Genetic Programming—GP

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- That is given some examples of data we want to learn a rule
- In GP we evolve a program or more usually a formula to learn the rule
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Typical Application

- Suppose you have a chemical plant with many control parameters and some observables (things you measure)
- One of the classic control problems is *system identification*
- That is, finding an equation which describes the system
- GP has been used to obtain formulae describing how the observables depend on the control parameters.
- One advantage of GP over many other machine learning techniques is that the formula is often interpretable by humans

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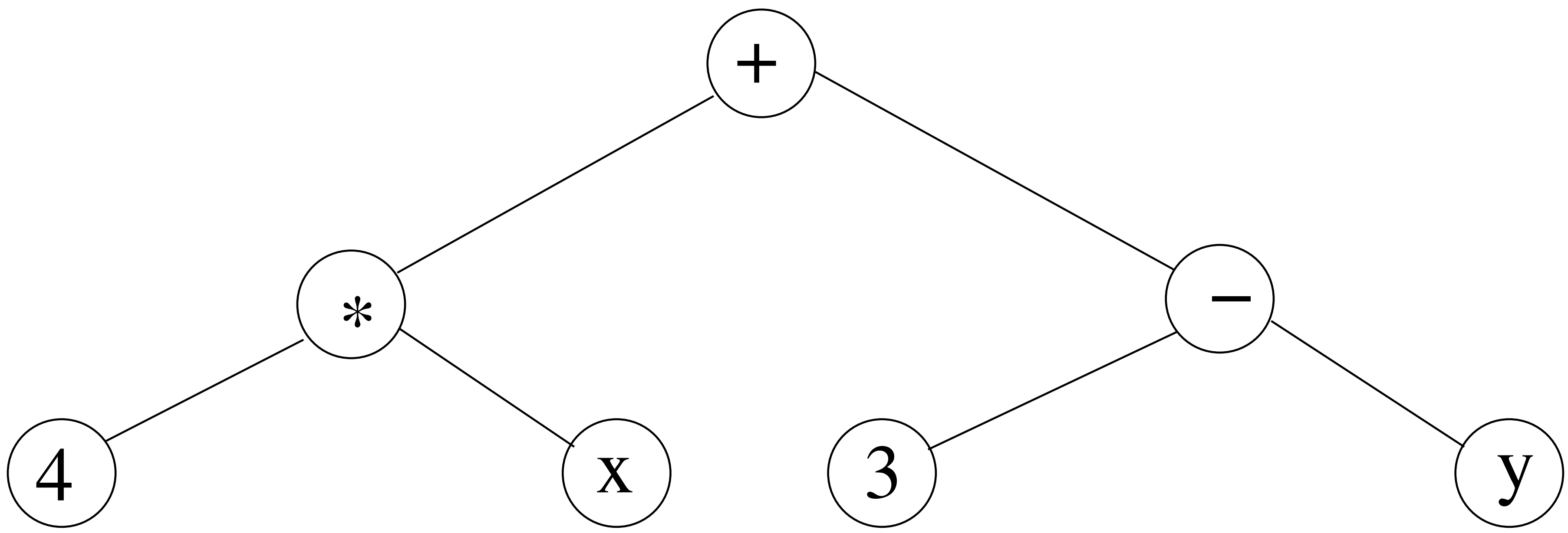
Representing Rules

- The first challenge in GP is deciding how to represent a rule or formula
- Different approaches, most commonly use expression trees



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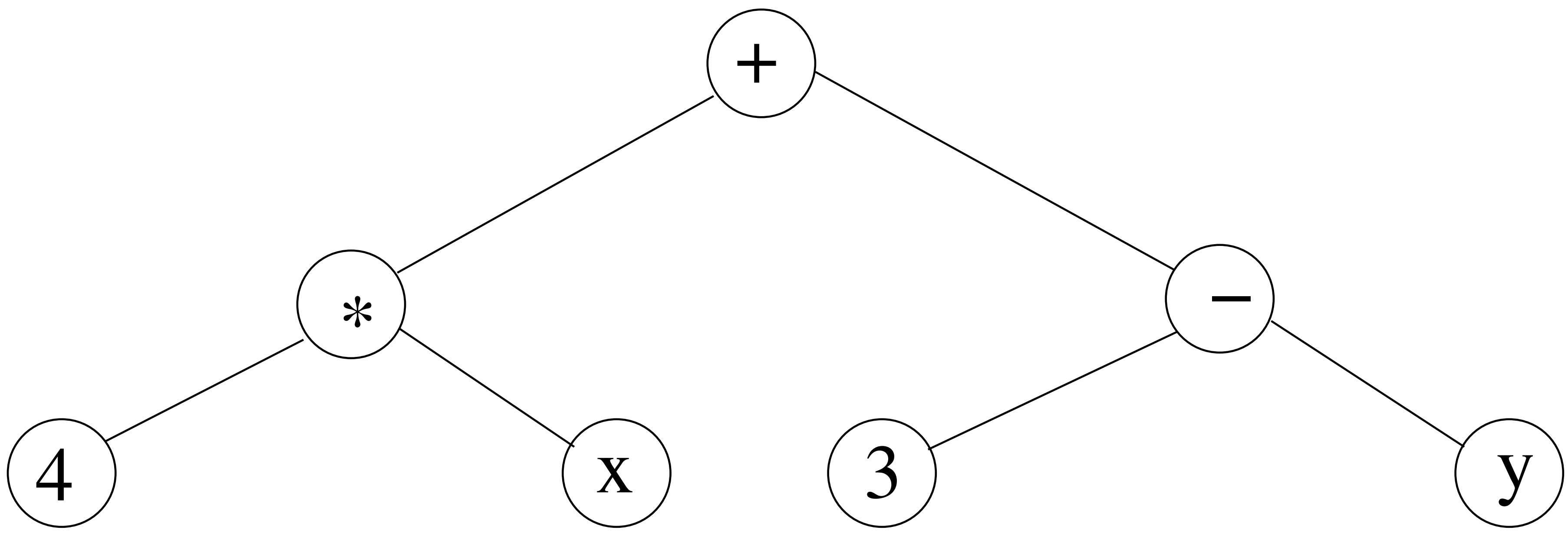

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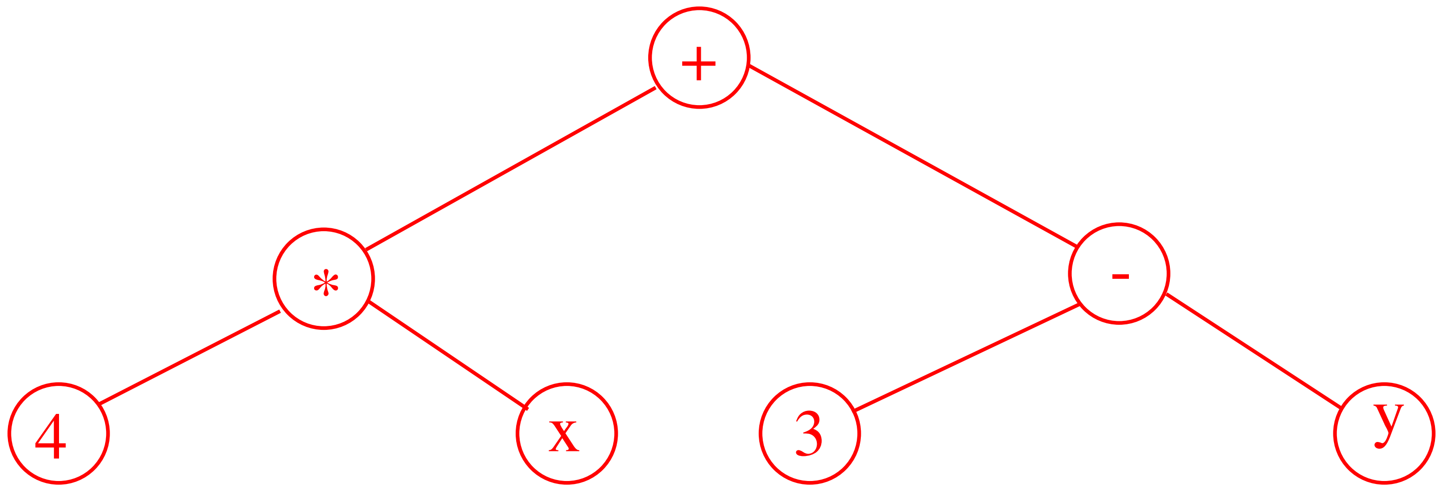
Mutations

- Mutations usually correspond to either
  - ⋆ changing a leaf or
  - ⋆ changing a binary node



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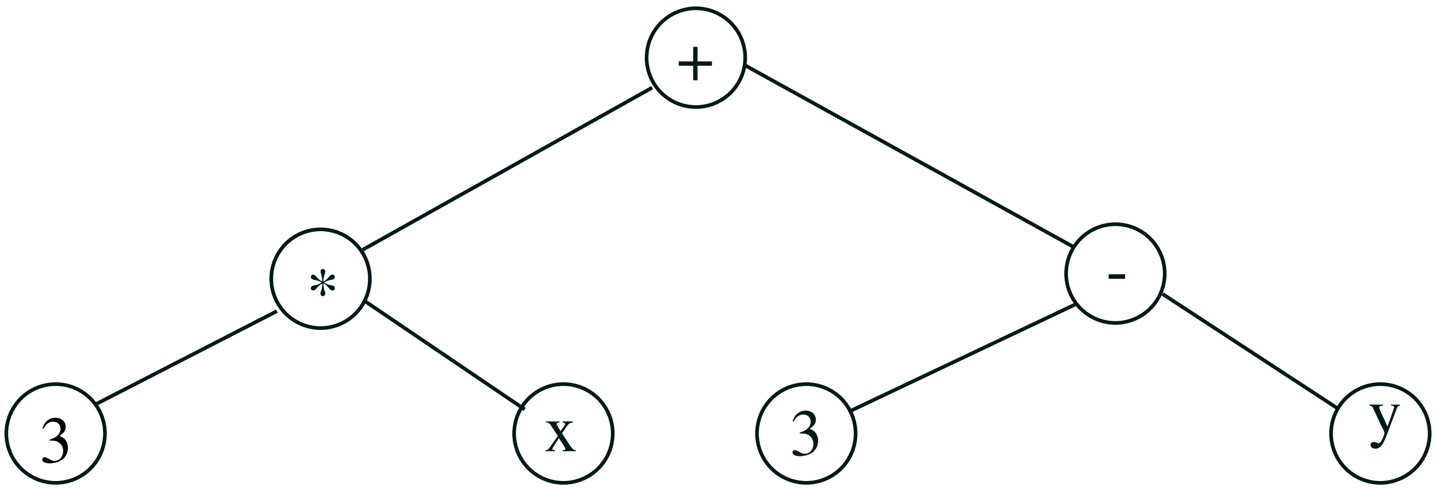

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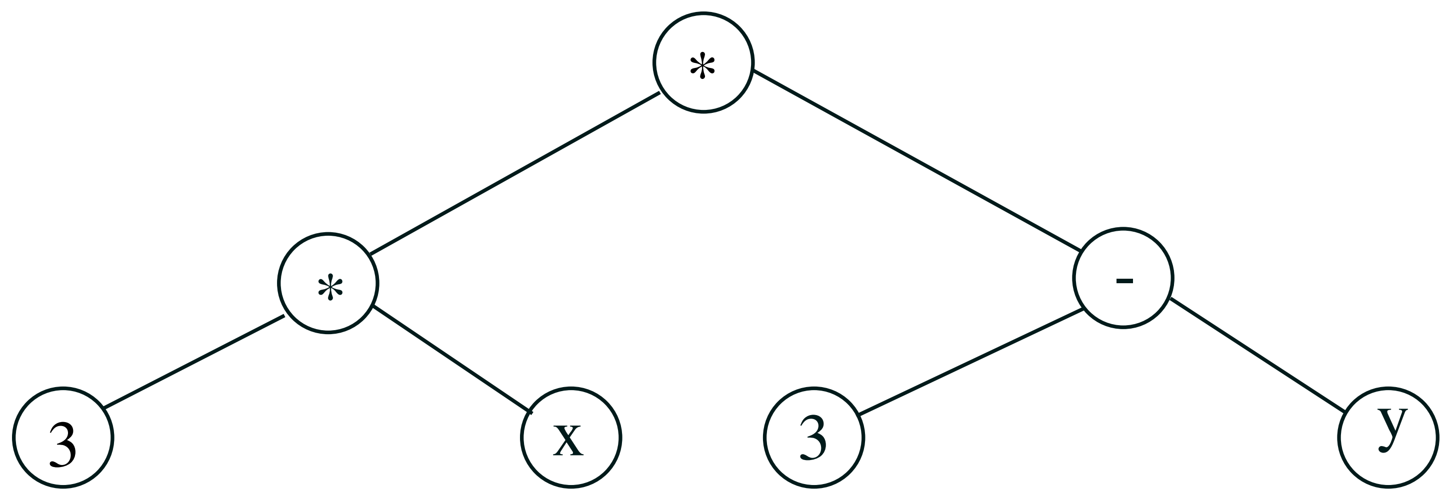
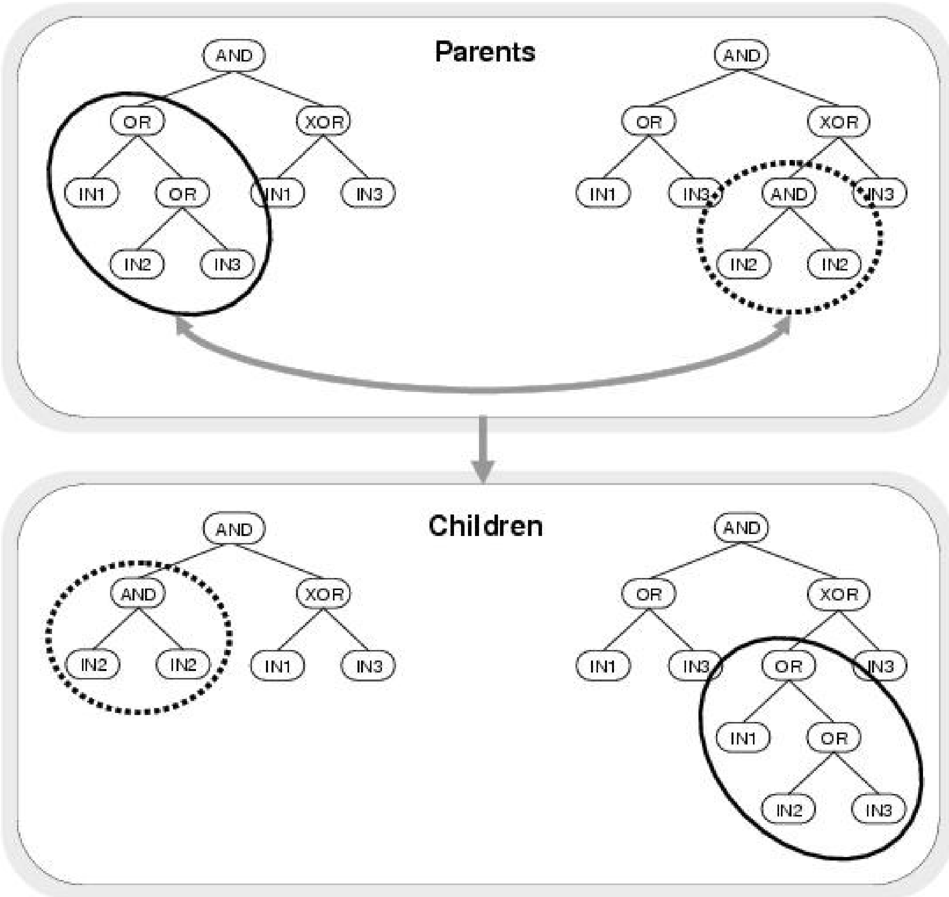


(3 * x) * (3-y)

Crossover

- The most common form of crossover is exchanging subtrees



Disruption

- Mutation and crossover can be quite disruptive

$$(29 * x + 33) - (5 + x)$$

$$(29 * x + 33)^{(5+x)}$$

- However, in a binary expression tree most nodes are at the leaves and this will usually cause much smaller changes

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Dysfunction Subtrees

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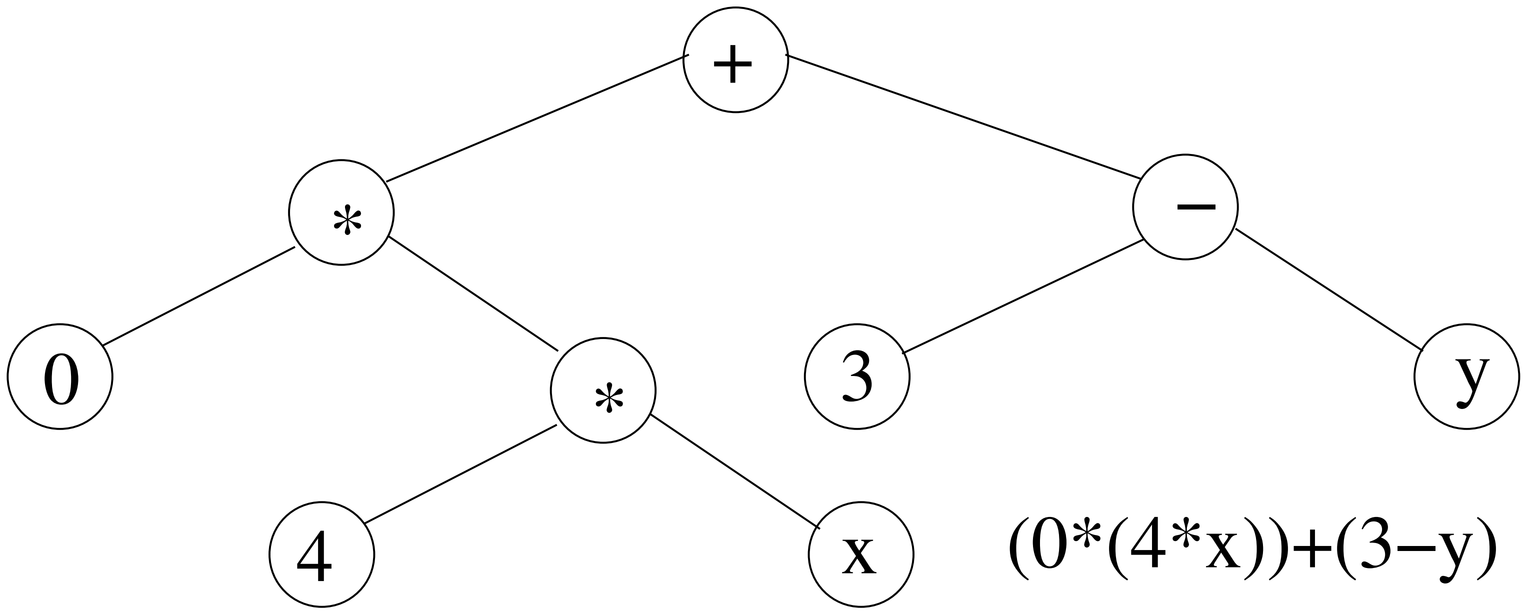

(0*(4*x))+(3−y)

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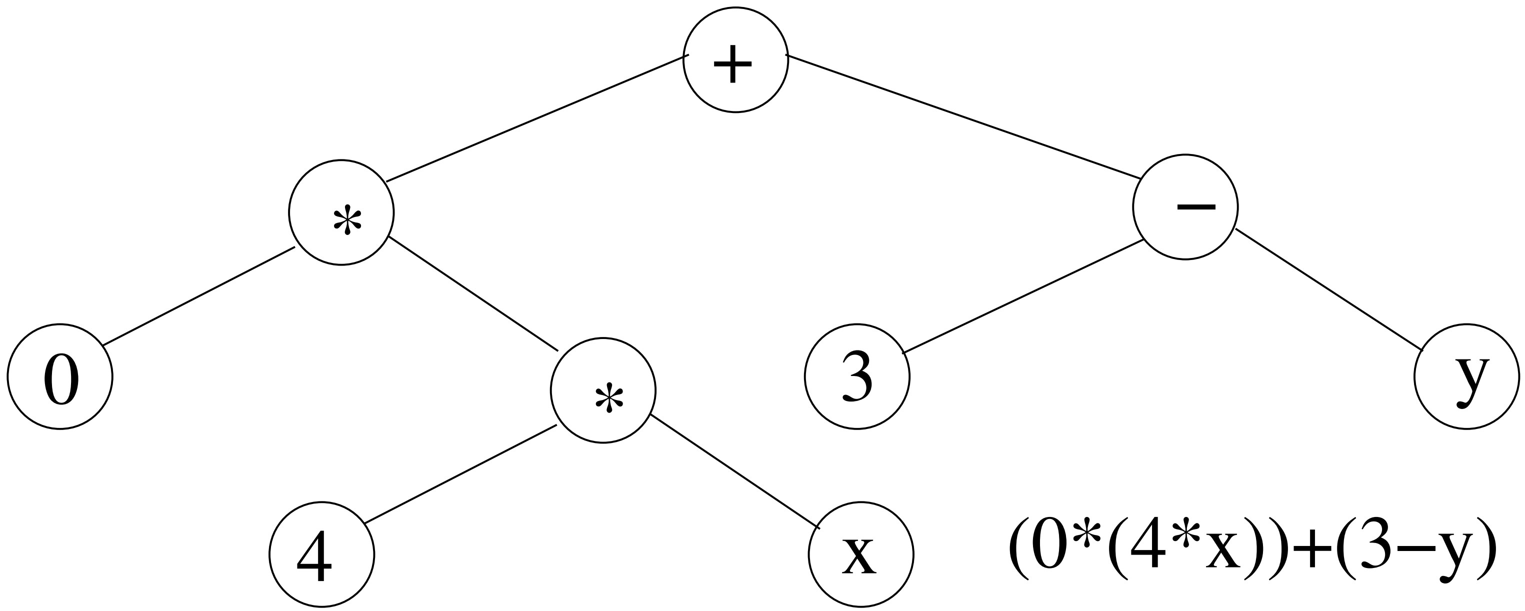

Bloat

- Over time expression trees tend to grow
- This is known as **bloat**
- Much of the tree might be dysfunctional
- One possible advantage of bloat is that it can reduce the disruptiveness of mutation—it decreases the amount of mutation suffered by the functional part of the expression tree

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Parsimony Pressure

- Bloat has a two downsides though
  - ⋆ It reduces the interpretibility of the formulae (a major attraction of using GP)
  - ⋆ It might produce over-complicated formulae (thus over-fitting the data and increasing the generalisation error)

- A common strategy to reduce the amount of bloat is to punish (through a fitness term) large expression trees

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Summary of GP

- GP is a big research field
- Advocates claim a few successes in finding phenomenological formulae for describing complex systems
- It is usually very compute intensive—evolving very large populations for a large number of generations
- There are a lot of challenges in really understanding how GP works and improving it
  - ⋆ Inheriting subroutines
  - ⋆ Intelligent guidance of search
  - ⋆ Controlling over-fitting