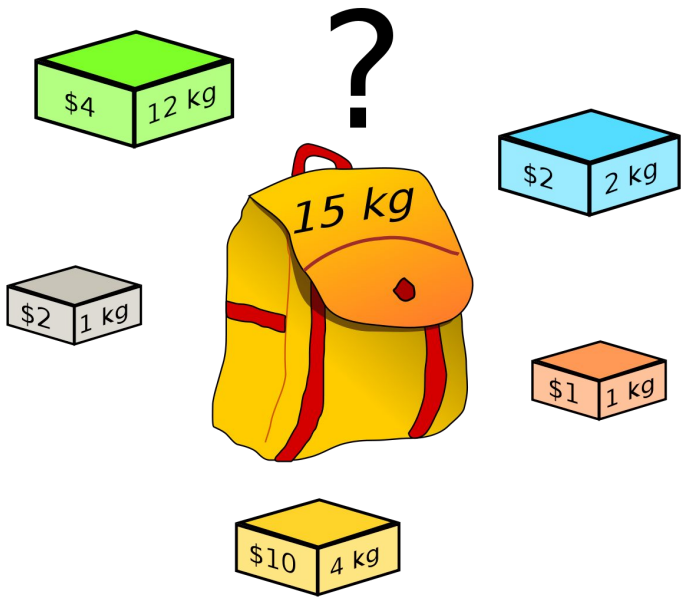
Genetic Programming

Individual/Potential Solution

Answer

[0 1 1 1 1]

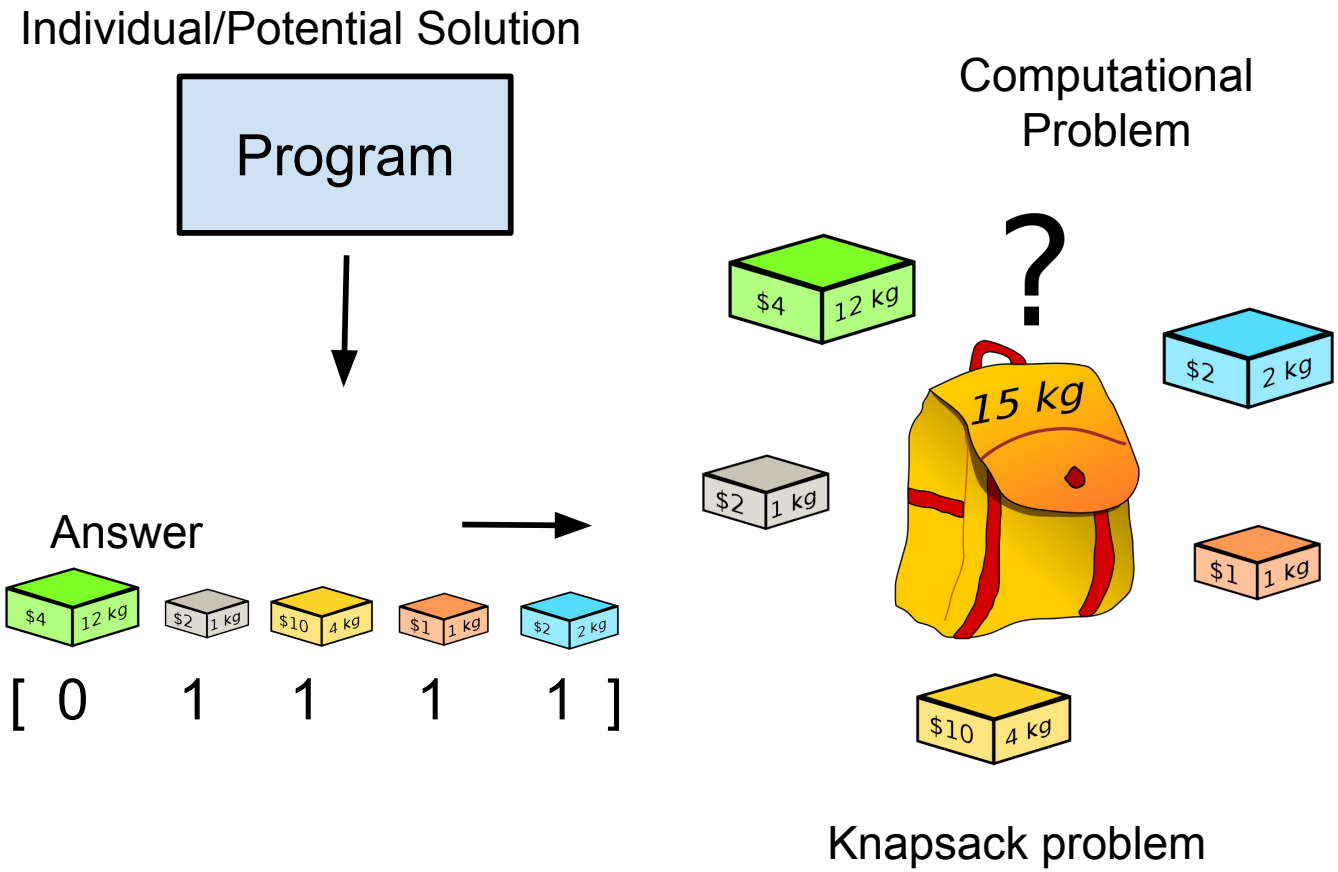
Computational Problem



Knapsack problem

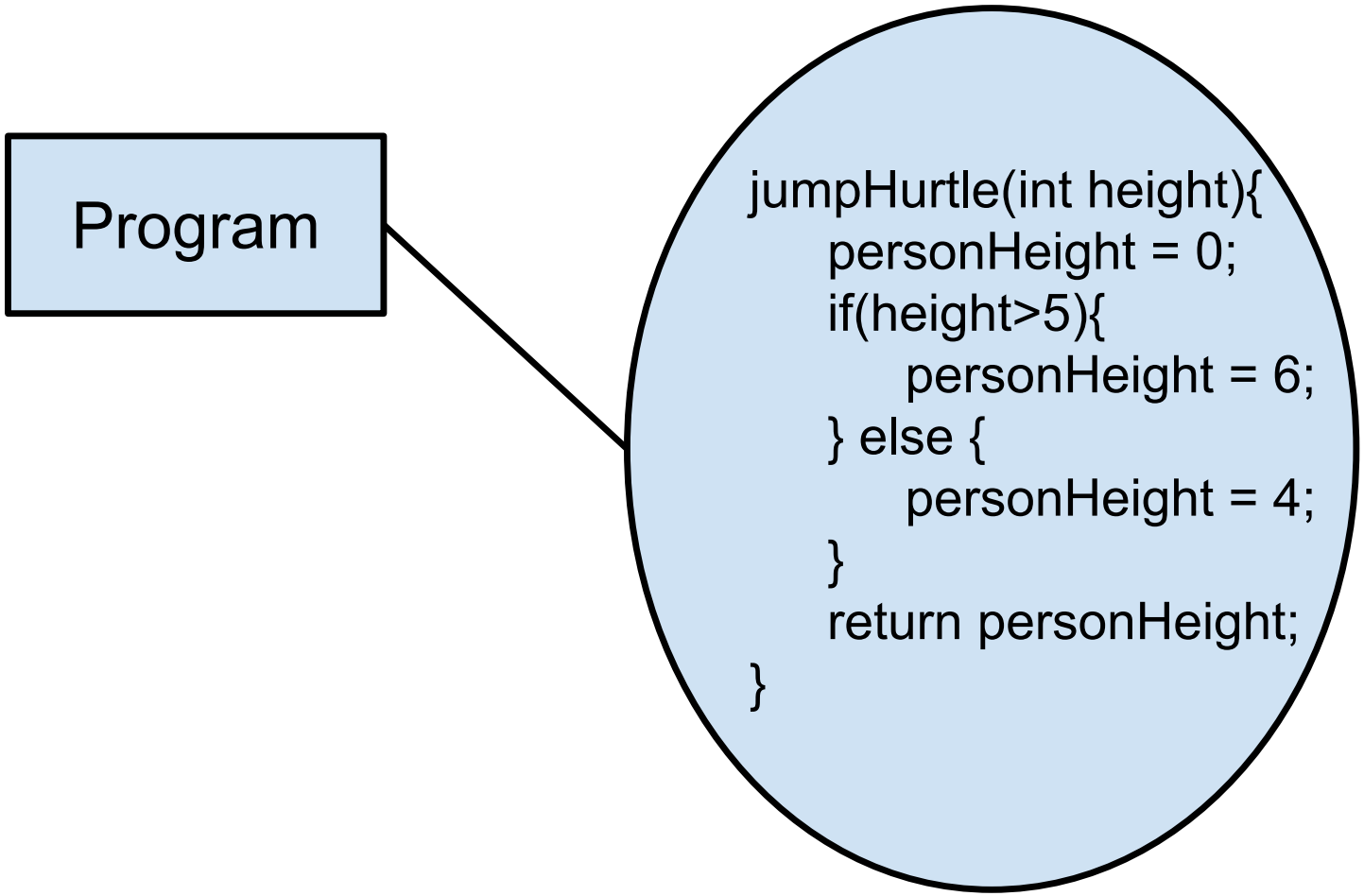
Based on https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

Genetic Programming

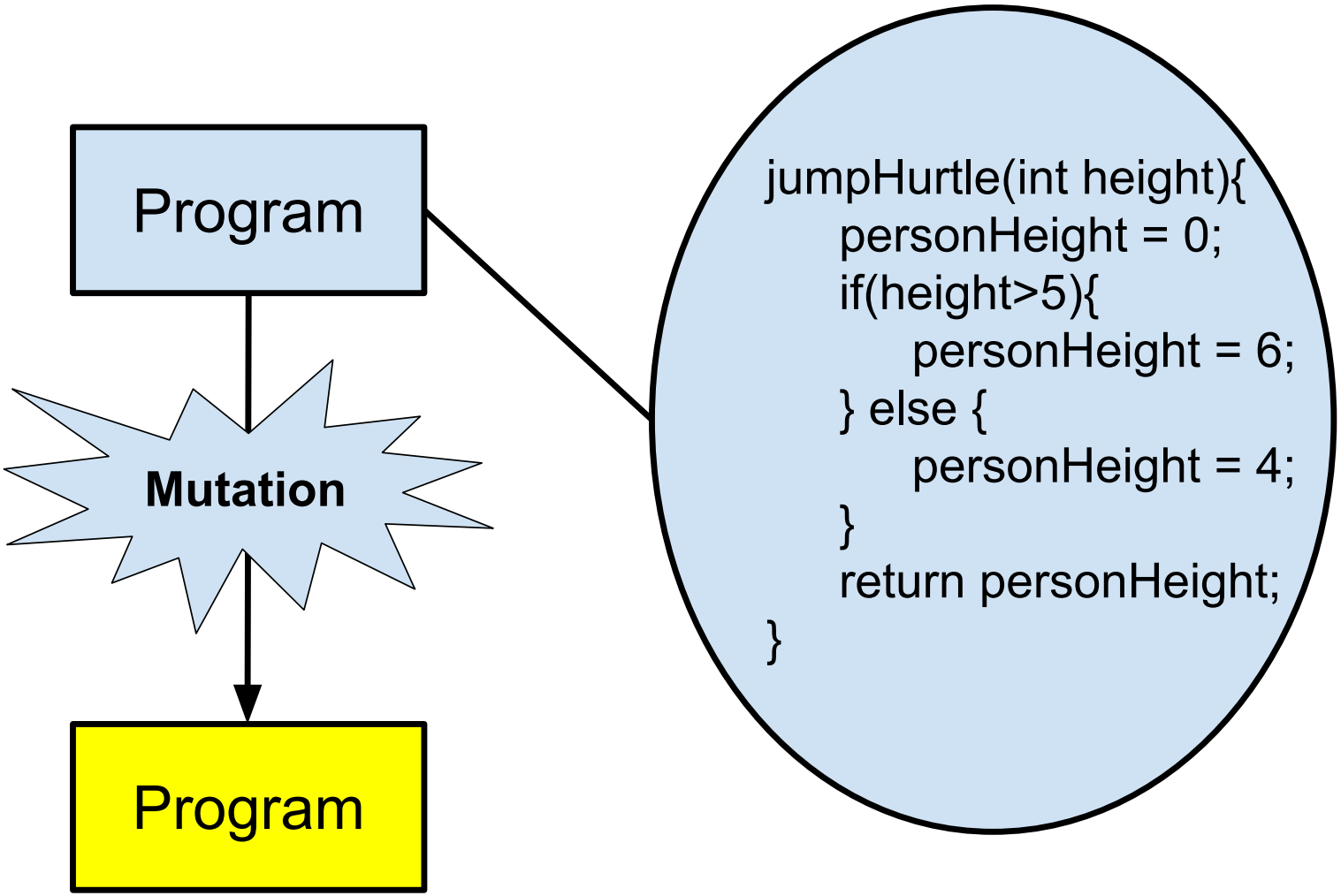


Based on `https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png`

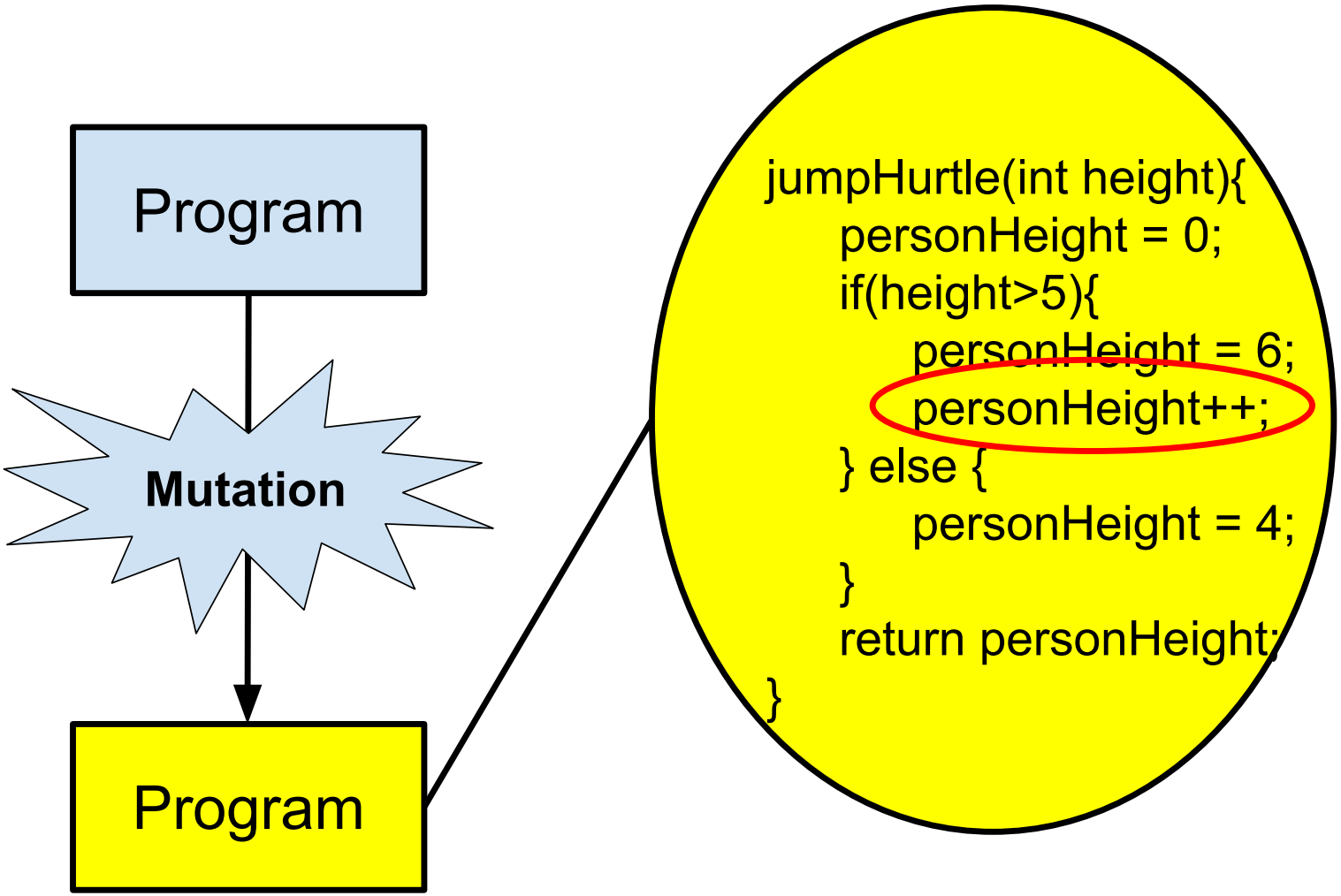
Genetic Programming



Genetic Programming



Genetic Programming



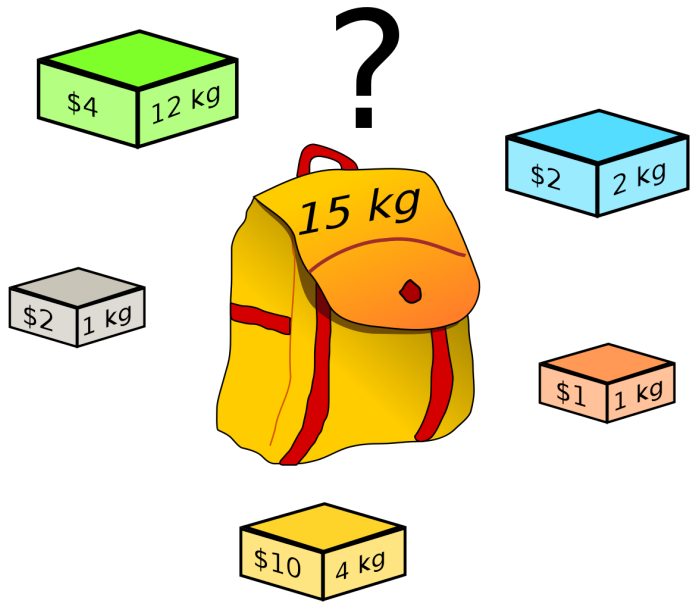
Outline

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.

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.

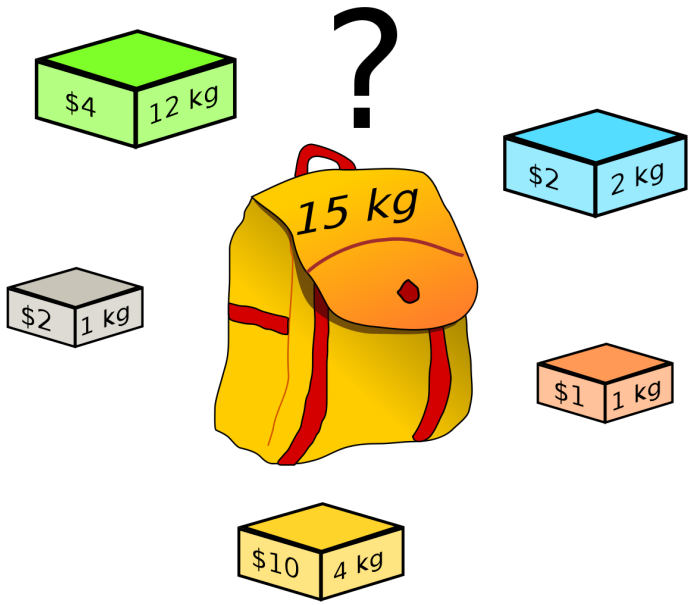


https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

Heuristics

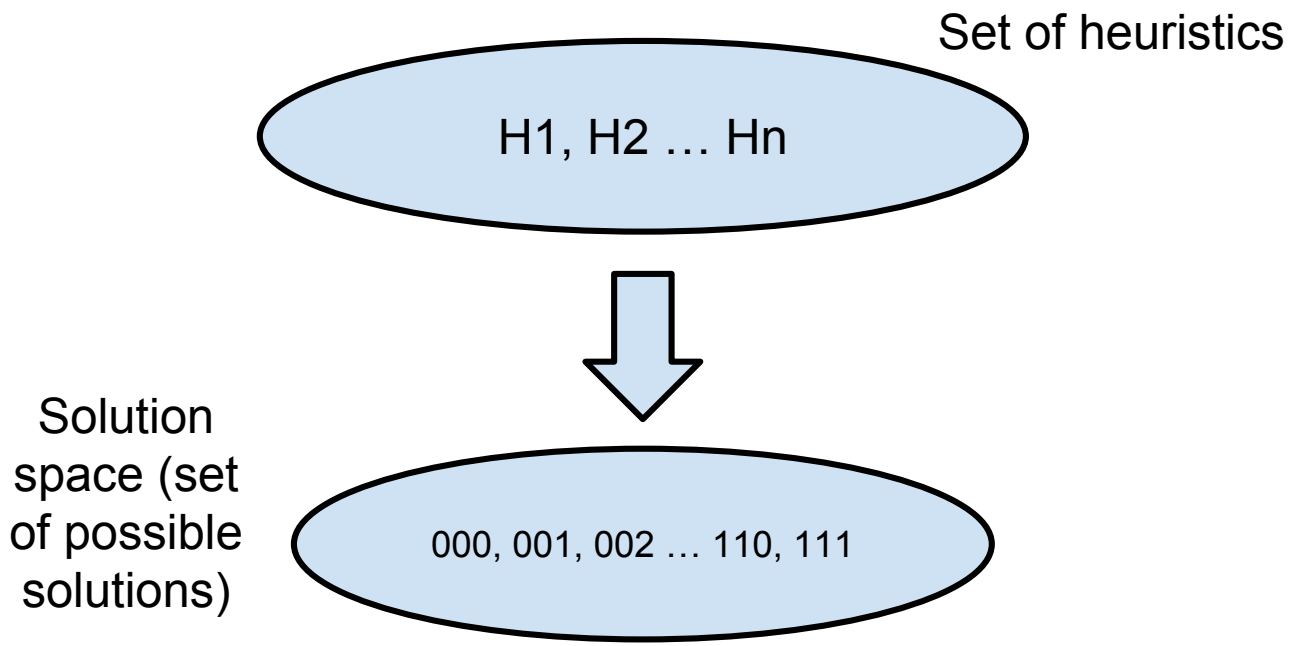
Heuristics – a function that ranks alternatives in a search algorithm at each branching step and uses that information to choose which branch to follow.

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"



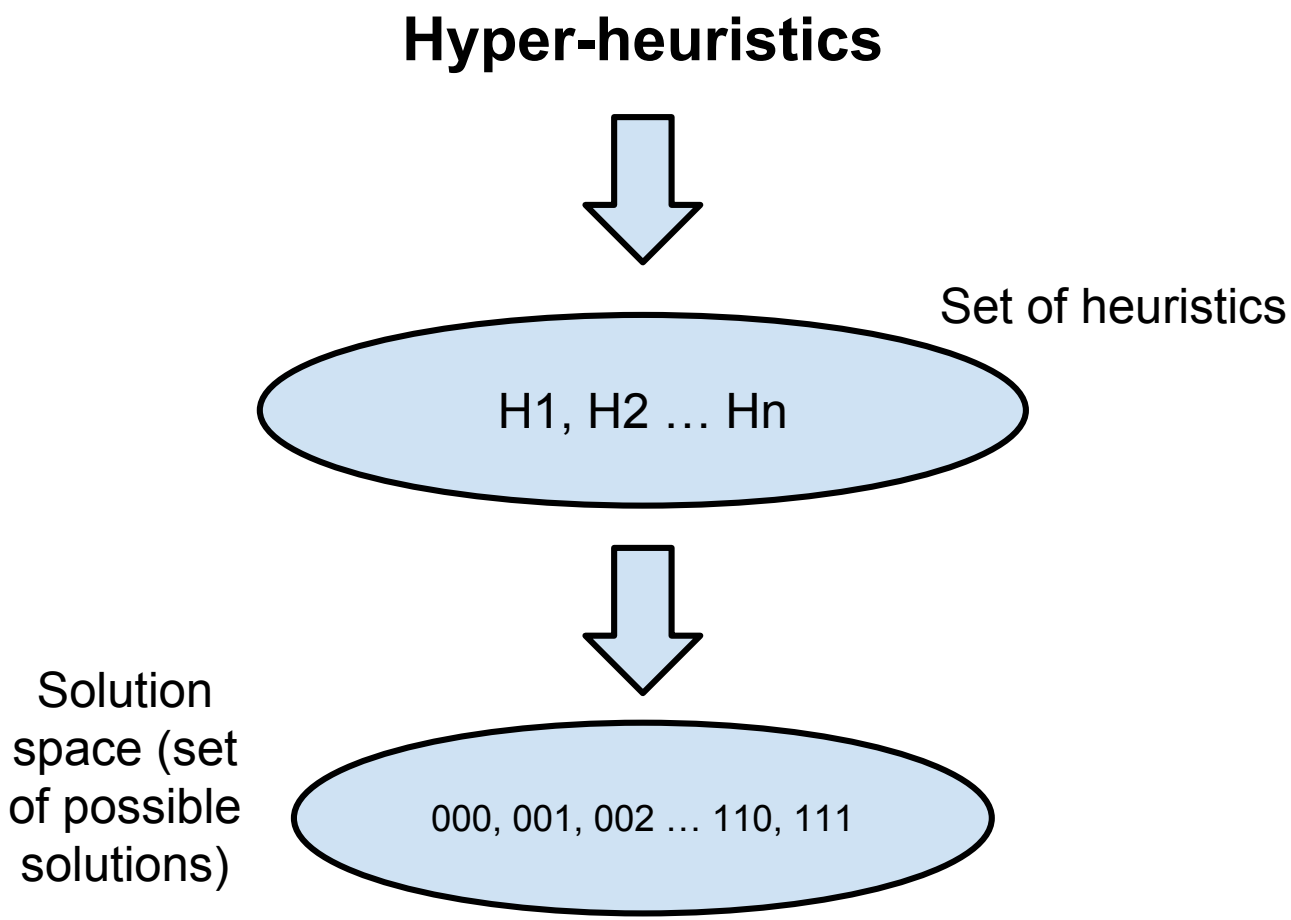
https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

Heuristics



Based on figures from Tauritz et al. (see paper for reference)

Hyper-heuristics



Based on figures from Tauritz et al. (see paper for reference)

Hyper-heuristics

Hyper-heuristics – heuristic search methods which seek to automate the process of selecting, generating, or adapting several simpler heuristics in order to solve computational search problems.

Hyper-heuristics

Hyper-heuristics – heuristic search methods which seek to automate the process of selecting, generating, or adapting several simpler heuristics in order to solve computational search problems.

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

Outline

Genetic programming variants

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

Genetic programming variants

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

Harris et al. [1] performed an experiment to address whether or not the GP variant used affected the success of the hyper-heuristic

Genetic programming variants

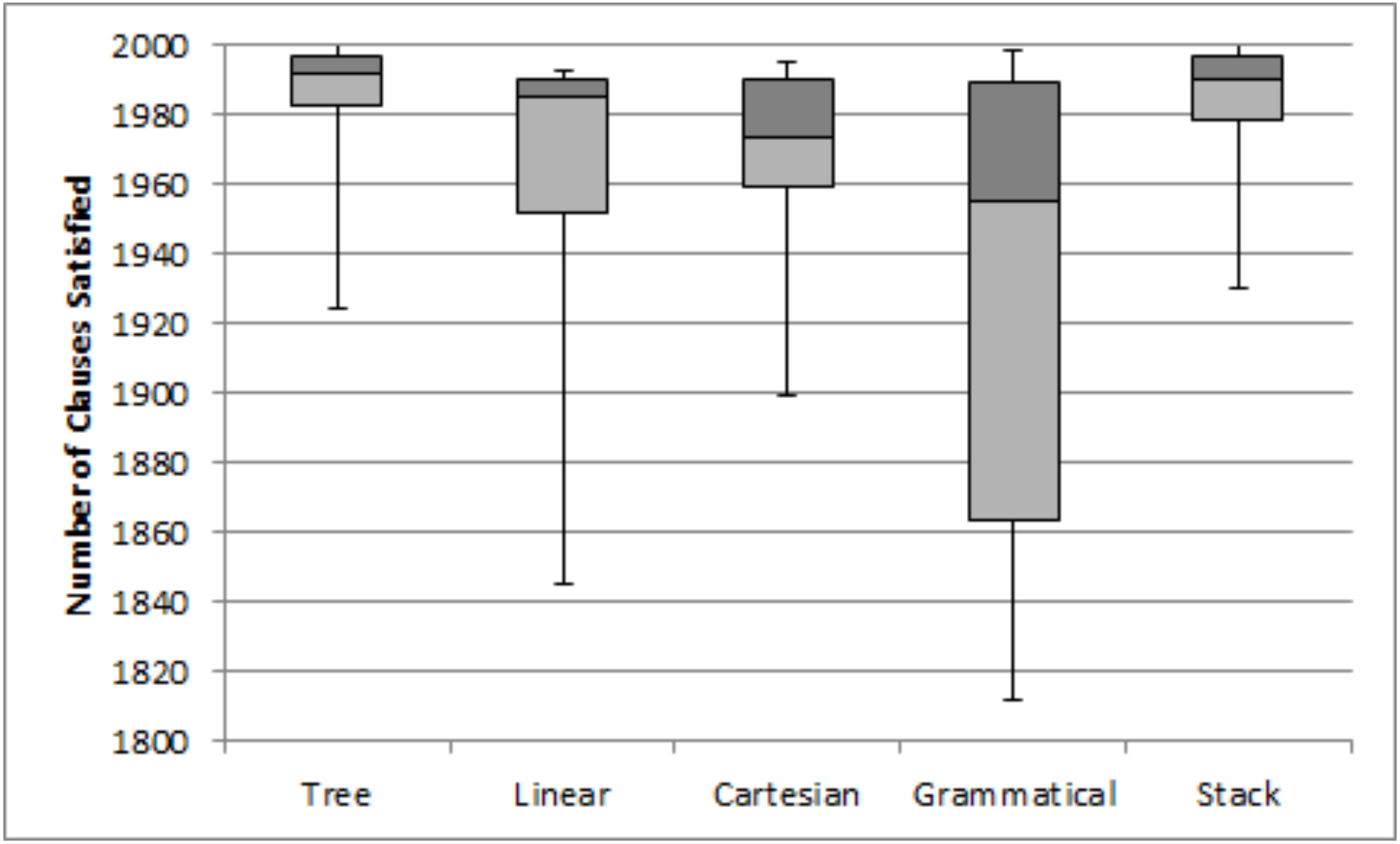
GP variants – variations on the structure and setup of a genetic programming system.

Harris et al. [1] performed an experiment to address whether or not the GP variant used affected the success of the hyper-heuristic

GP variants tested:

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

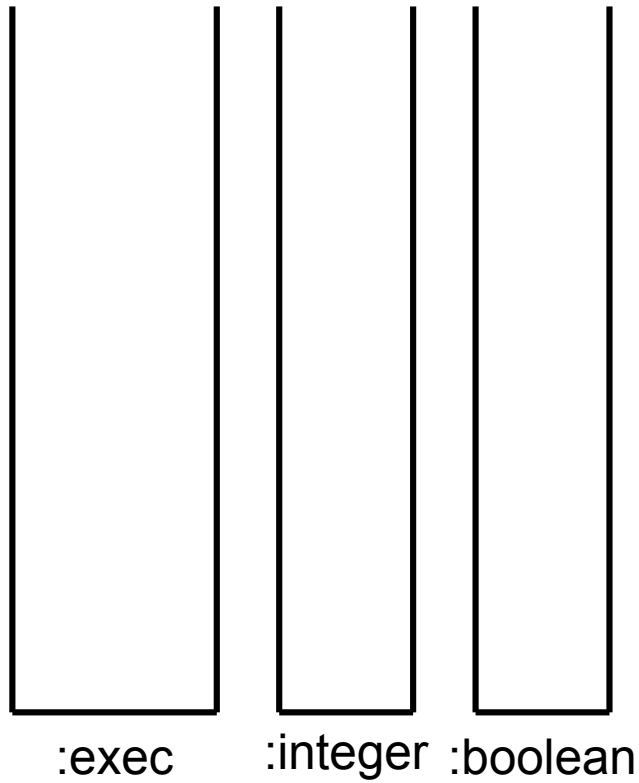
Why should we care?



Graph taken from Harris et al. [1]

Stack-based genetic programming

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

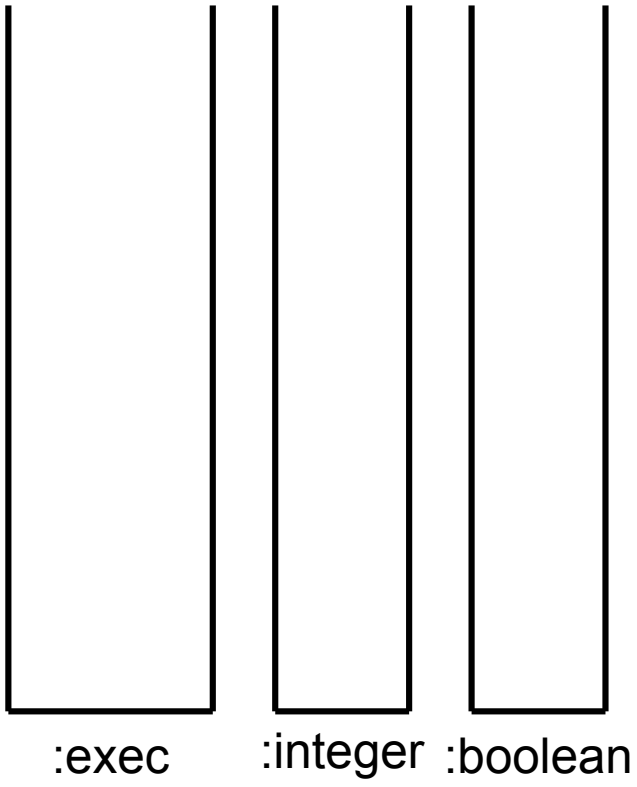


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

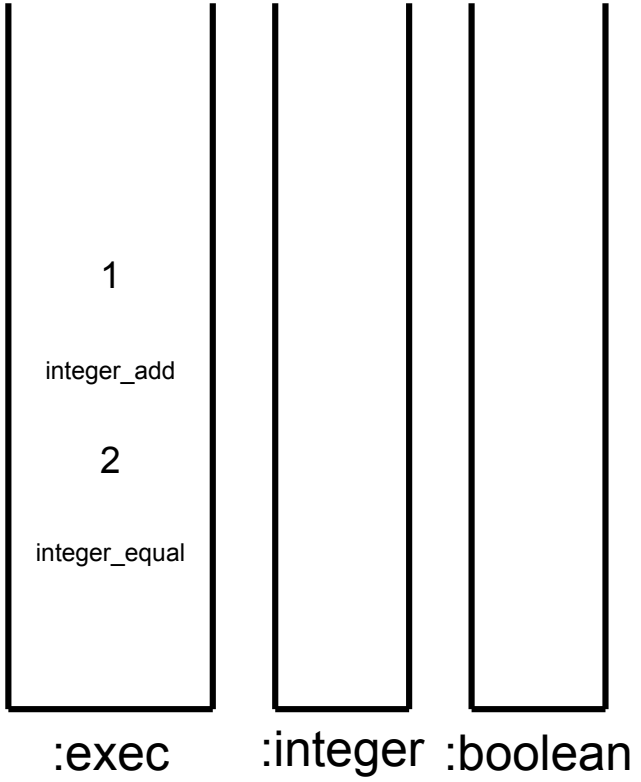


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

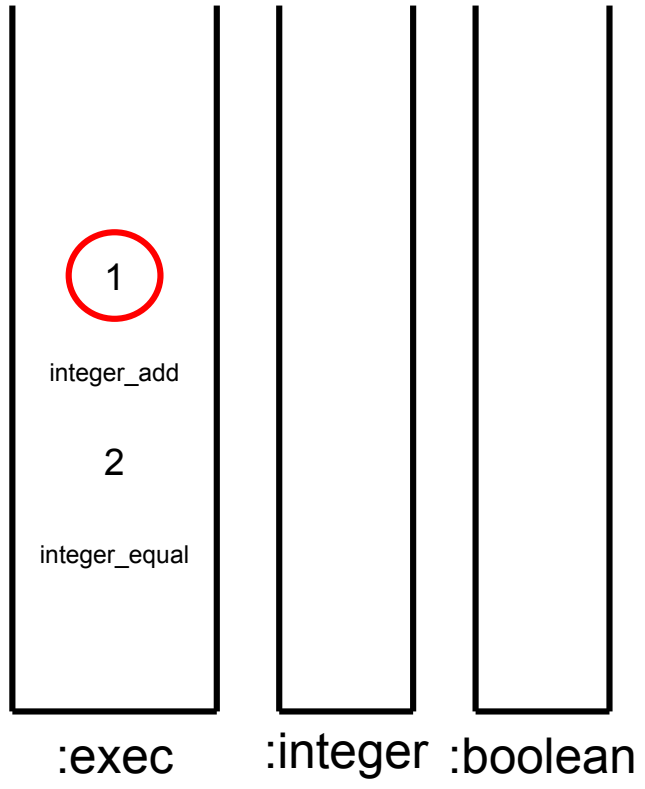


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

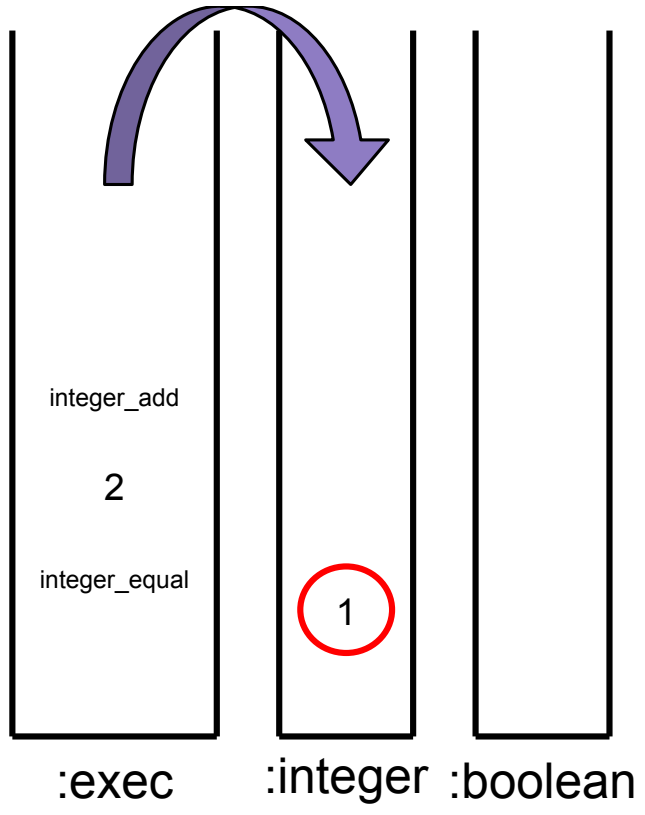


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

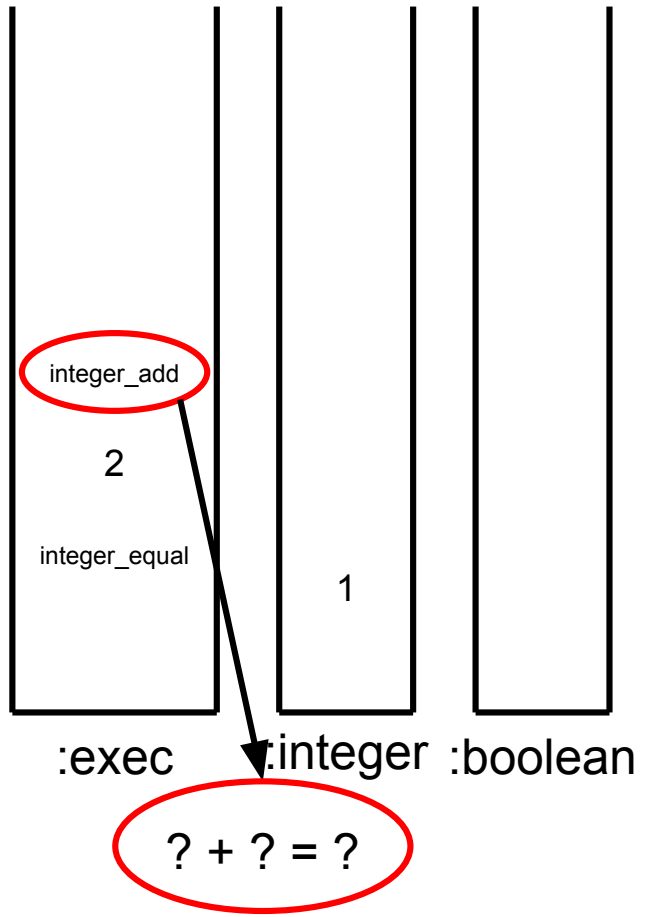


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

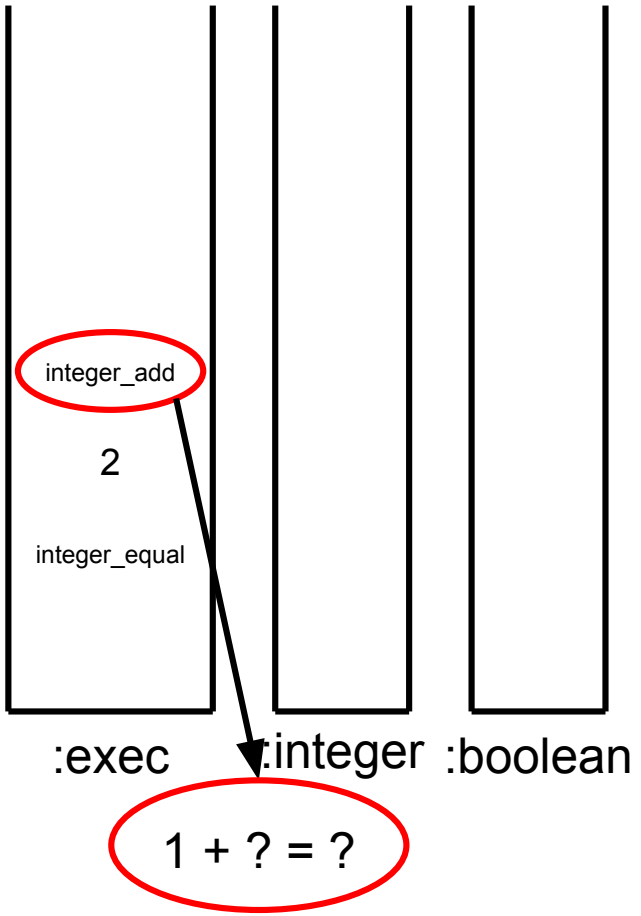


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

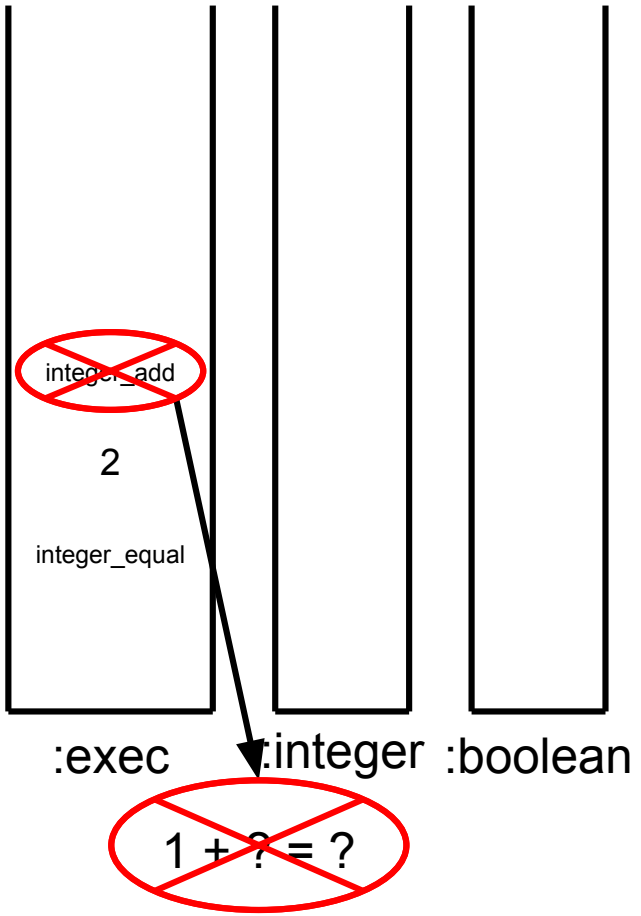


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

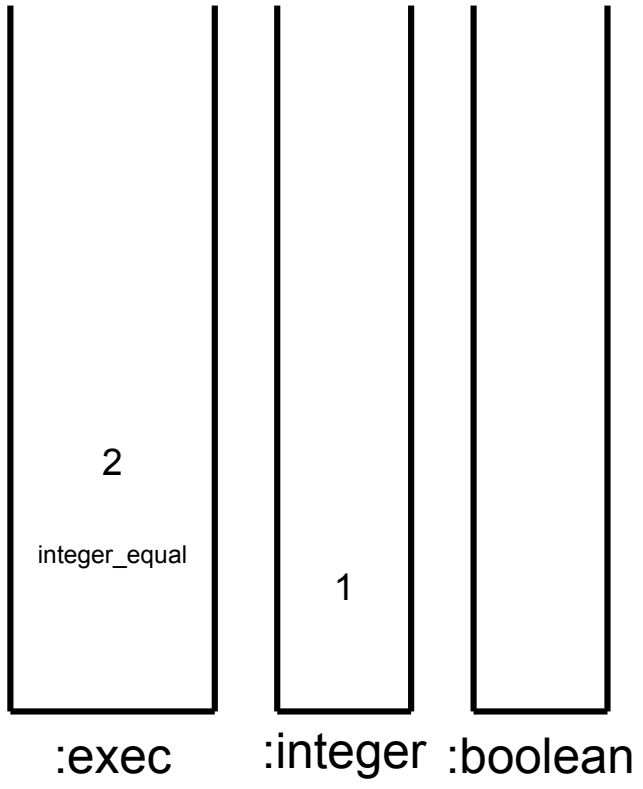


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

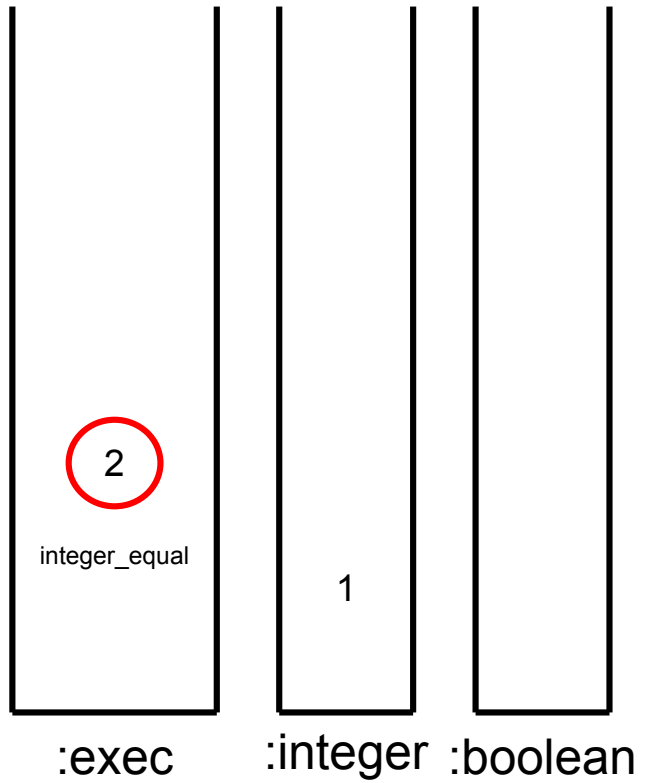


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

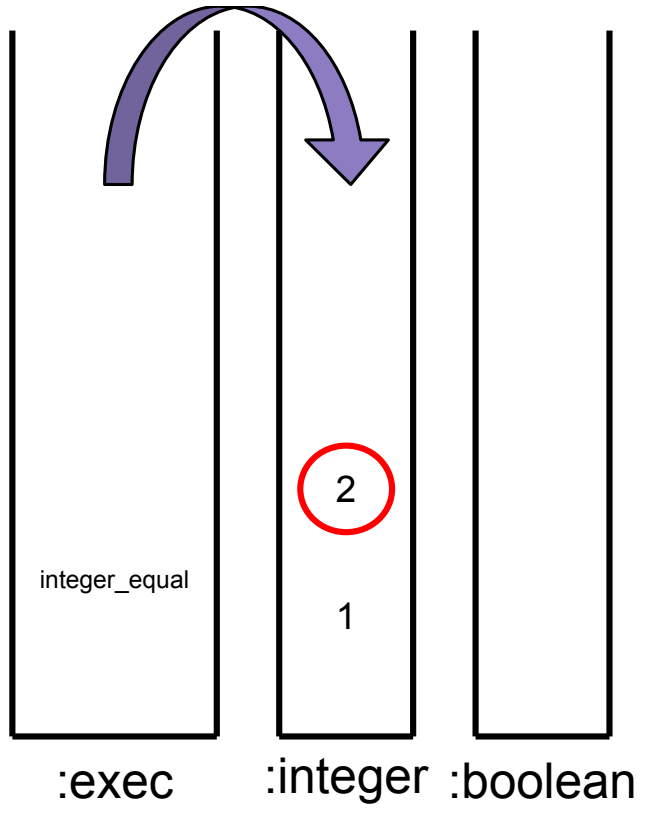


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

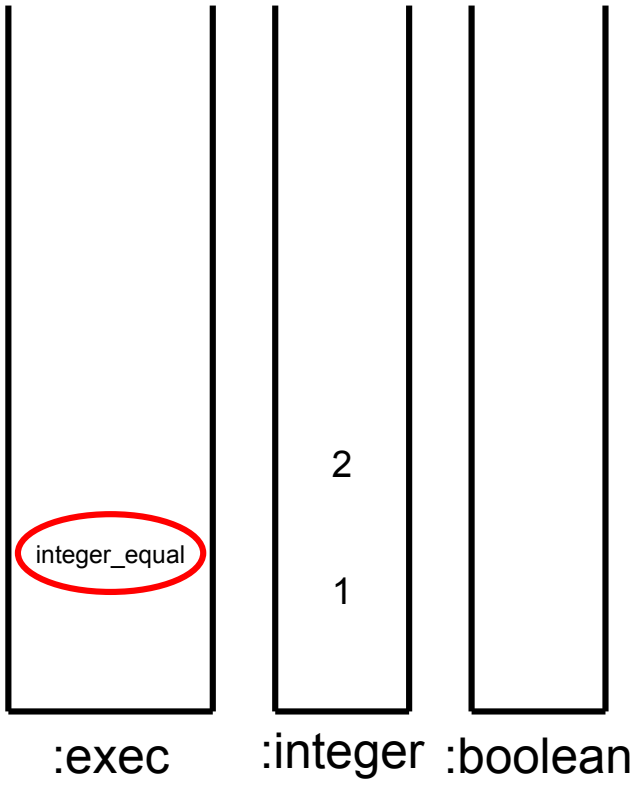


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

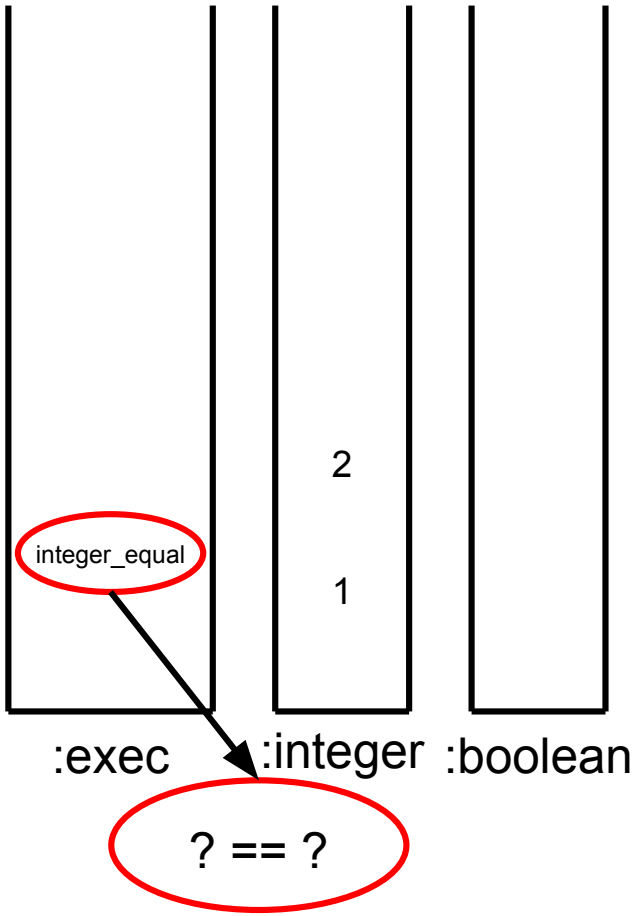


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

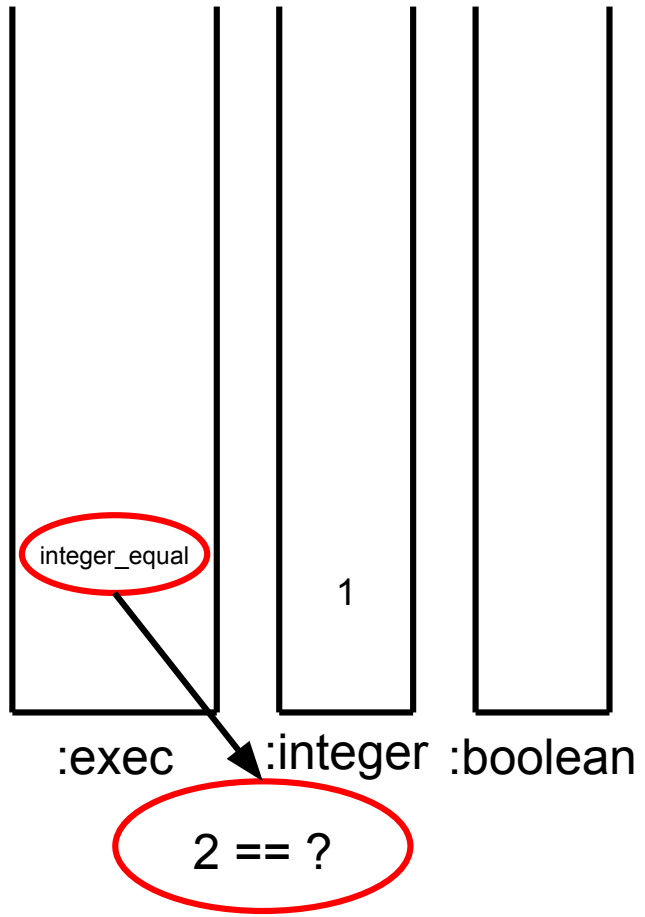


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

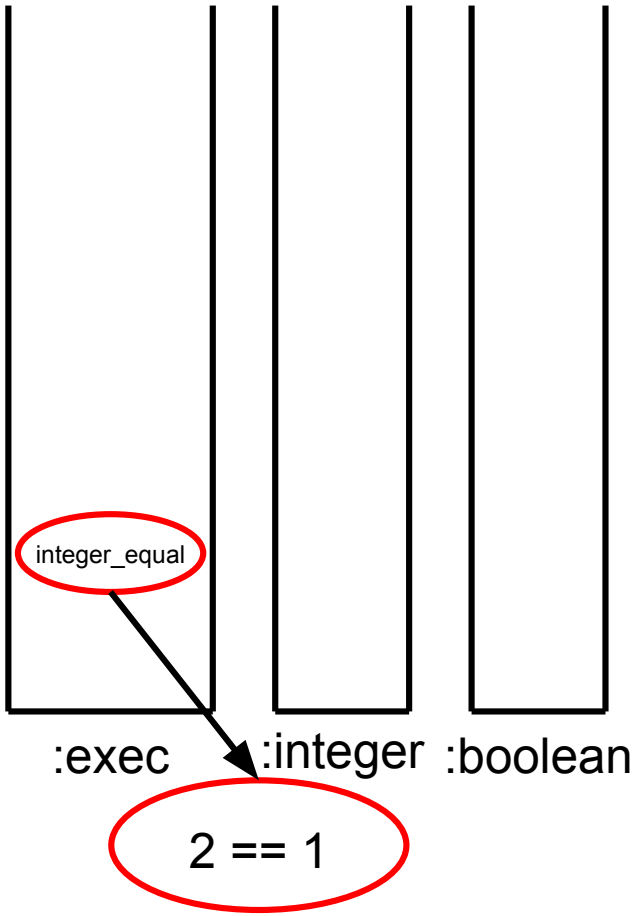


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

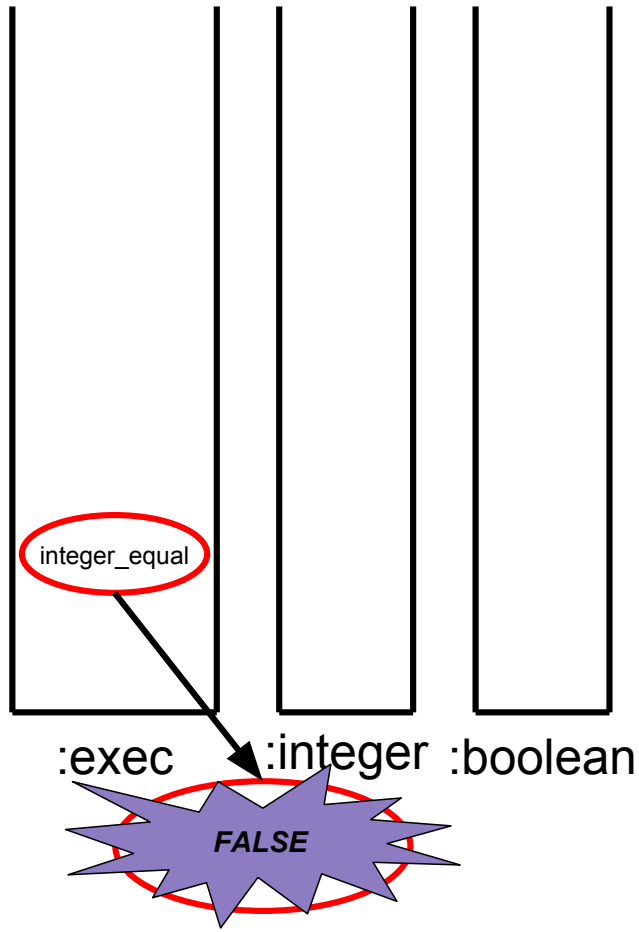


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```

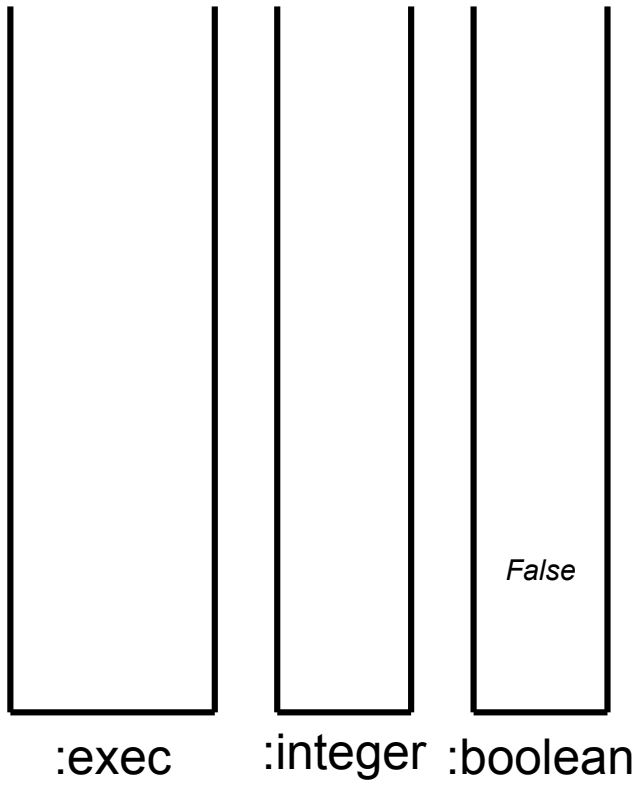


Stack-based genetic programming

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

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

```
(1 integer_add 2 integer_equal)
```



Outline

What is Autoconstruction?

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

What is Autoconstruction?

- 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.

What is Autoconstruction?

- 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

- A system designed by Spector et al. [2] that uses autoconstruction to evolve programs.
- Uses the Push programming language

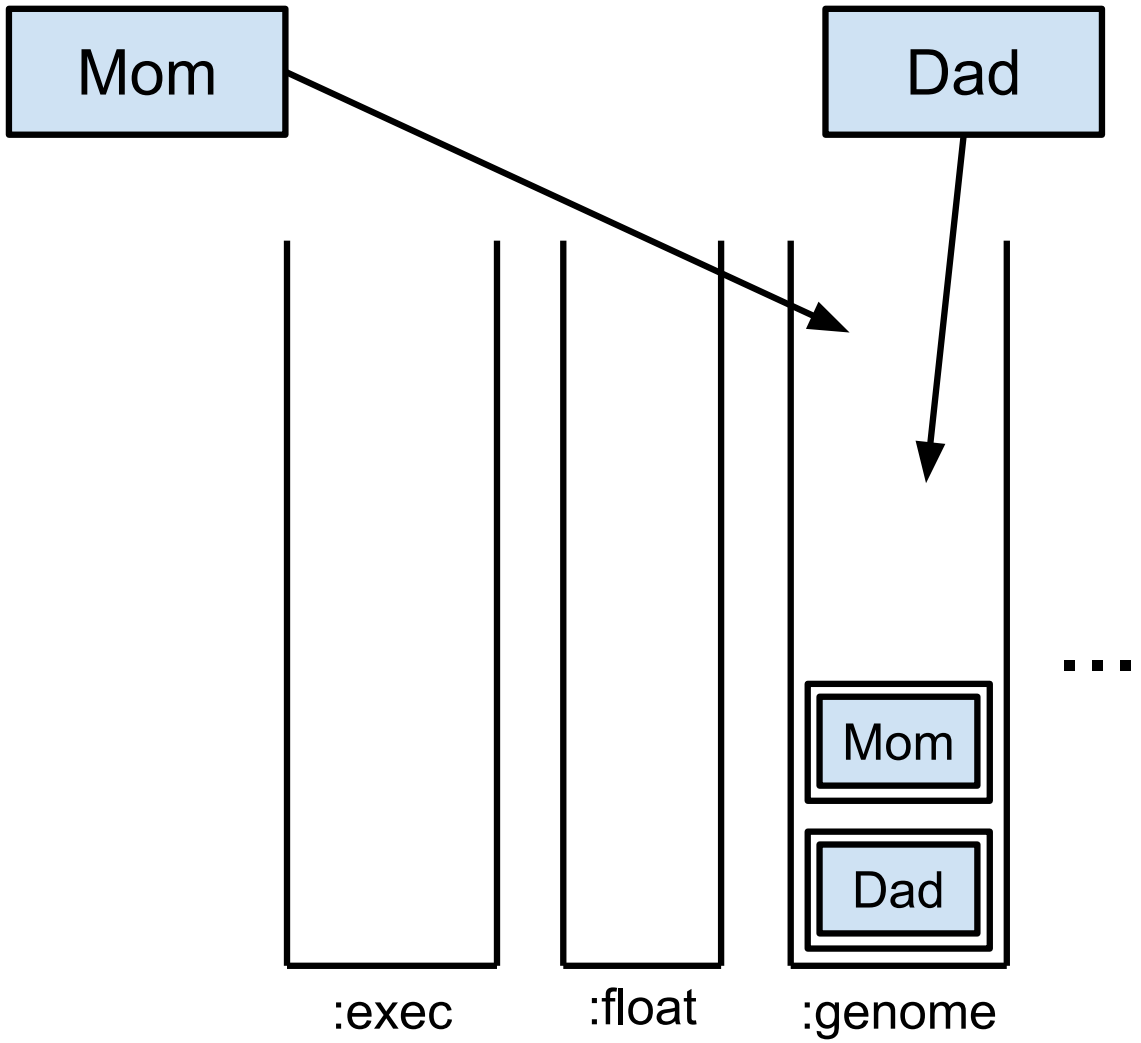
AutoDoG

- 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

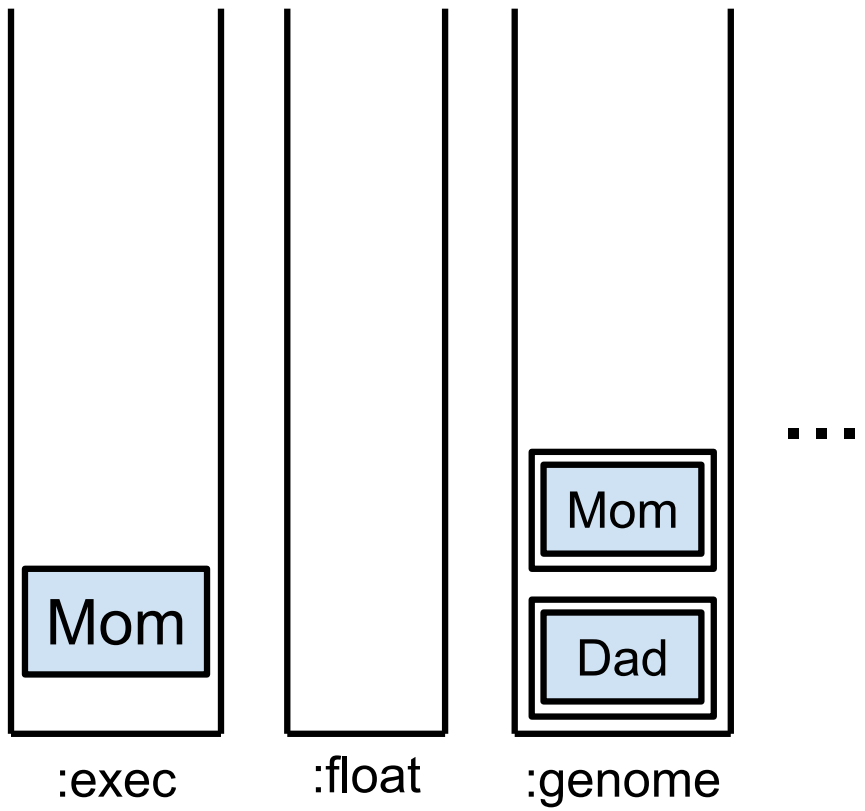
AutoDoG – reproduction

AutoDoG – reproduction

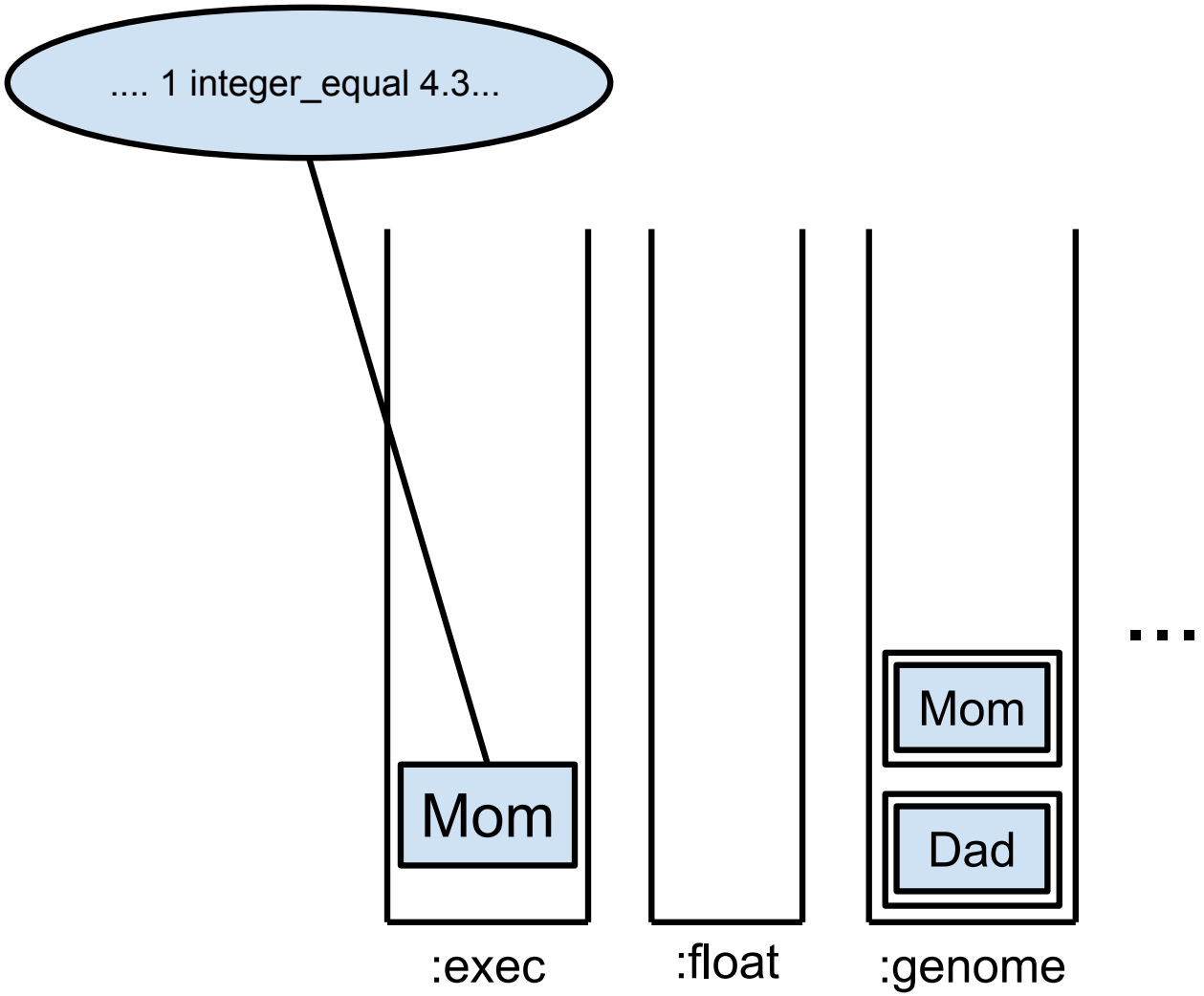
AutoDoG – reproduction



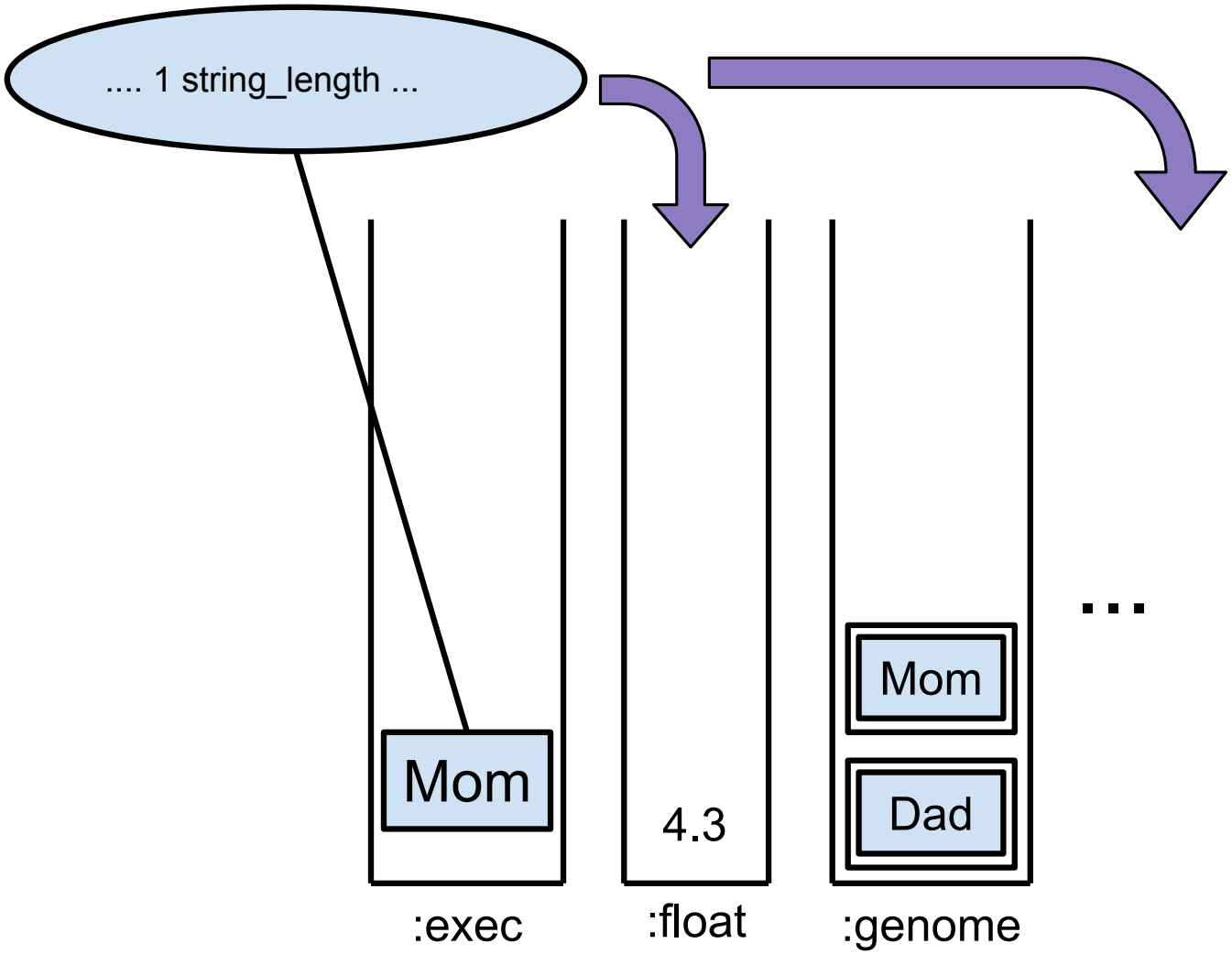
AutoDoG – reproduction



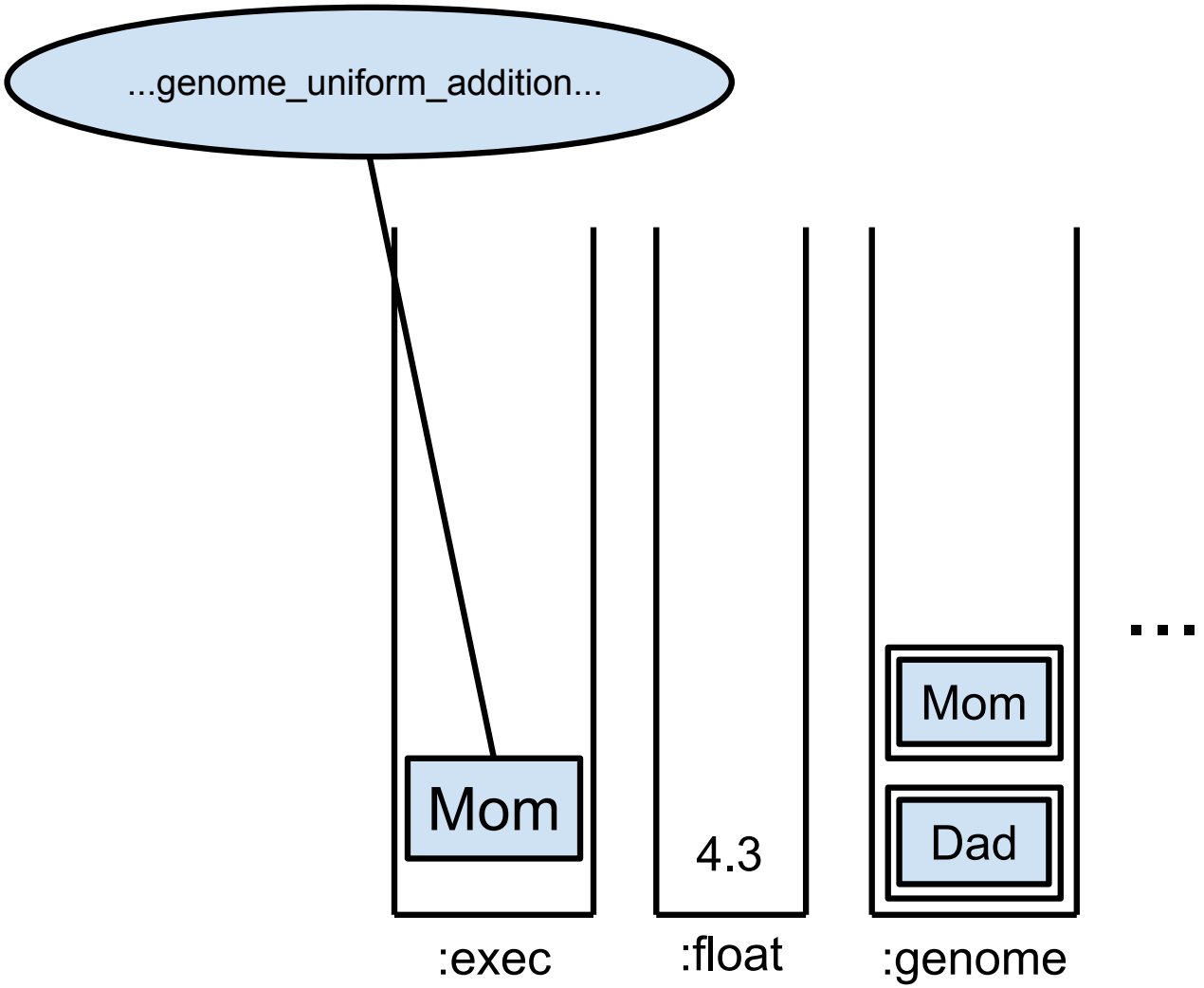
AutoDoG – reproduction



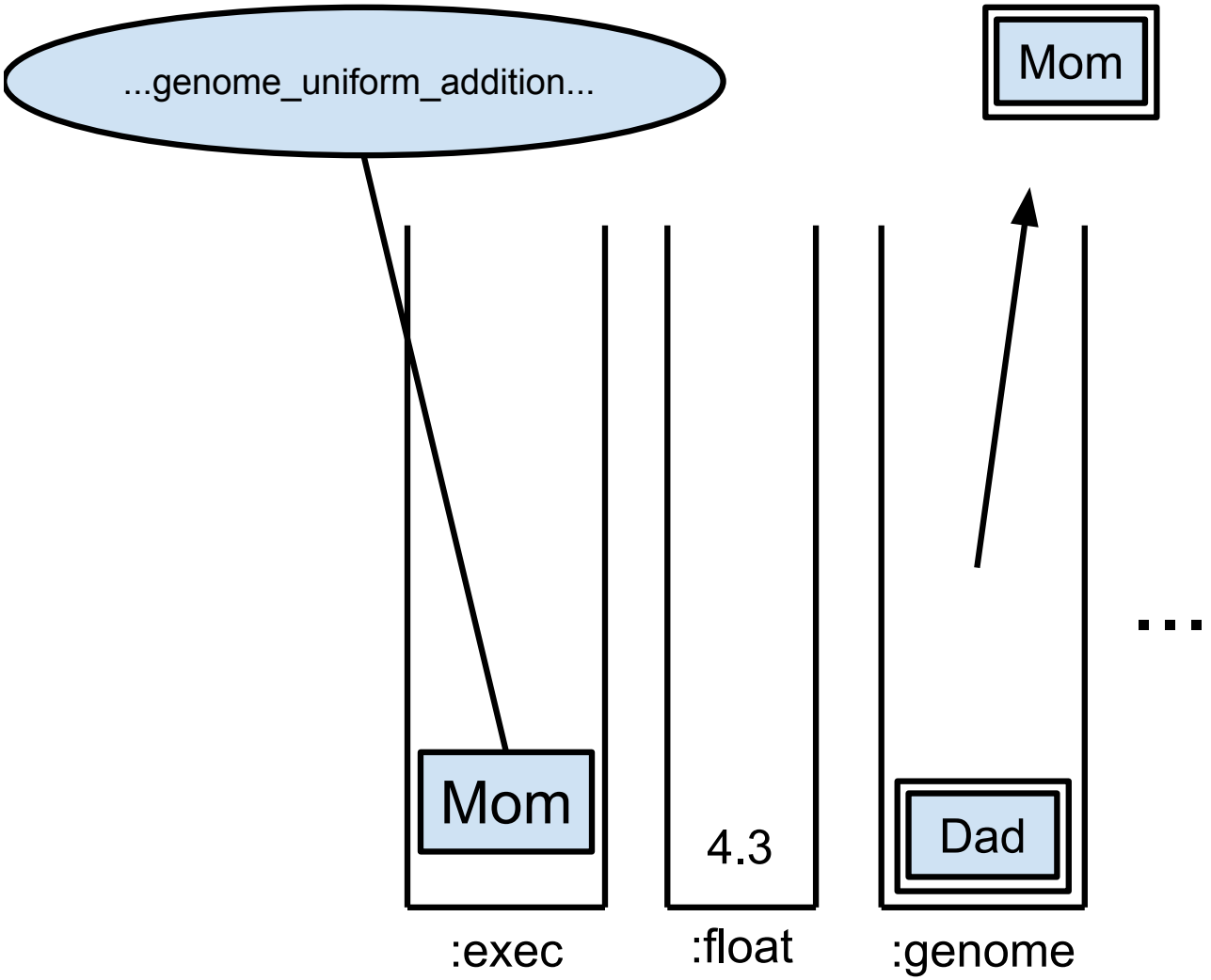
AutoDoG – reproduction



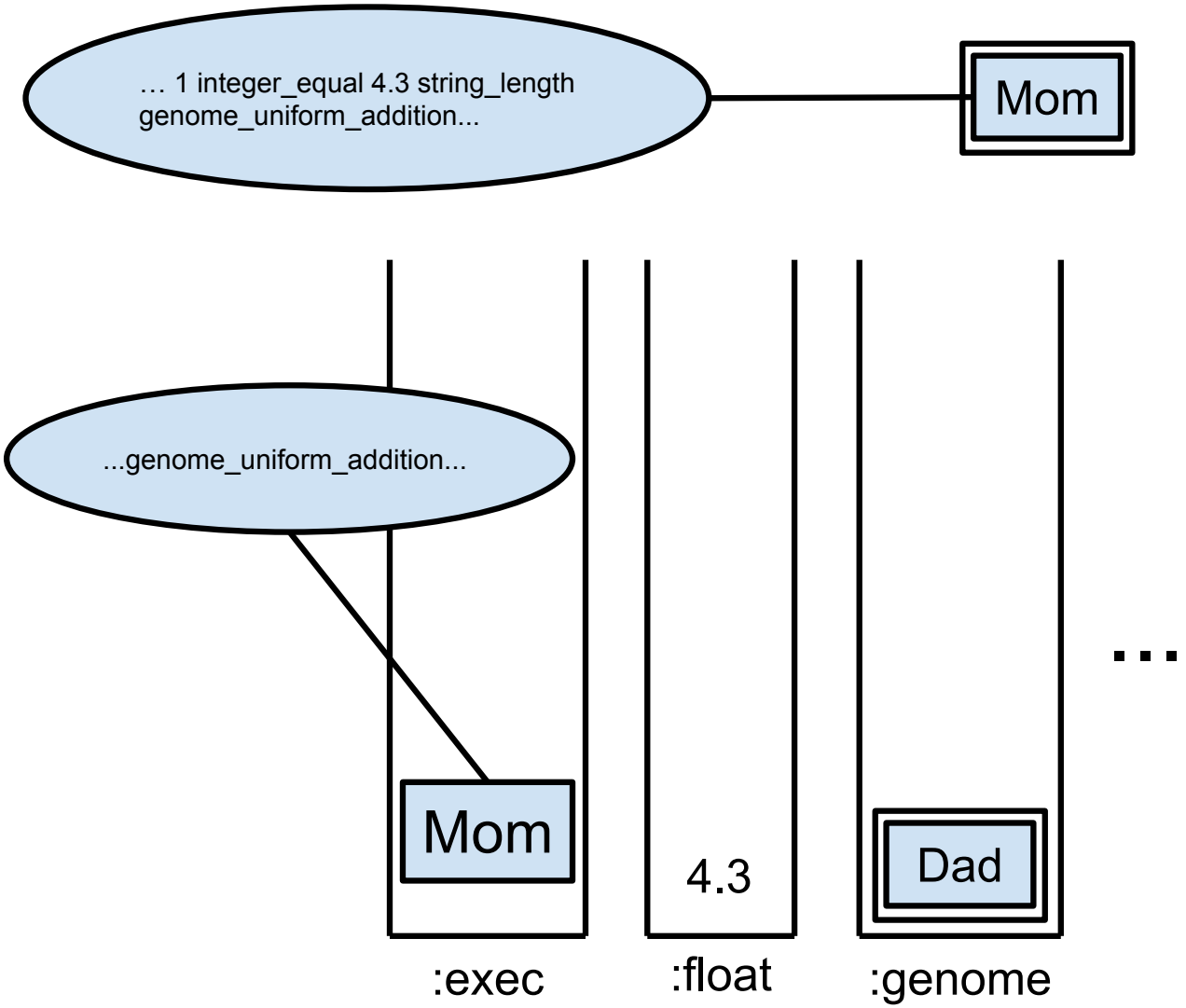
AutoDoG – reproduction



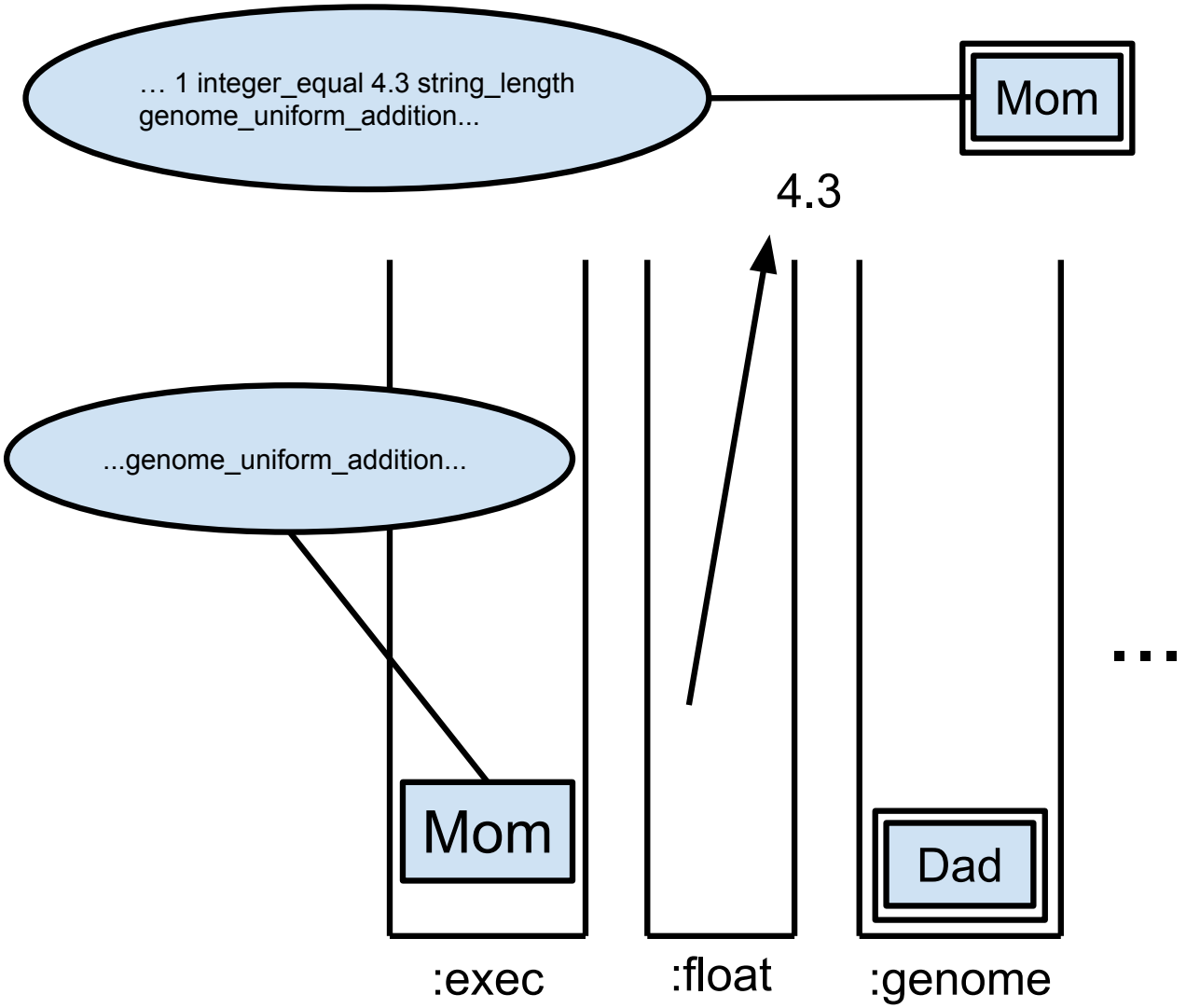
AutoDoG – reproduction



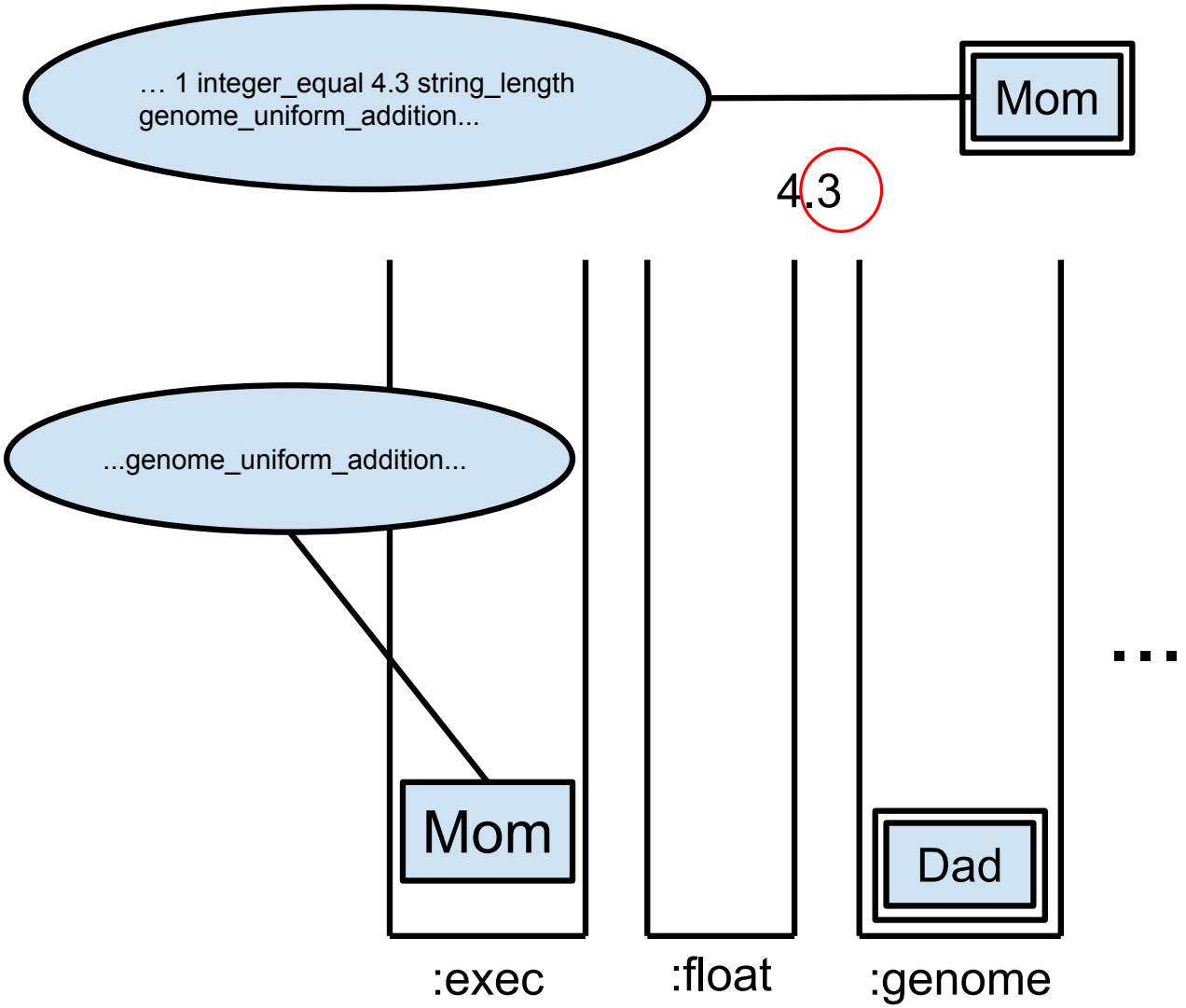
AutoDoG – reproduction



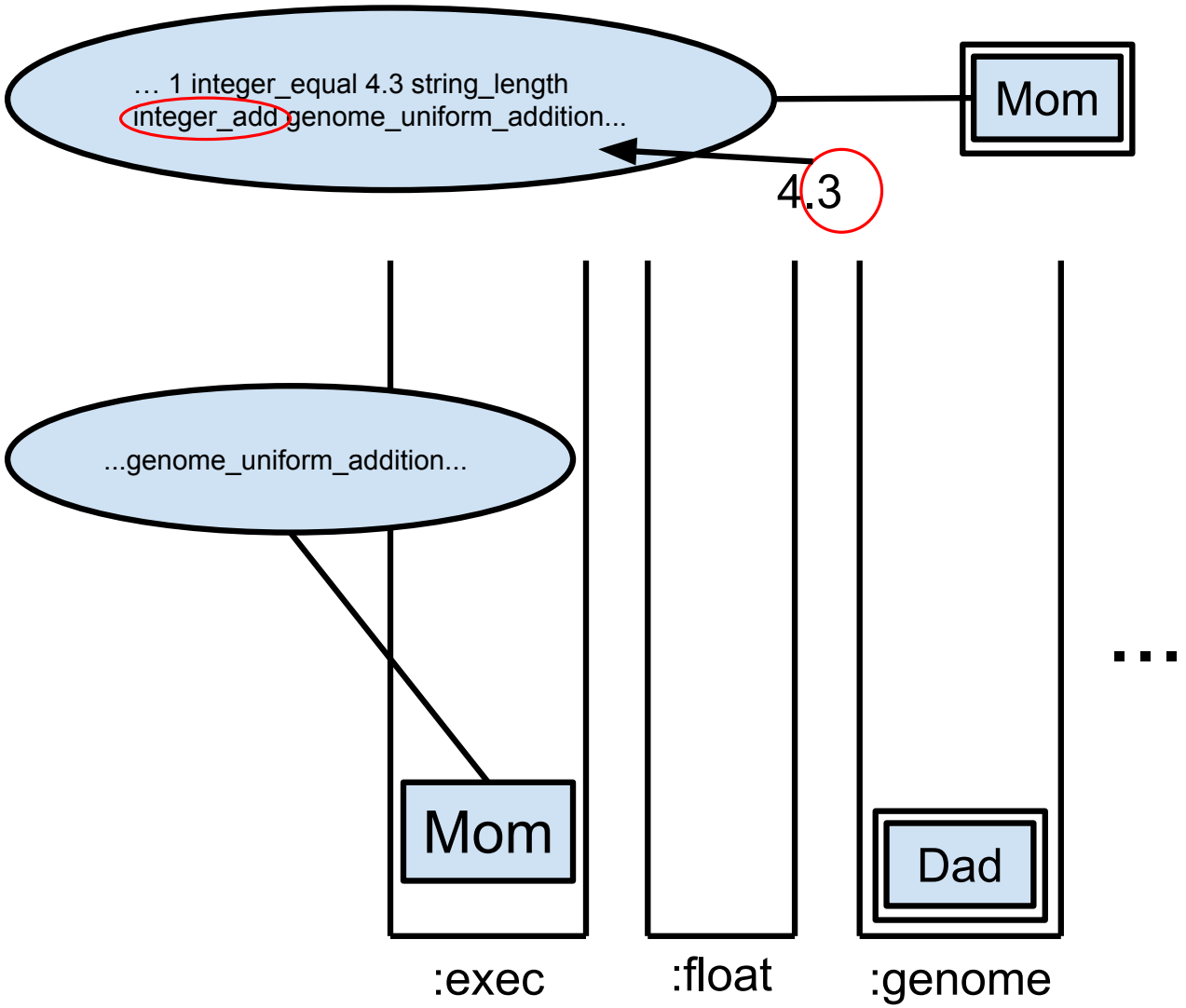
AutoDoG – reproduction



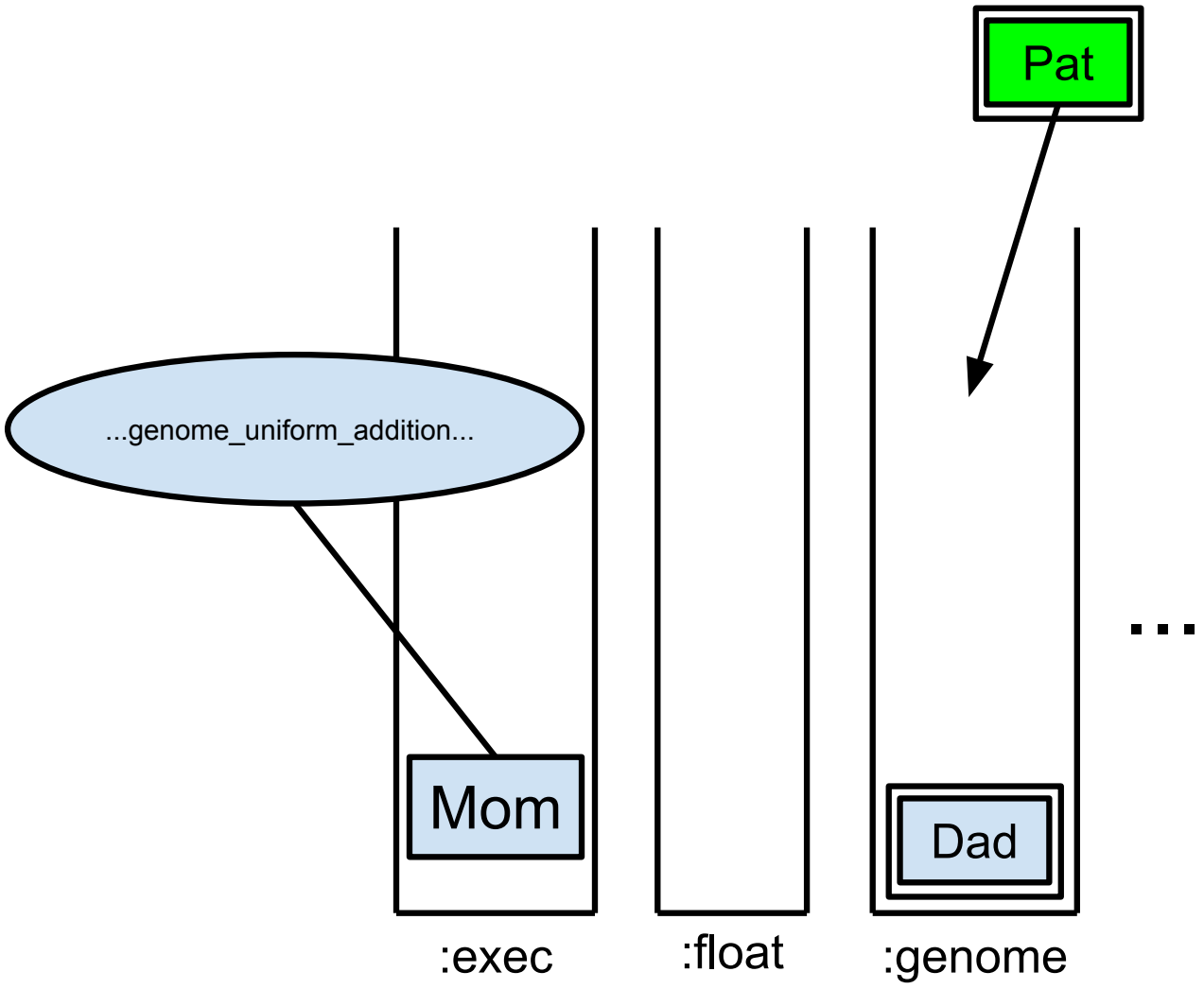
AutoDoG – reproduction



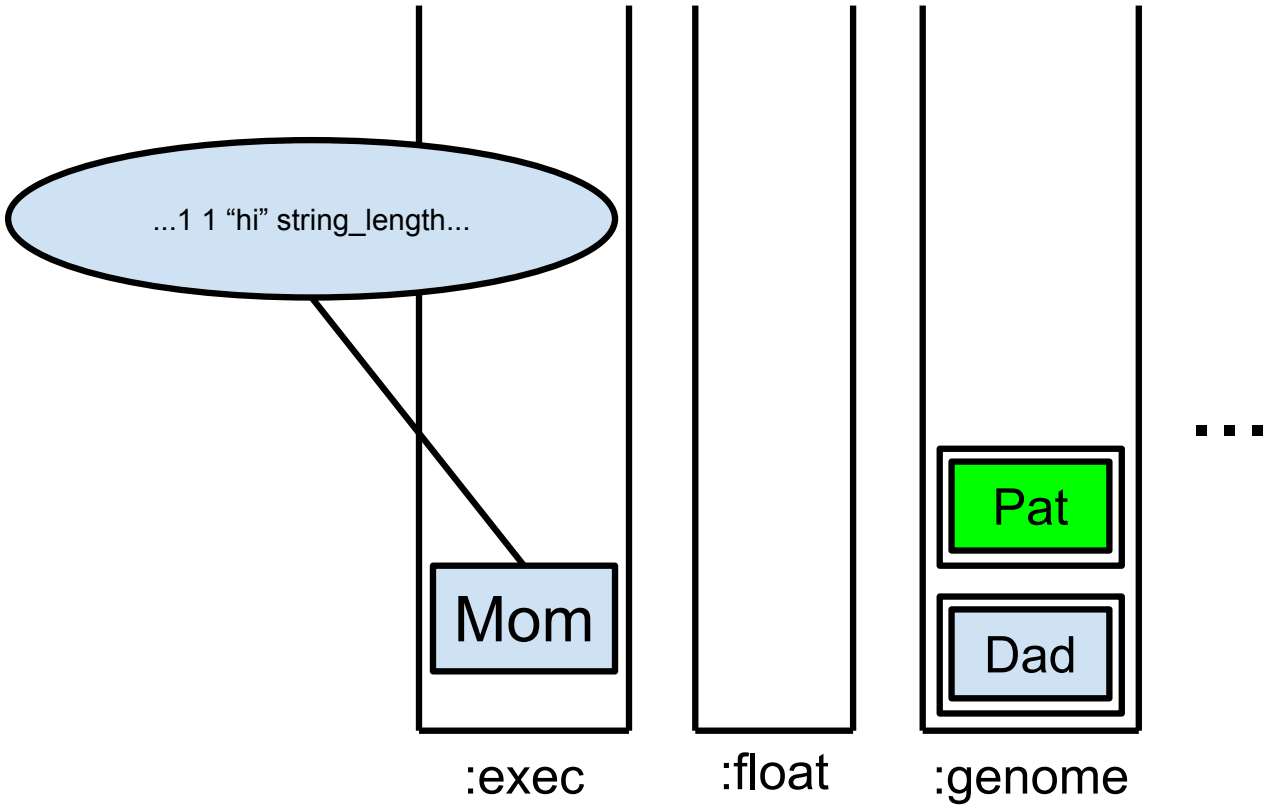
AutoDoG – reproduction



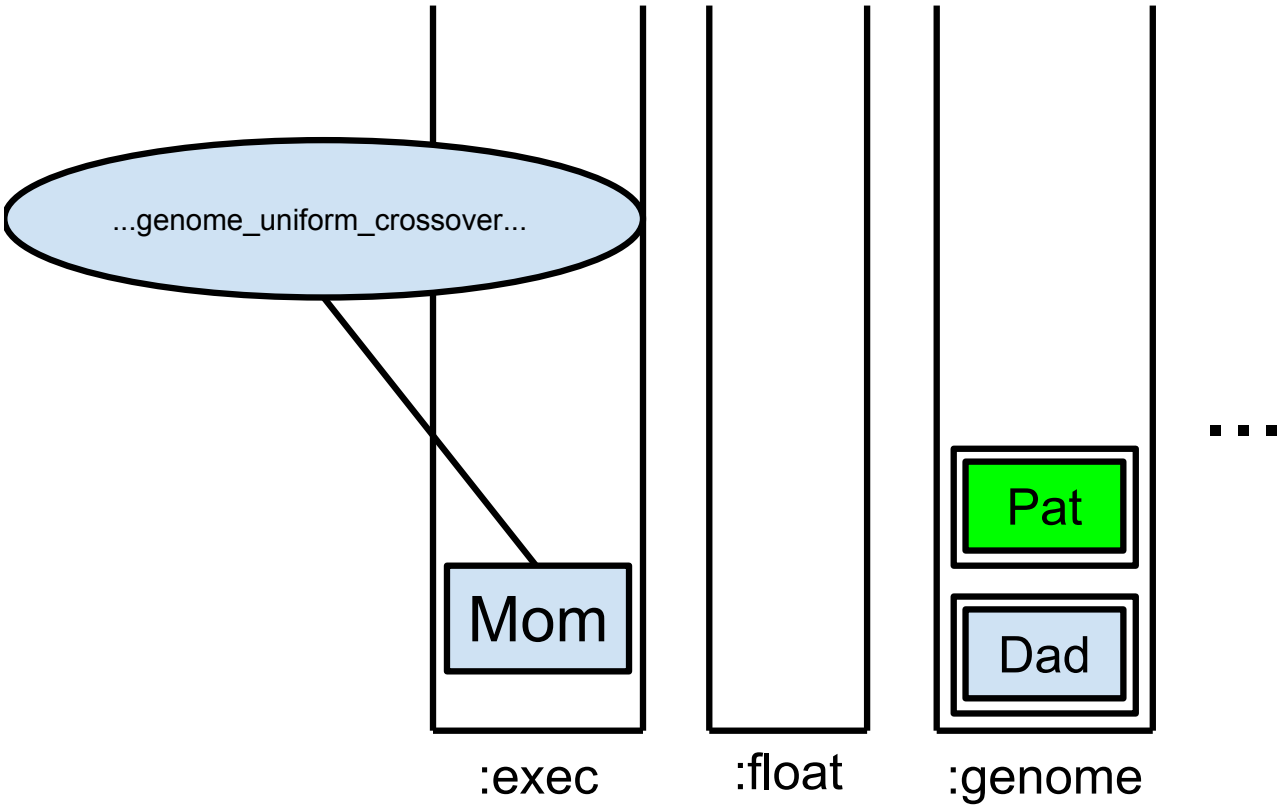
AutoDoG – reproduction



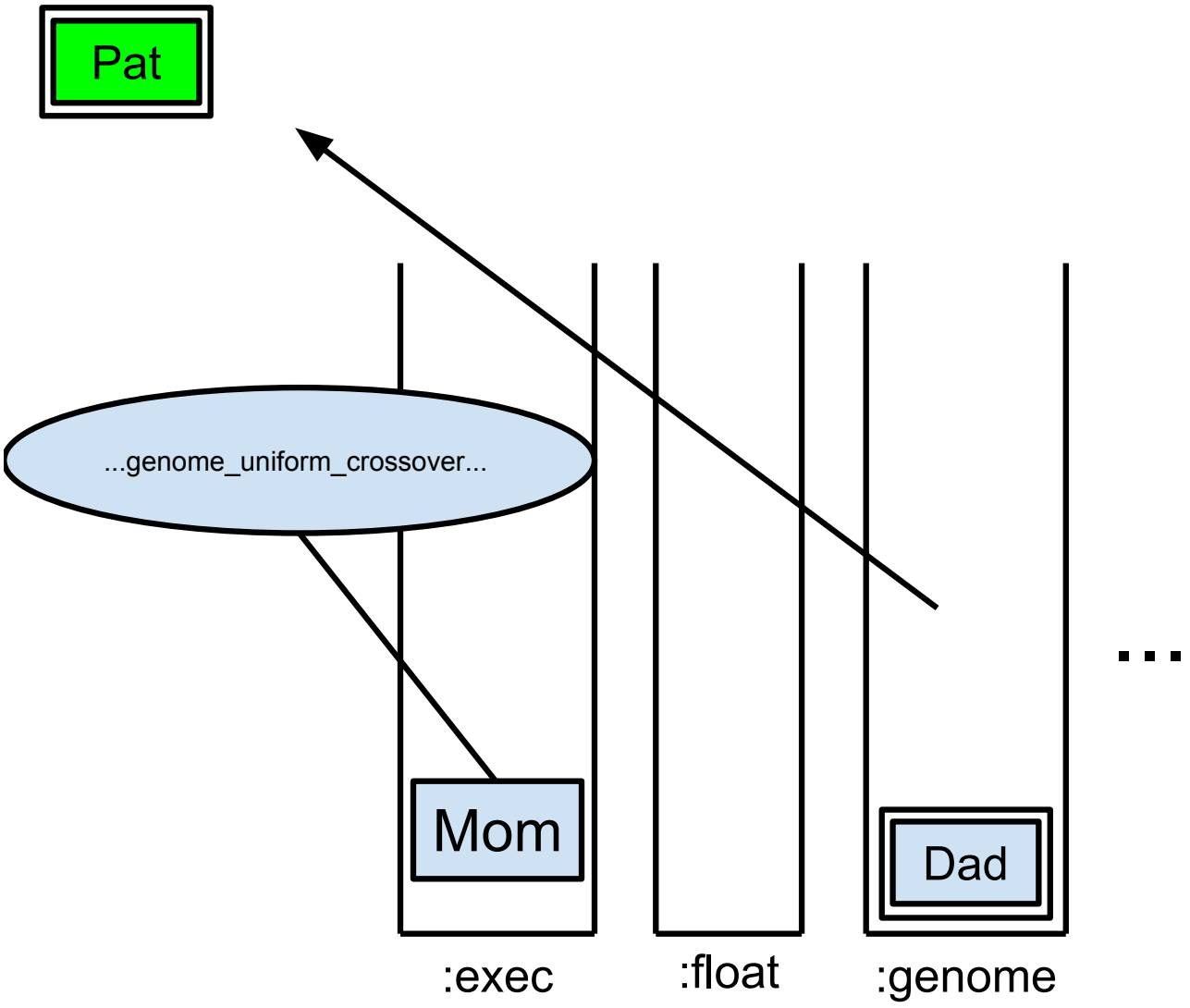
AutoDoG – reproduction



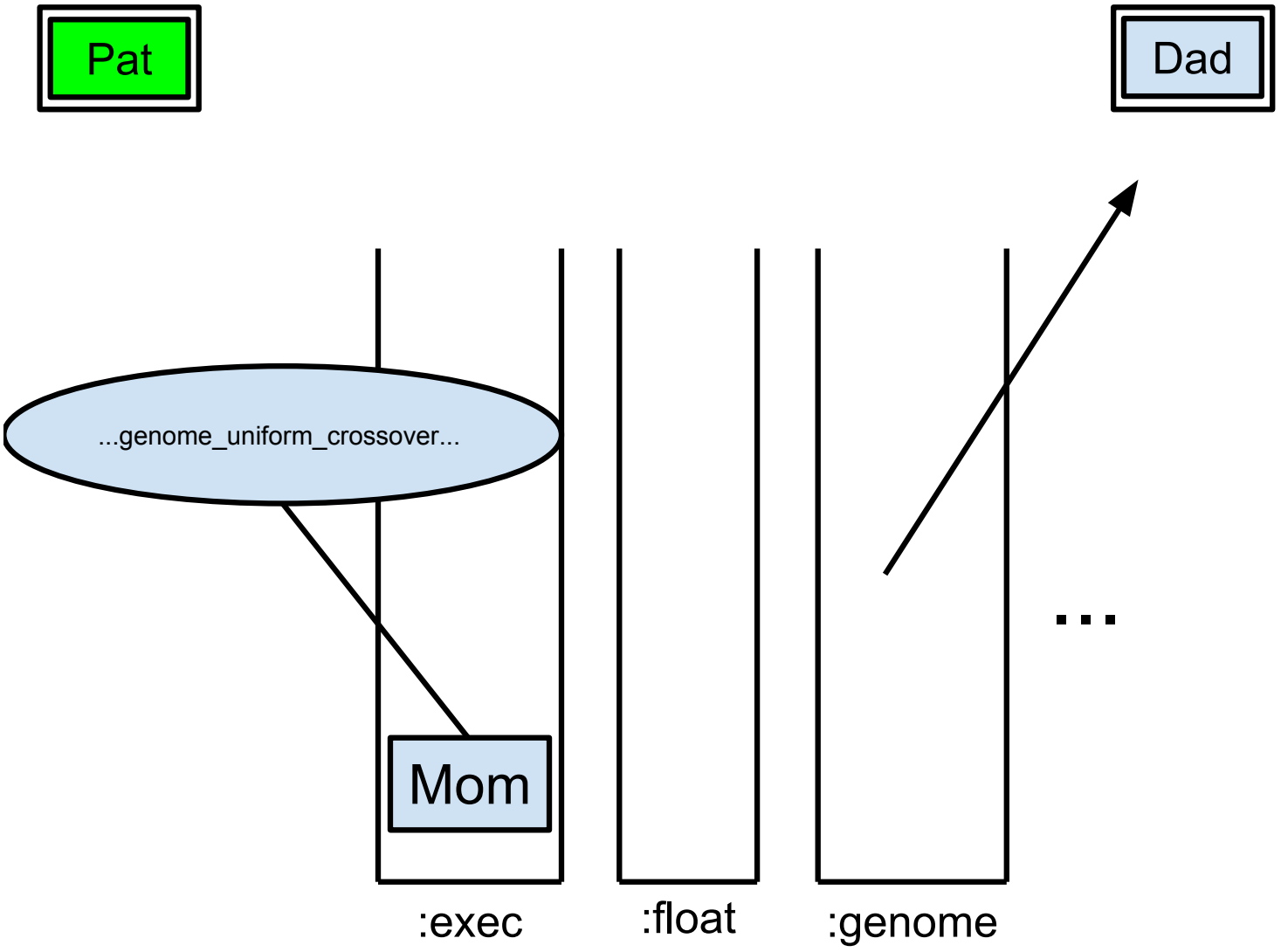
AutoDoG – reproduction



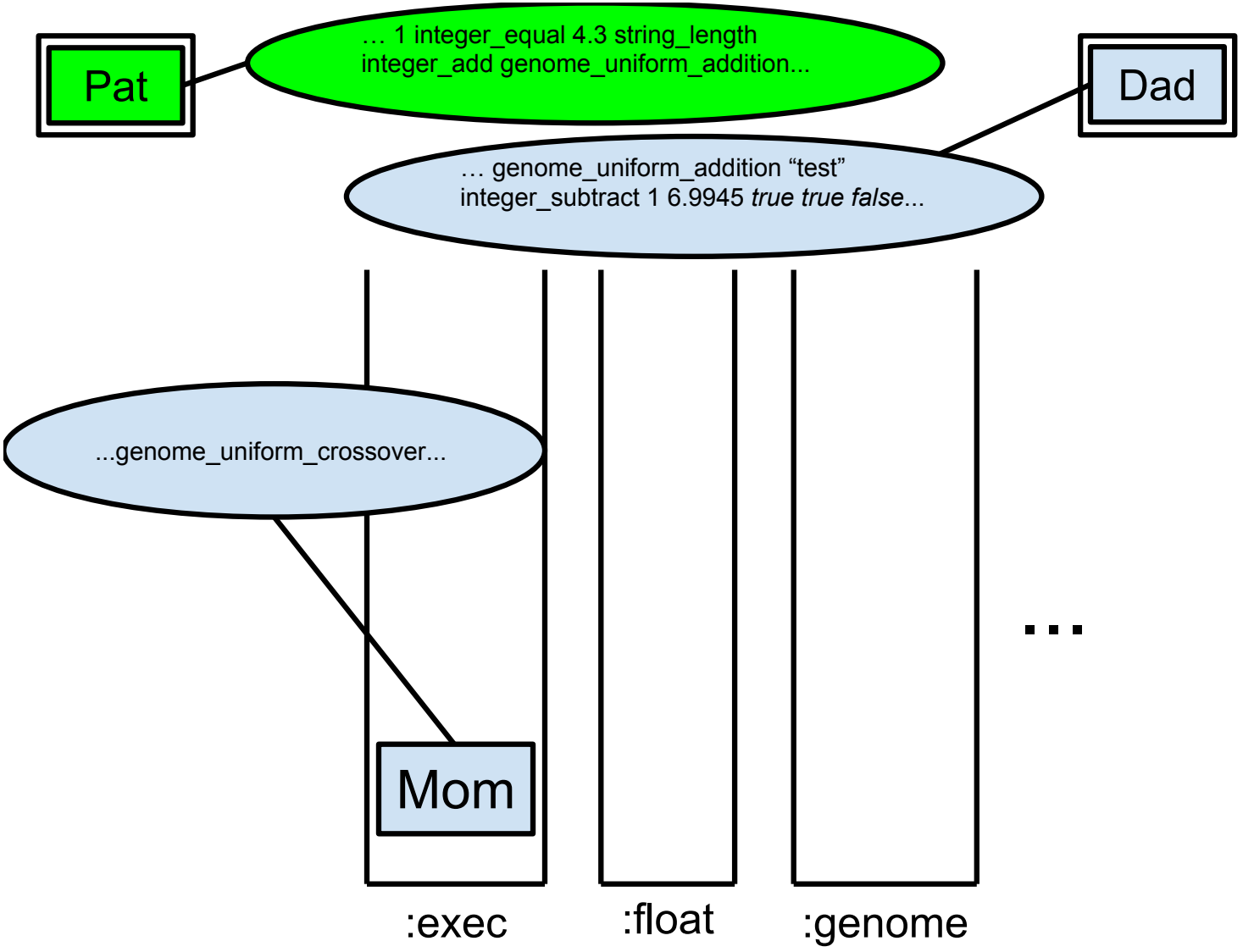
AutoDoG – reproduction



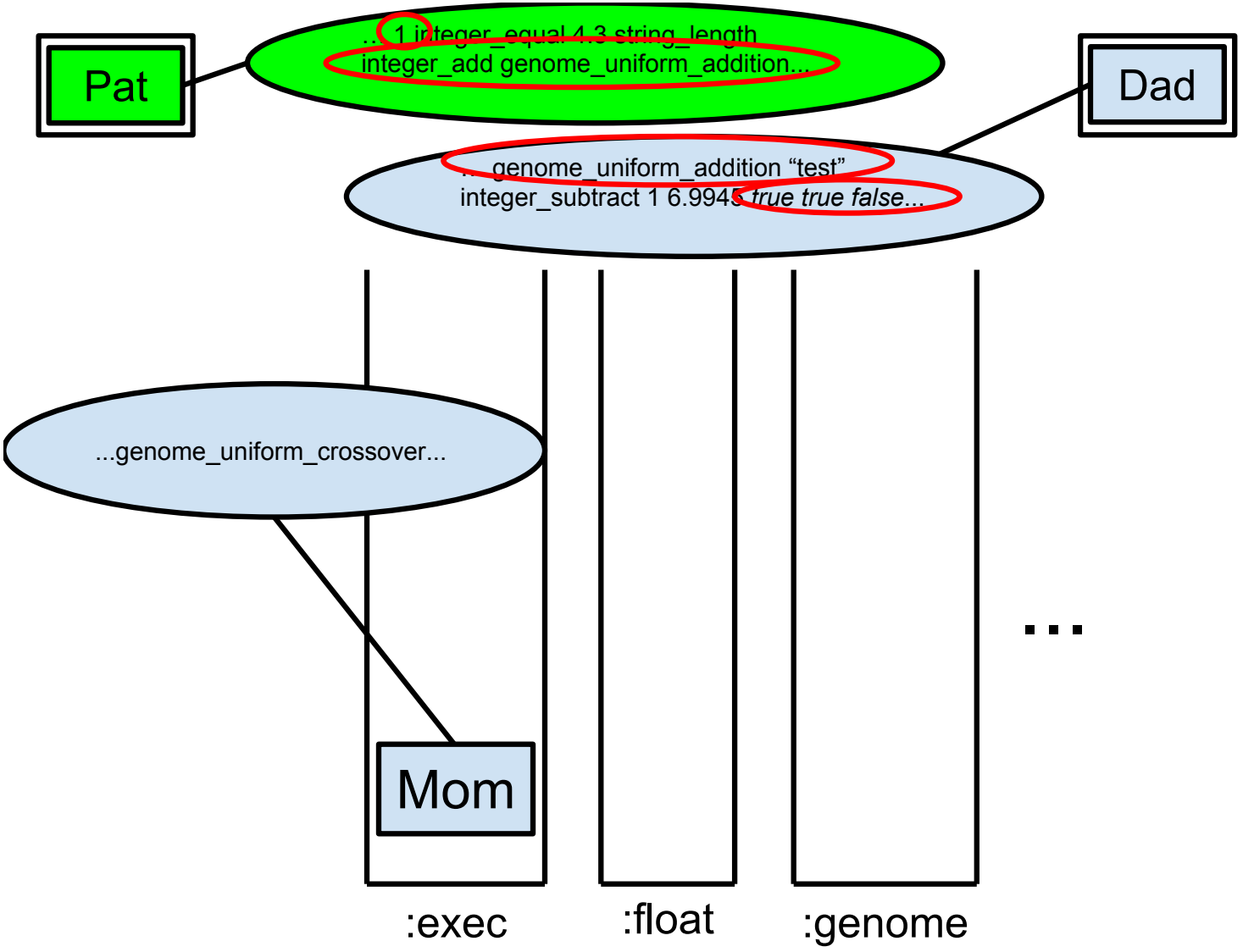
AutoDoG – reproduction



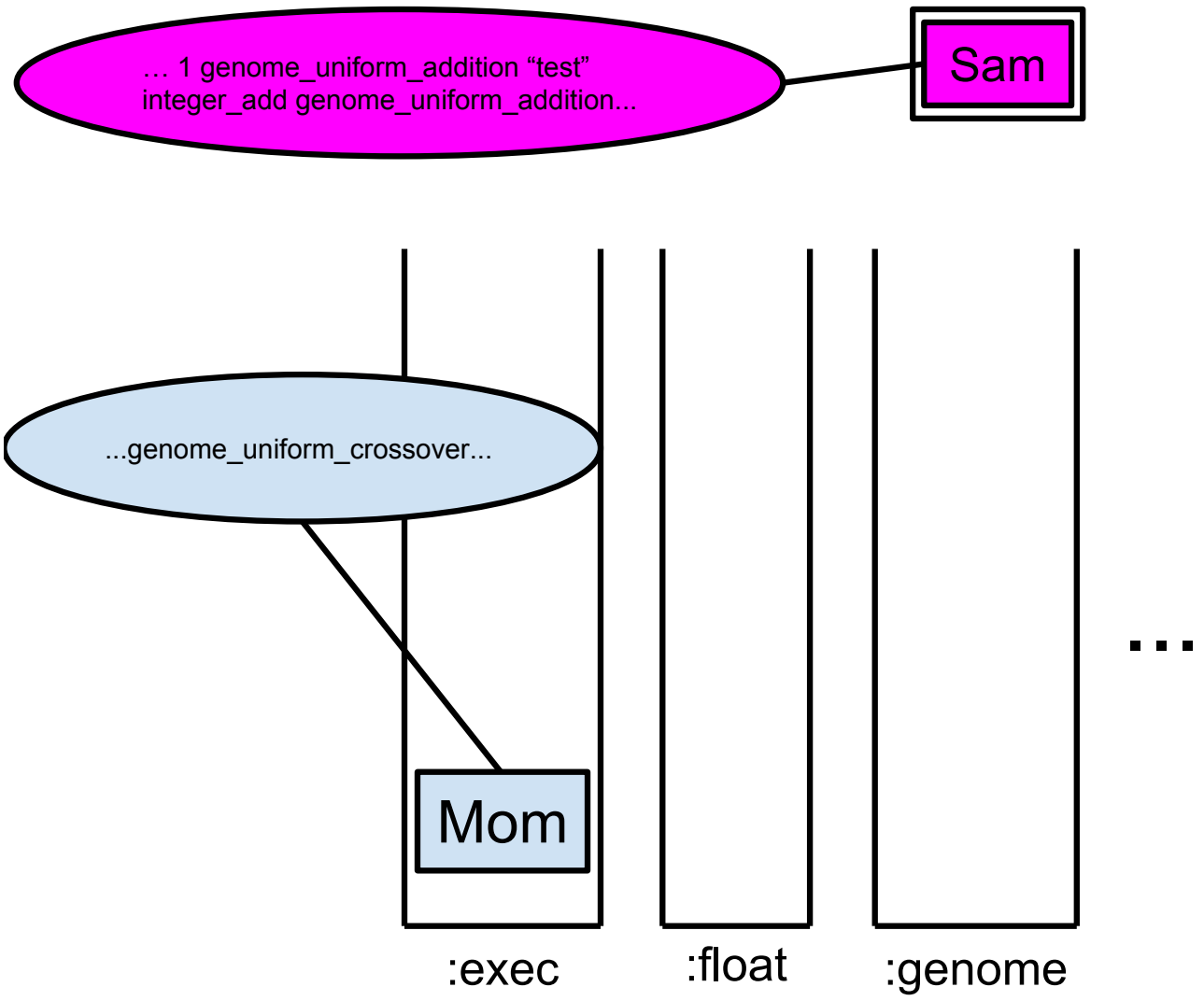
AutoDoG – reproduction



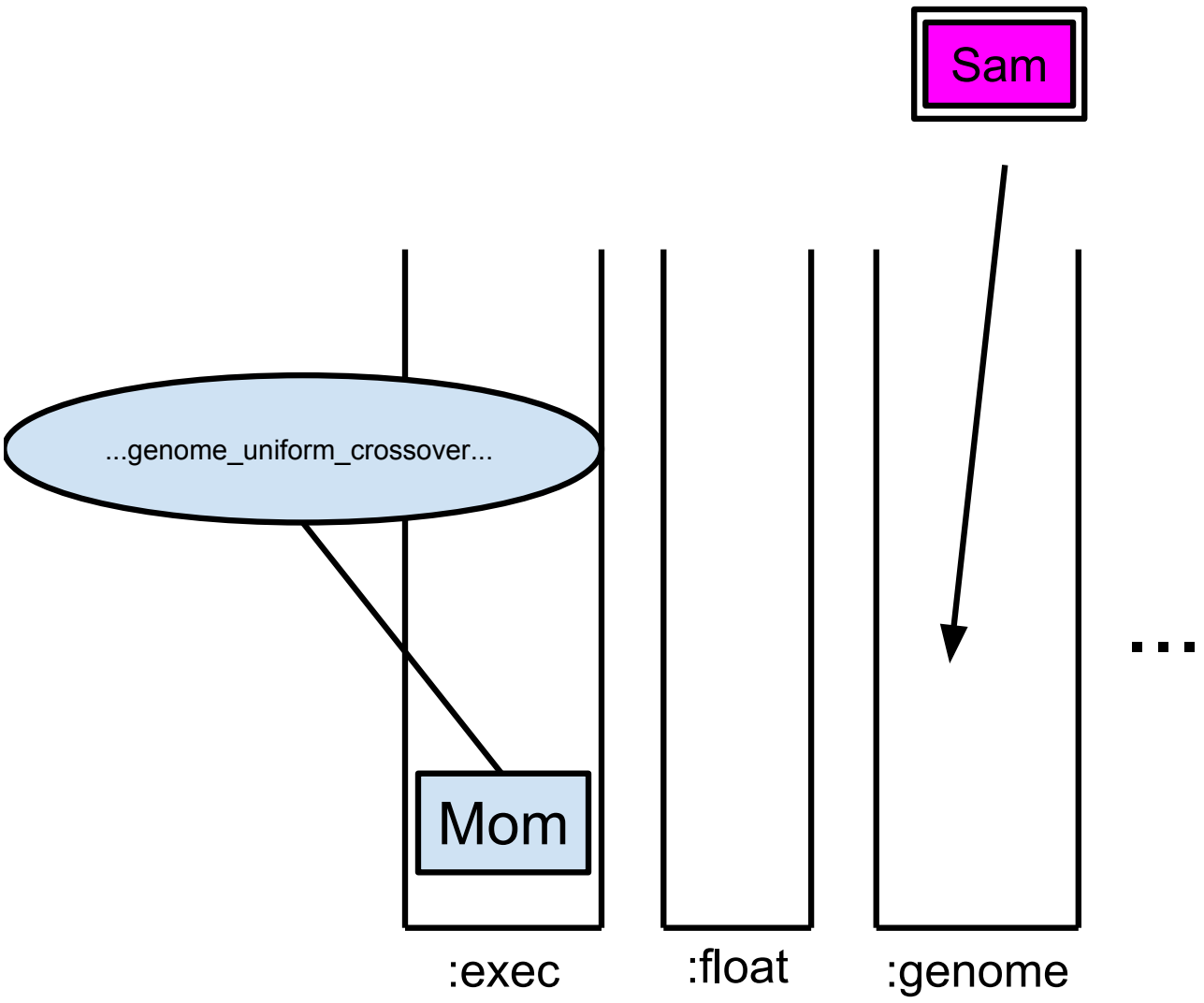
AutoDoG – reproduction



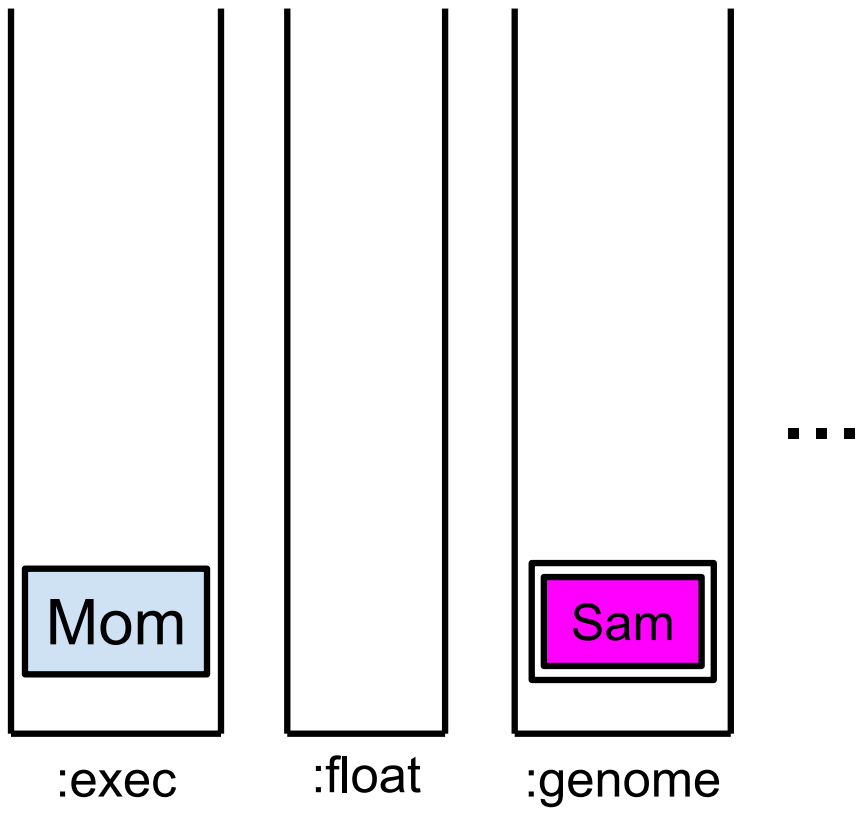
AutoDoG – reproduction



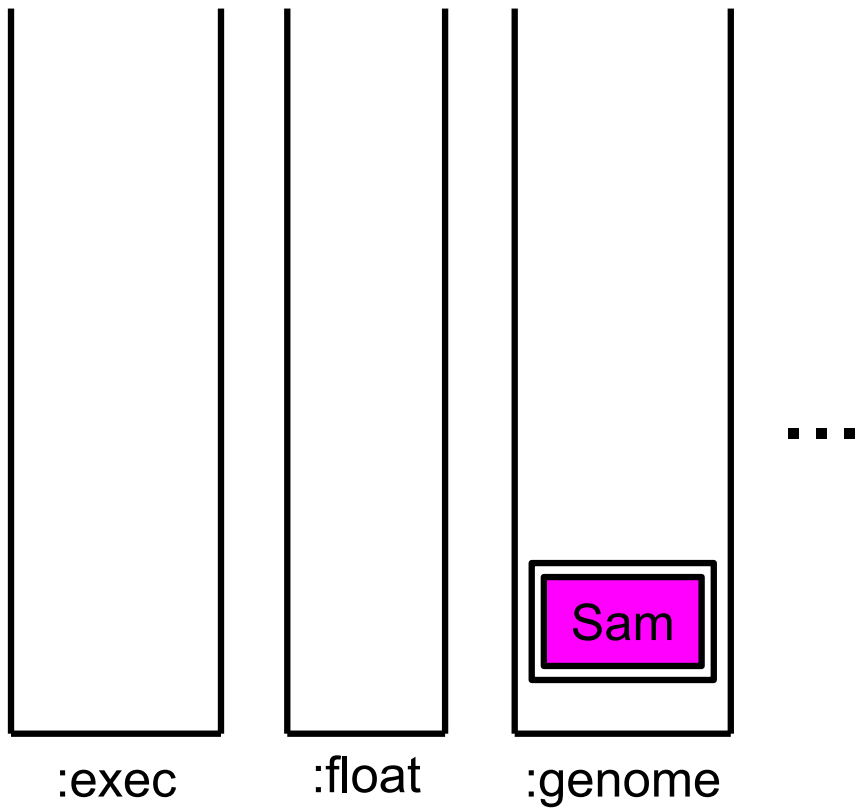
AutoDoG – reproduction



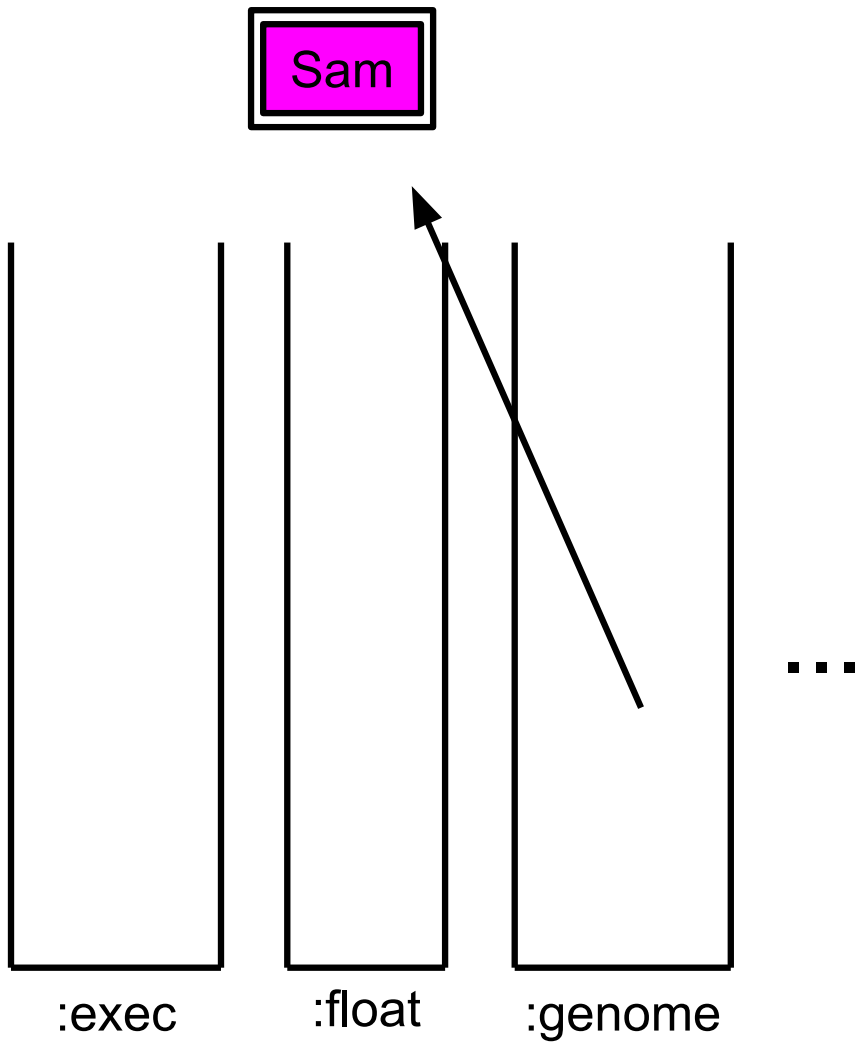
AutoDoG – reproduction



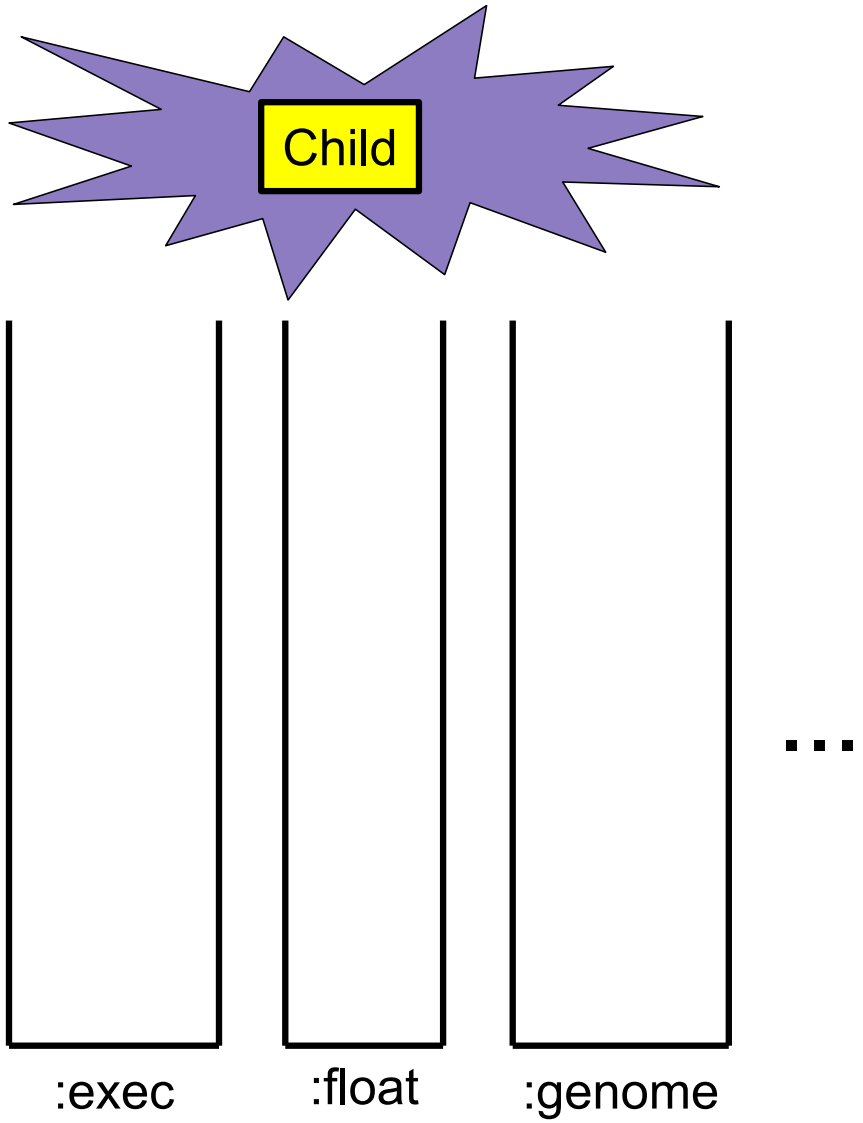
AutoDoG – reproduction



AutoDoG – reproduction



AutoDoG – reproduction



AutoDoG – reproduction

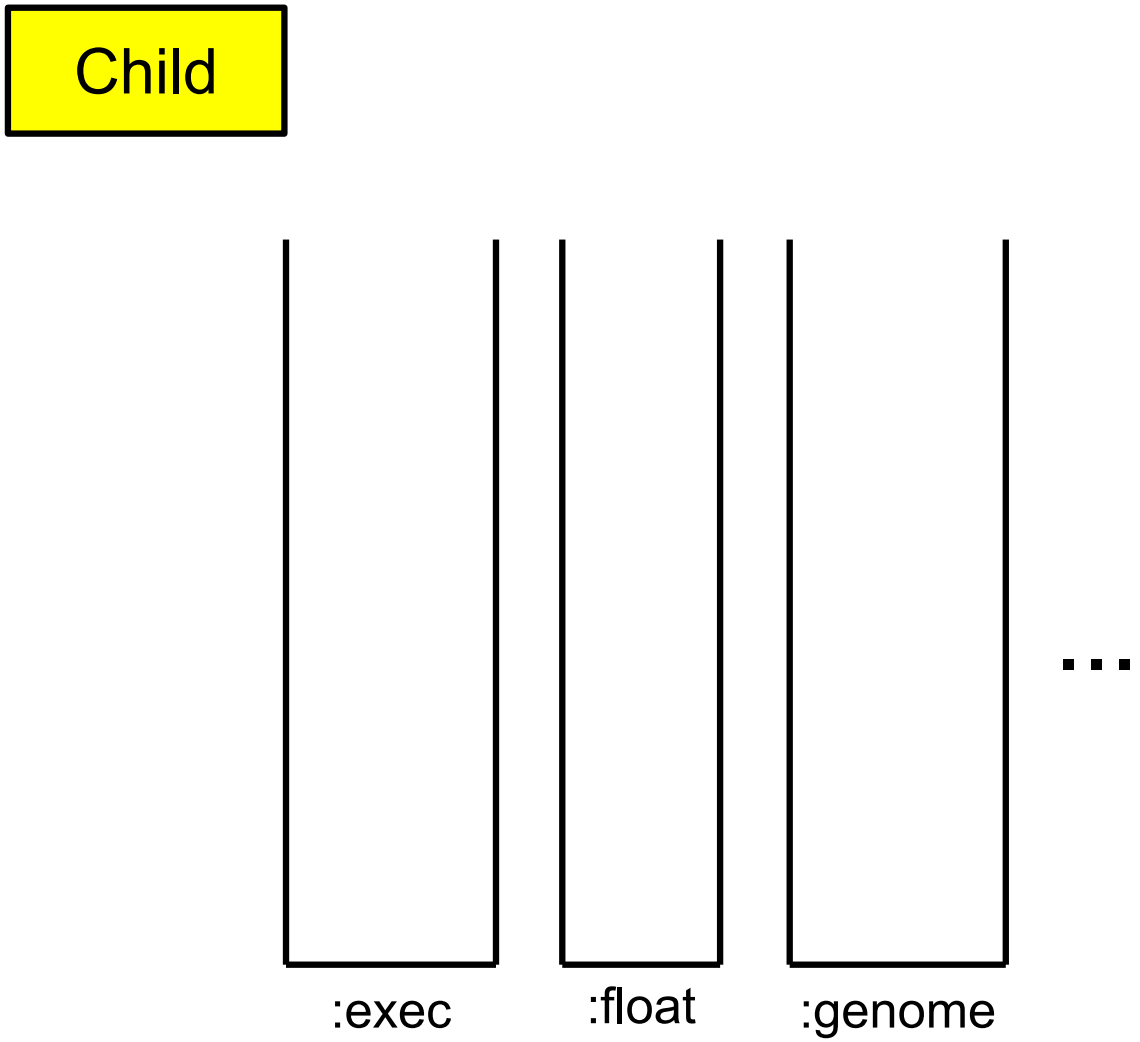
Now Child moves on to the next generation, right?

AutoDoG – reproduction

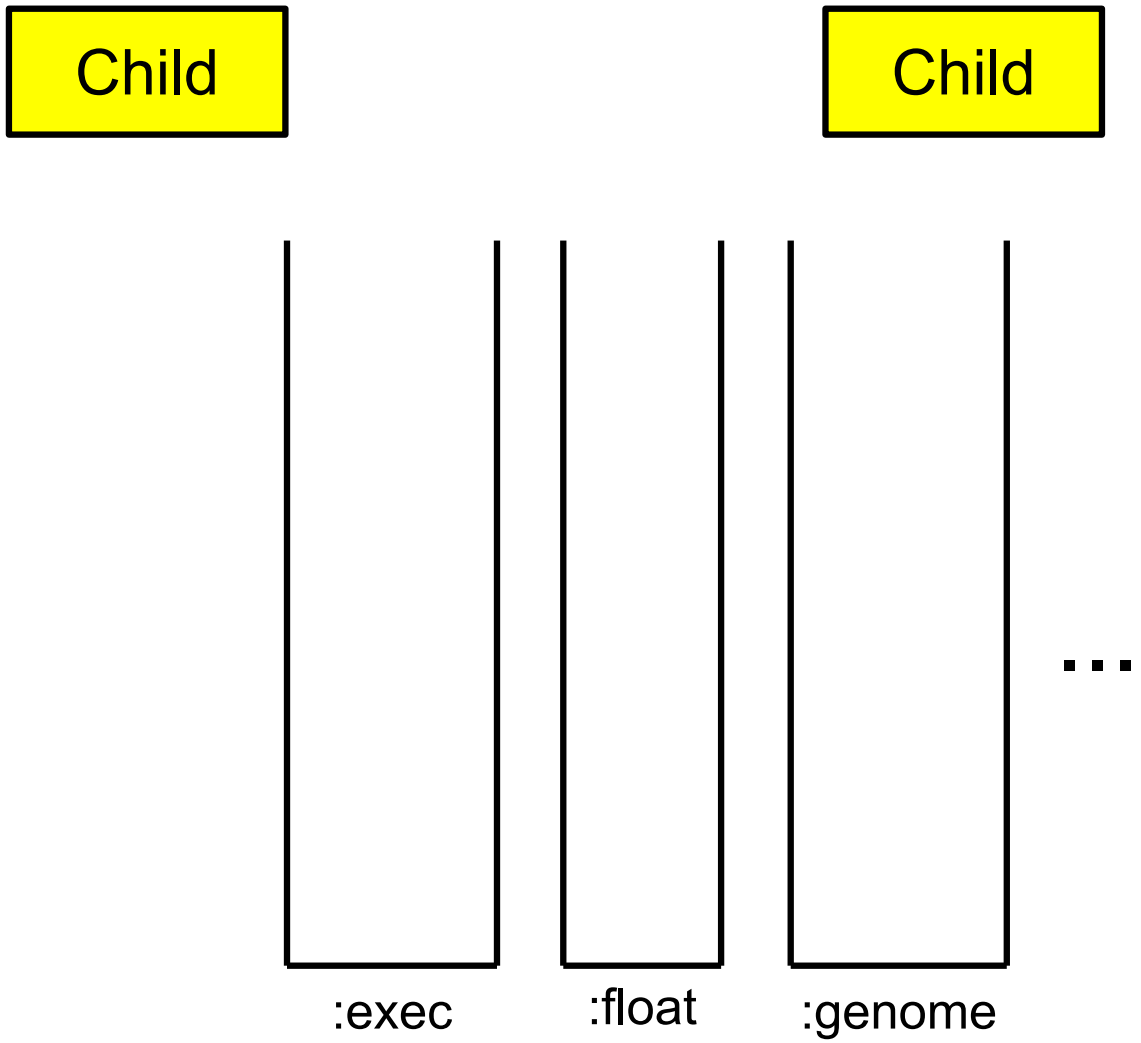
Now Child moves on to the next generation, right?

WRONG!

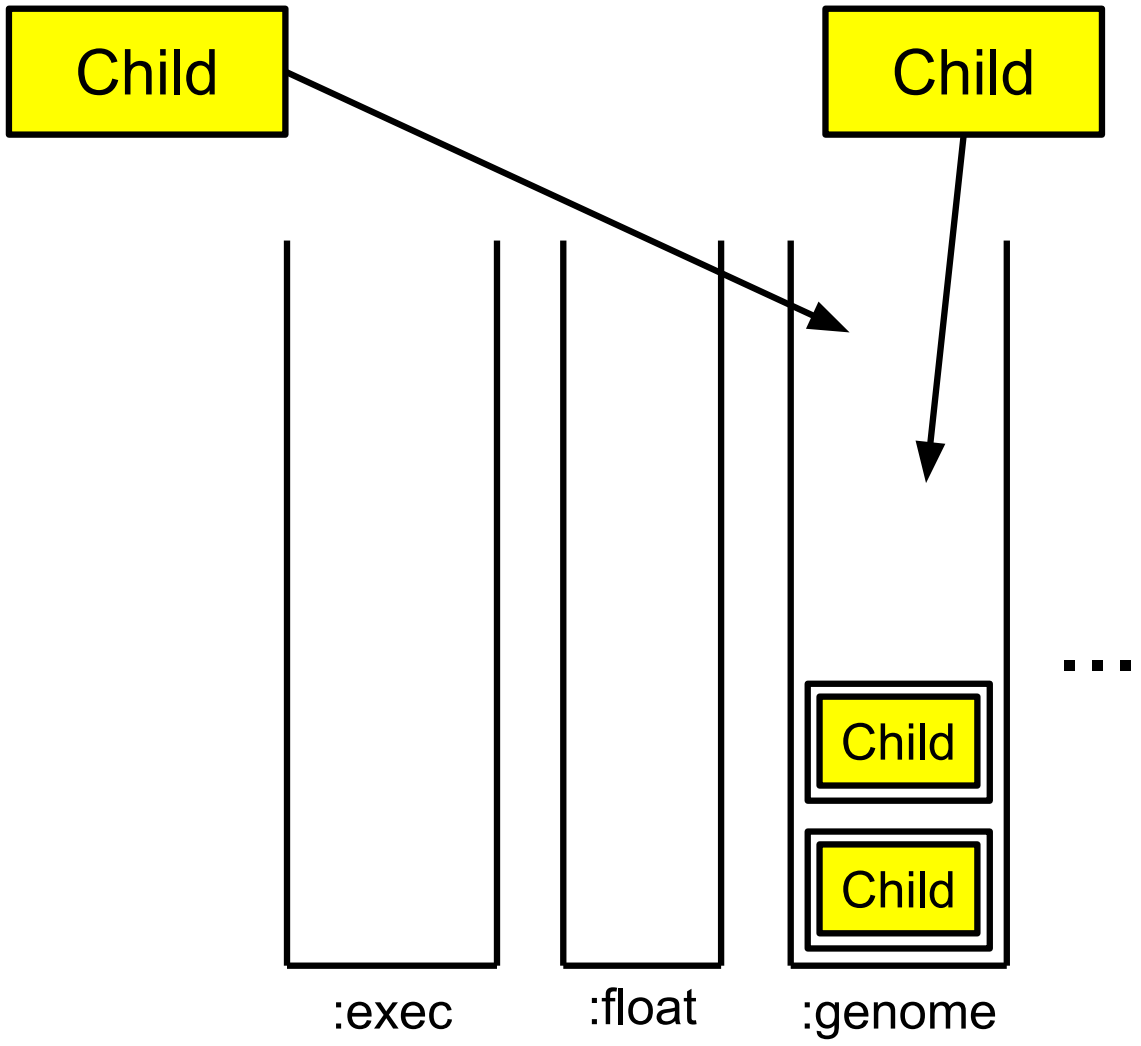
AutoDoG – diversification test



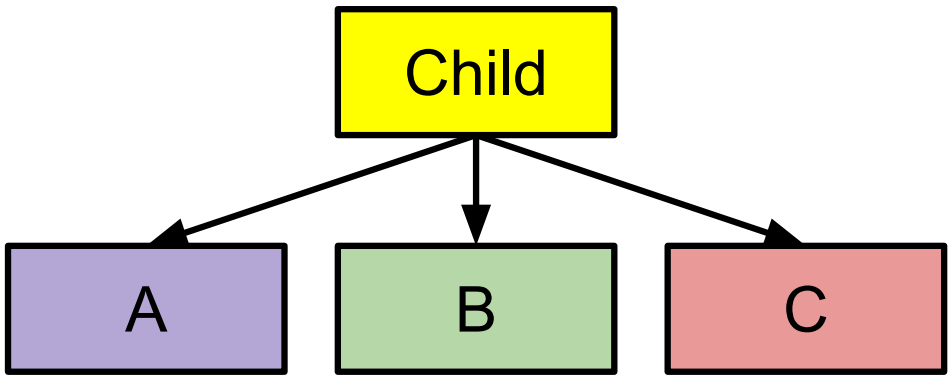
AutoDoG – diversification test



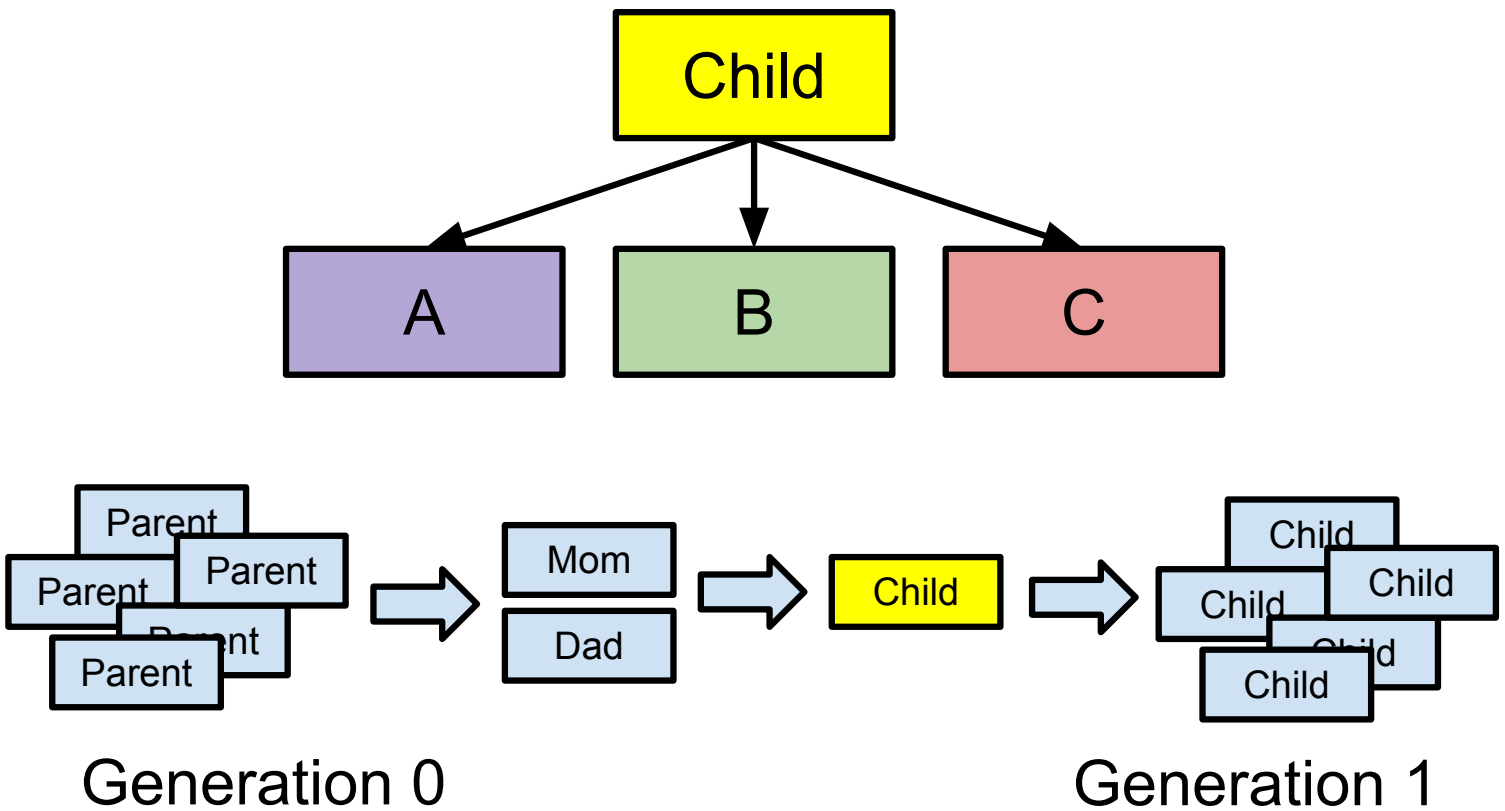
AutoDoG – diversification test



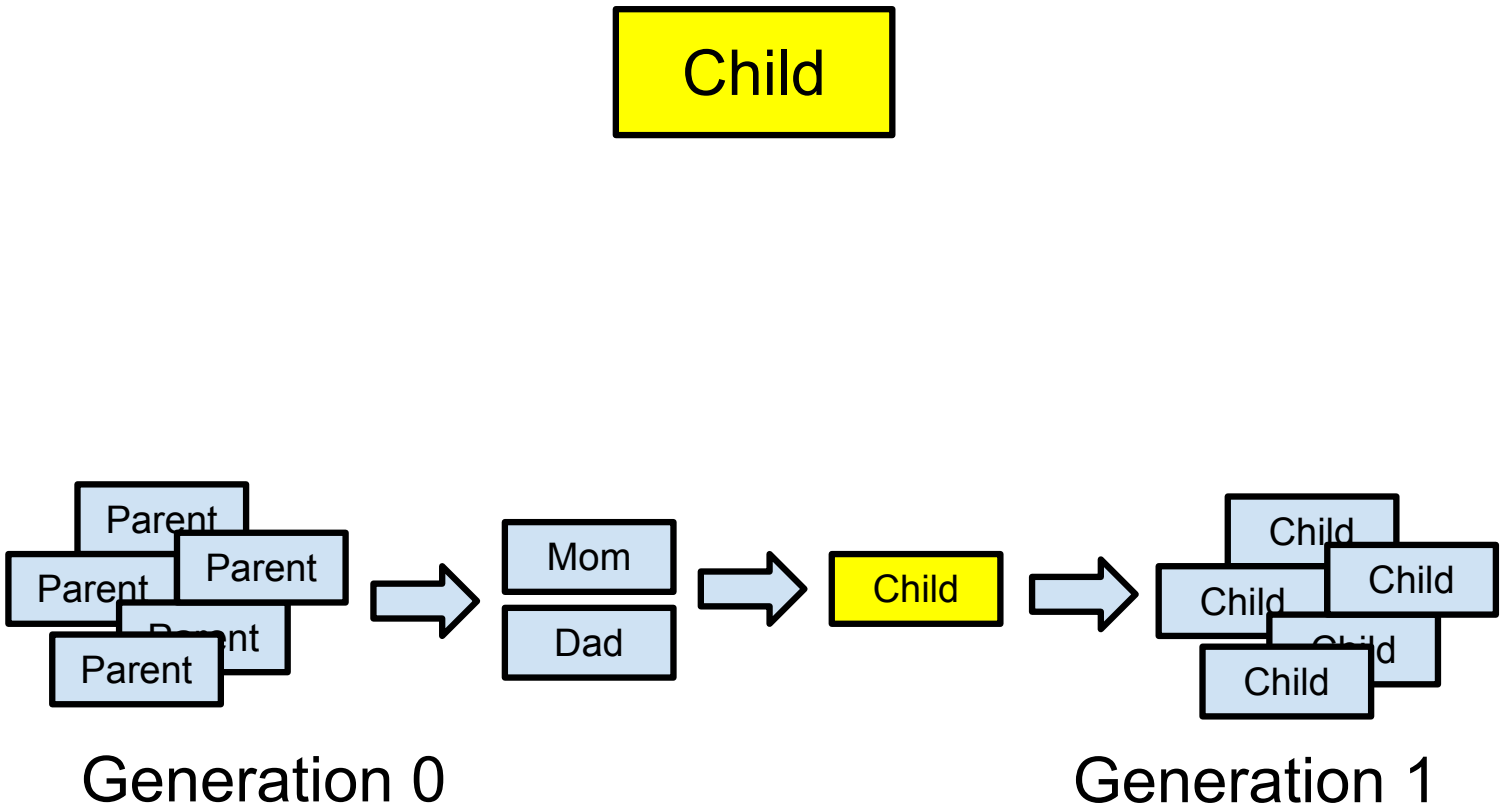
AutoDoG – diversification test



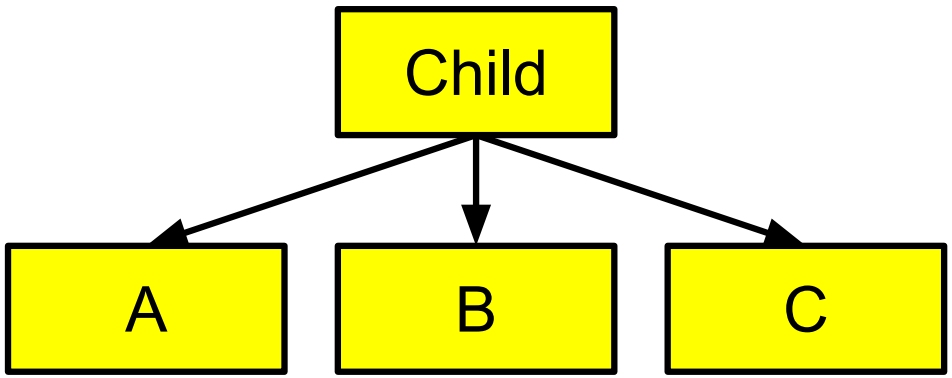
AutoDoG – diversification test



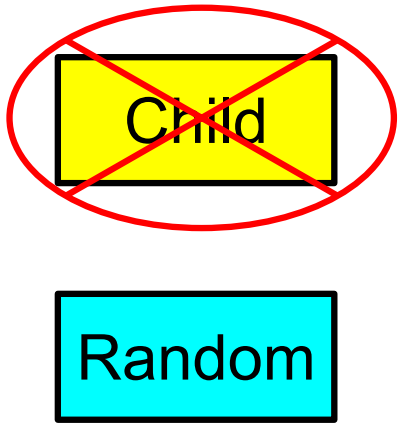
AutoDoG – diversification test



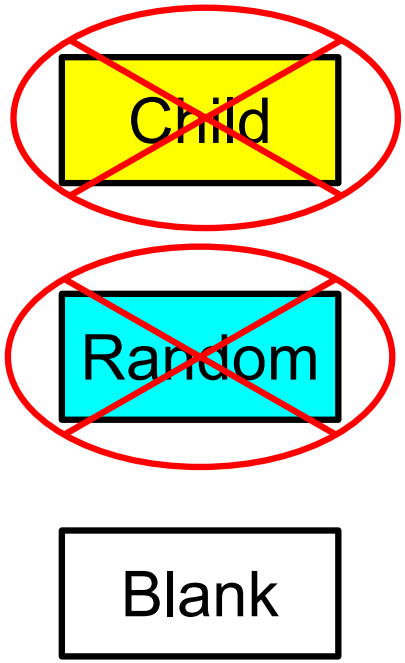
AutoDoG – diversification test



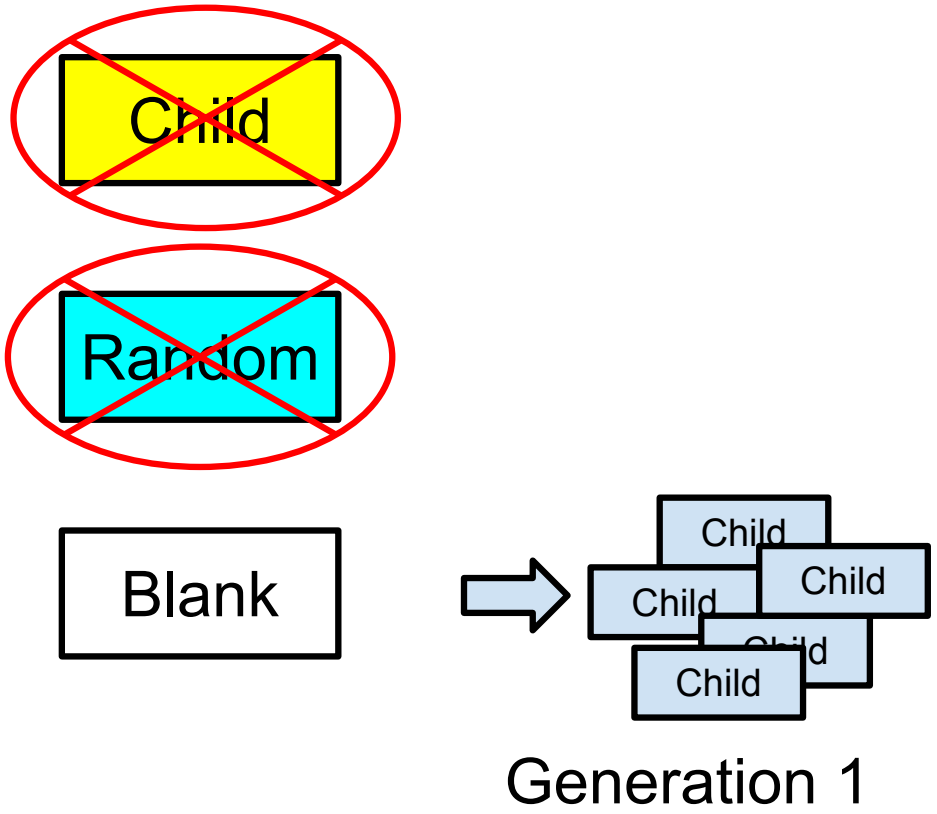
AutoDoG – diversification test



AutoDoG – diversification test



AutoDoG – diversification test



Results of AutoDoG

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

Results of AutoDoG

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

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

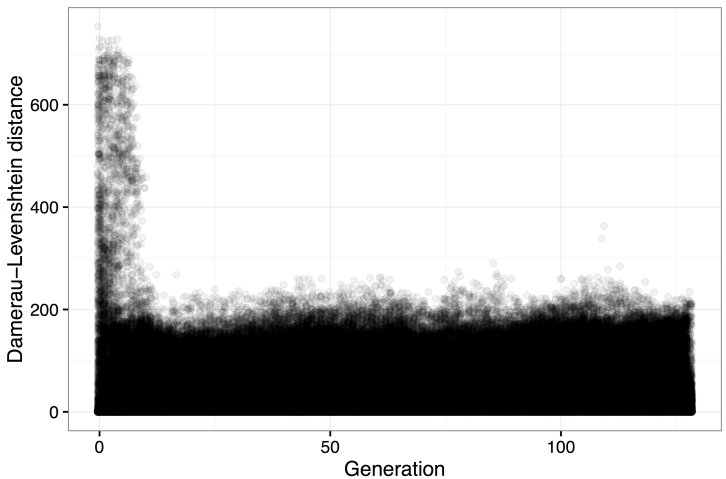
AutoDoG solves RSWN 5–10% of the time, where PushGP solves this problem 50% of the time.

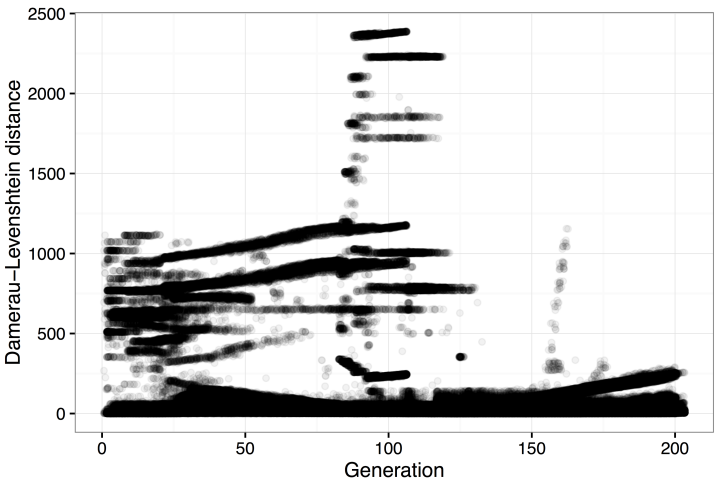
Results of AutoDoG

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

Summary

- Genetic programming hyper-heuristics (GPHH) for heuristic/program evolution

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

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

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

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!

Acknowledgments

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

Thanks for coming!

References


S. Harris, T. Bueter, and D. R. Tauritz.
A Comparison of Genetic Programming Variants for Hyper-Heuristics.
In Sara Silva, editors, *GECCO '15*, pages 1043–1050, Madrid, Spain 2015.


L. Spector, N. F. McPhee, T. Helmuth, M. M. Casale, and J. Oks.
Evolution Evolves with Autoconstruction.
In T. Friedrich, *et al*, editors, *GECCO '16*, pages 1349–1356, Denver, Colorado, USA 2016.

See my paper for additional references.

Questions?

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