Genetické programování v typovaných jazycích

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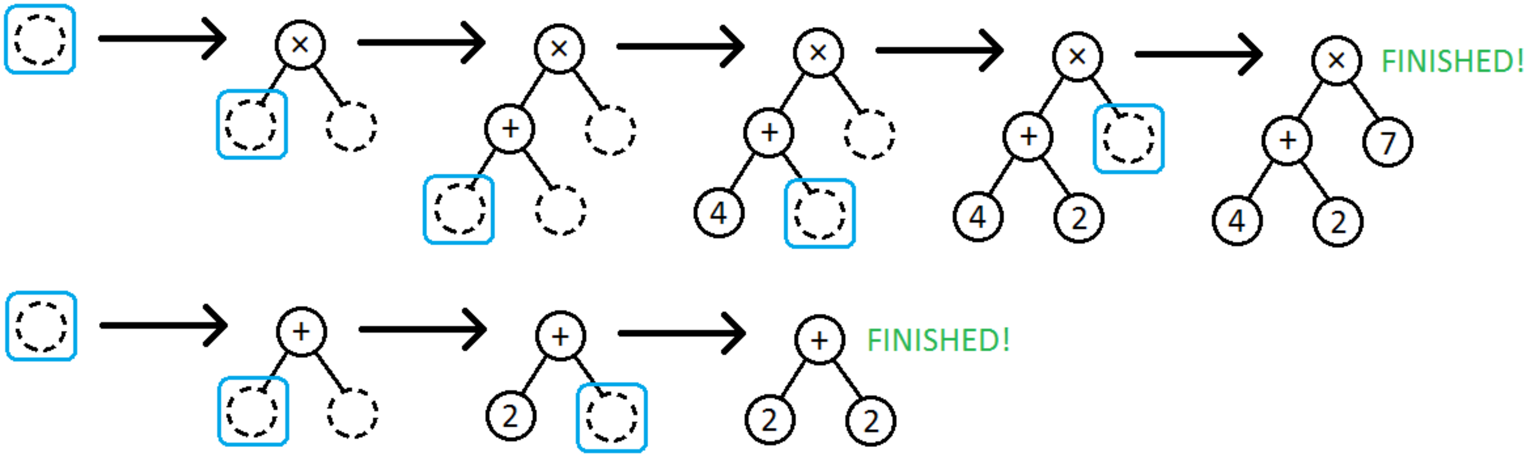
Články

- Generating Lambda Term Individuals in Typed Genetic Programming Using Forgetful A*
  - Konference IEEE WCCI 2014, Peking
- Utilization of Reductions and Abstraction Elimination in Typed Genetic Programming
  - Konference GECCO 2014, Vancouver

Standard generating procedure

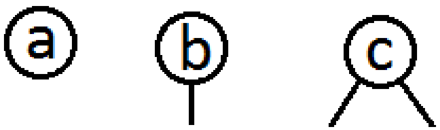
- works in separate iterations
  - In each iteration one tree individual is generated.



- We can do this differently:
  - “Generating of shared parts can be shared.”

Exhaustive enumeration

INPUT



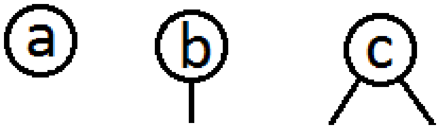
e.g. T = {a}, F = {b:1 arg, c:2 args}

PRIORITY QUEUE

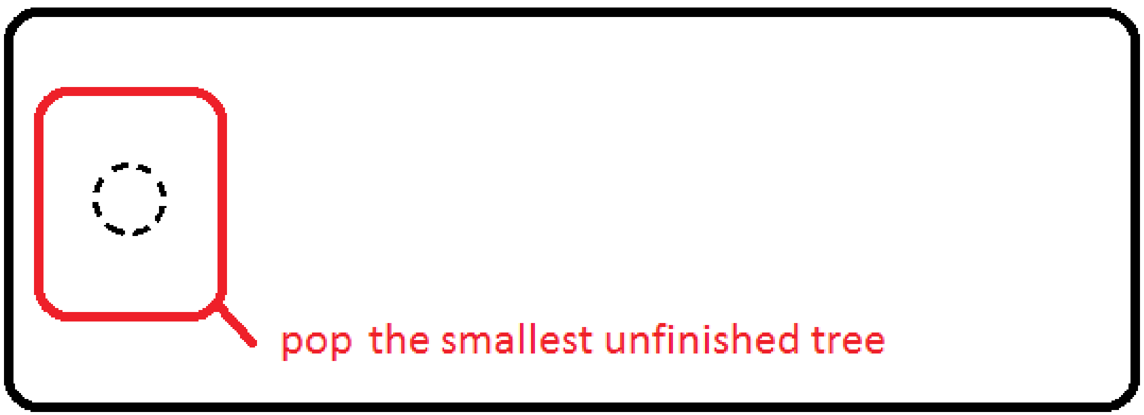
OUTPUT

Exhaustive enumeration

INPUT

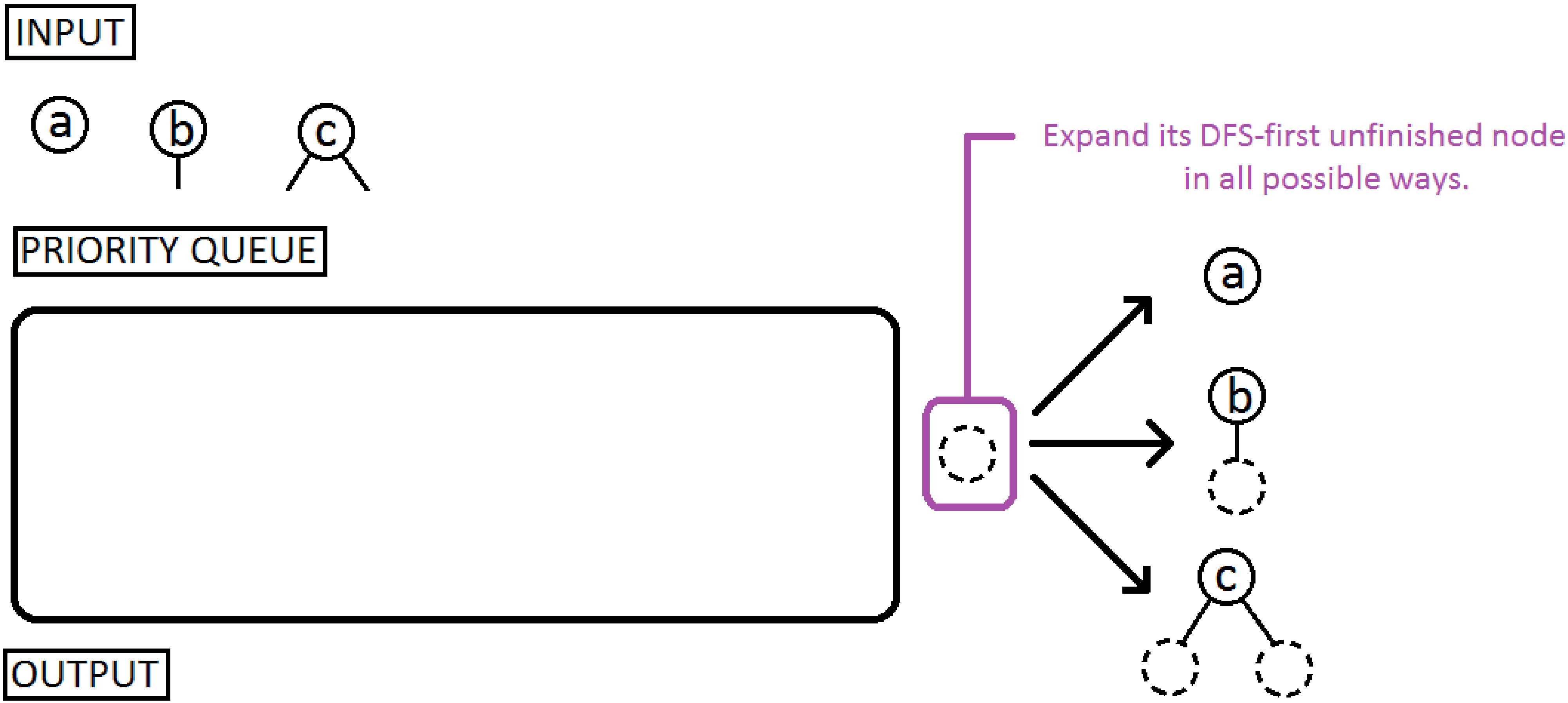


PRIORITY QUEUE

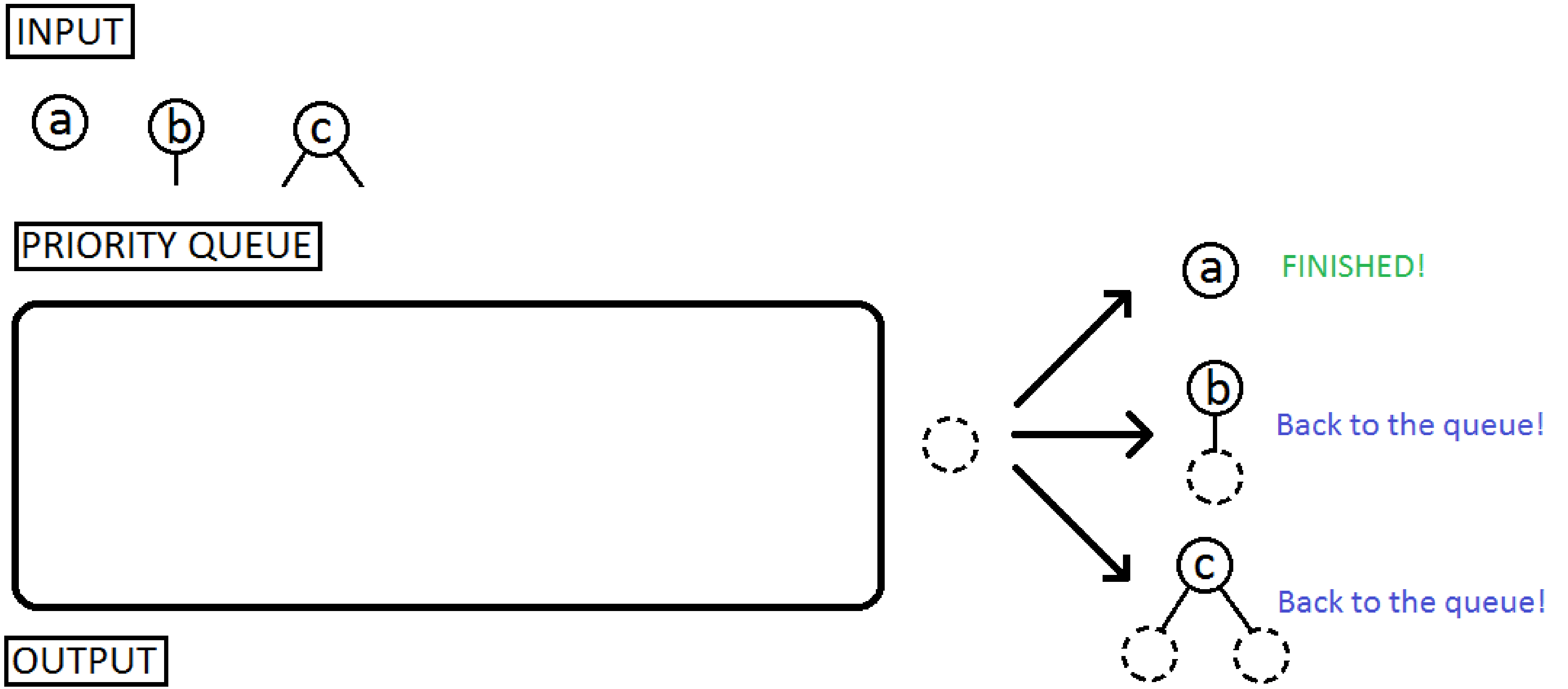


OUTPUT

Exhaustive enumeration



Exhaustive enumeration



Exhaustive enumeration

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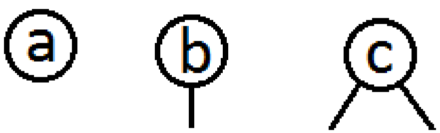
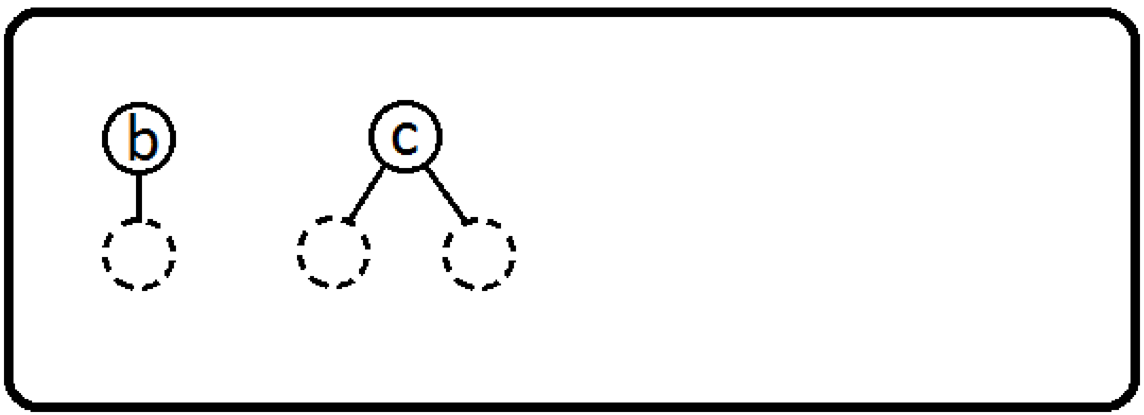
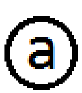


PRIORITY QUEUE

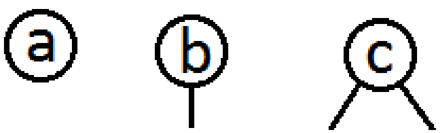


OUTPUT

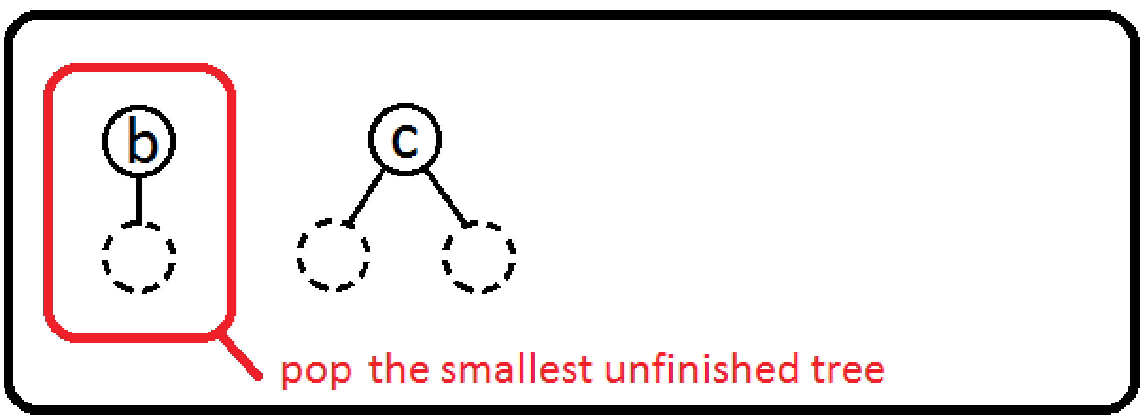


Exhaustive enumeration

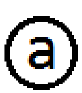
INPUT



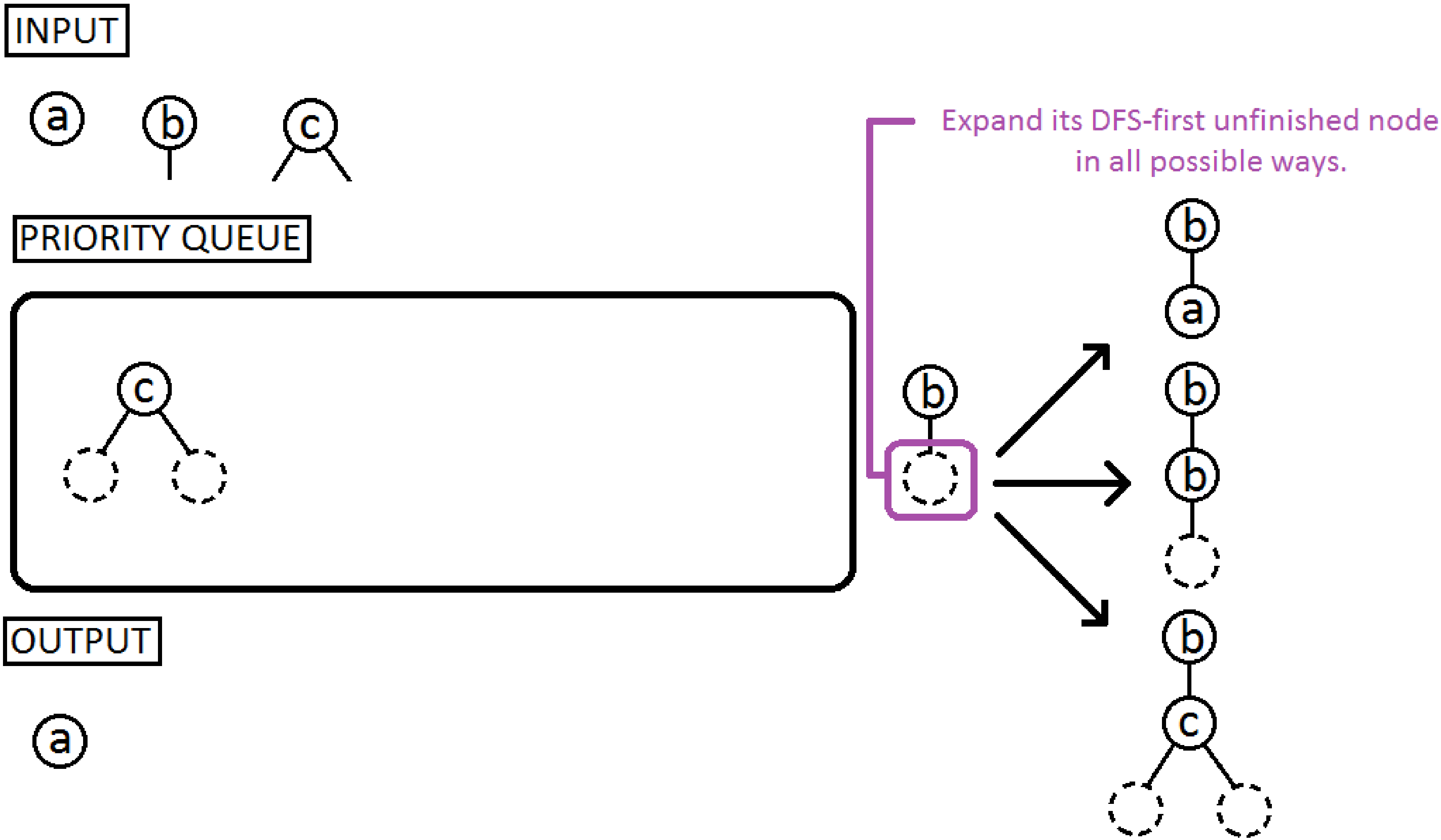
PRIORITY QUEUE



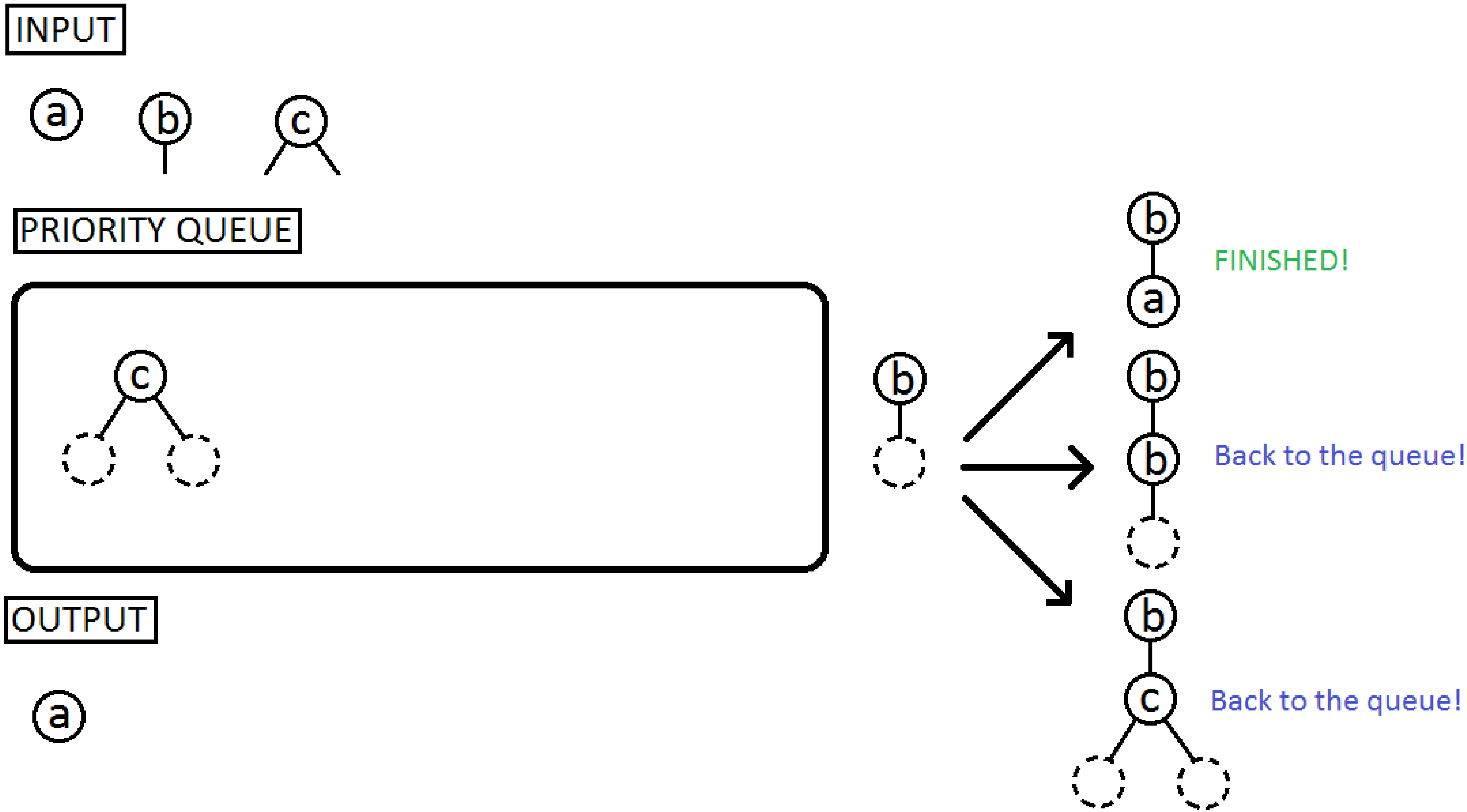
OUTPUT



Exhaustive enumeration

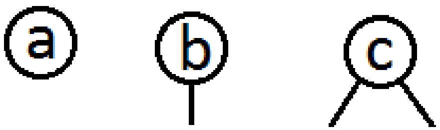


Exhaustive enumeration

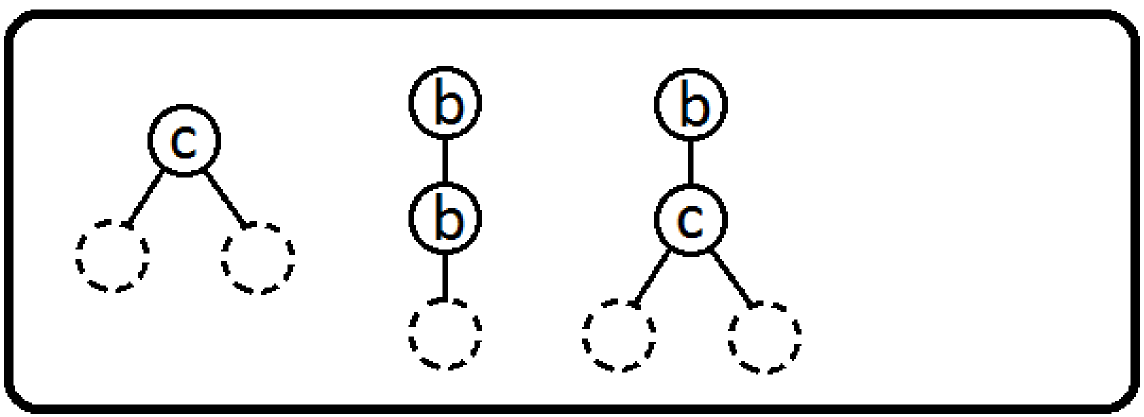


Exhaustive enumeration

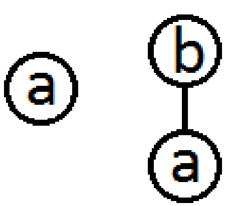
INPUT



PRIORITY QUEUE

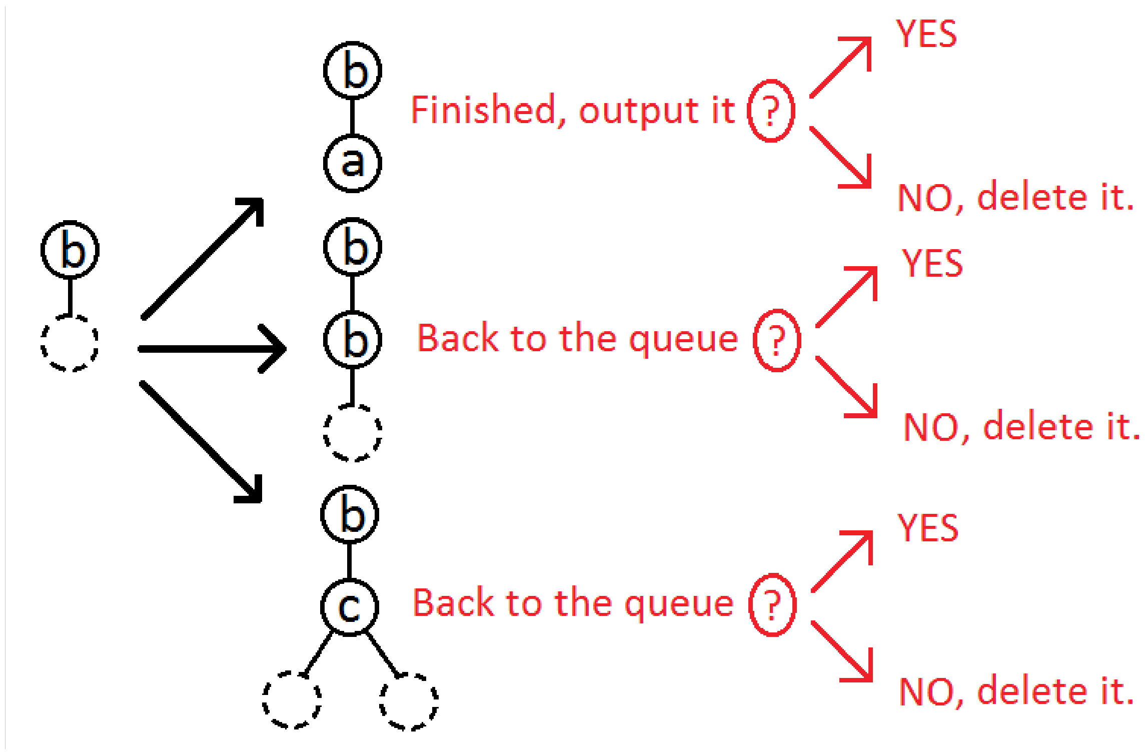


OUTPUT



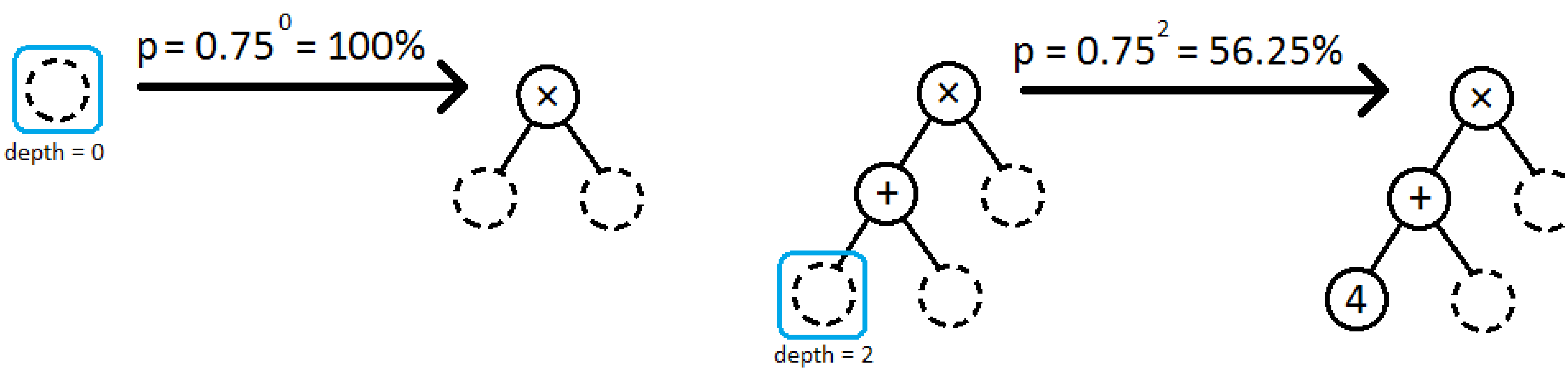
How to make enumeration more random?

- We add a new step deciding what to do with an expanded tree:
  - keep it,
  - or delete it?
- We call this additional decision procedure a *generating strategy.*
  - *"Keep all"* strategy = exhaustive enumeration
  - *"Delete all but one"* strategy = standard generating approach

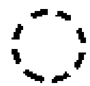
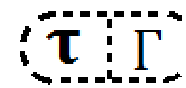
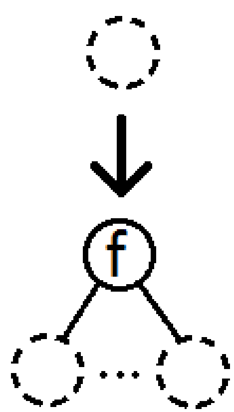
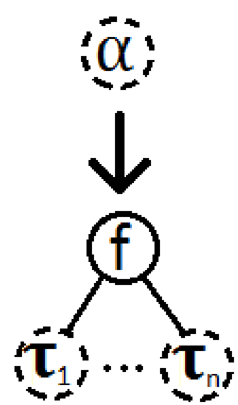
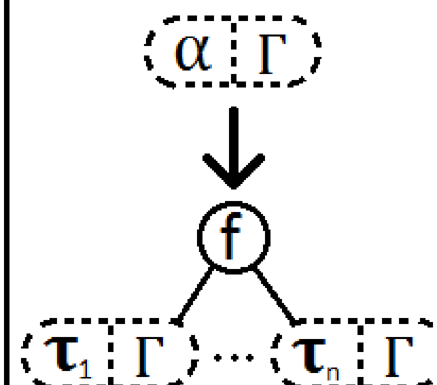
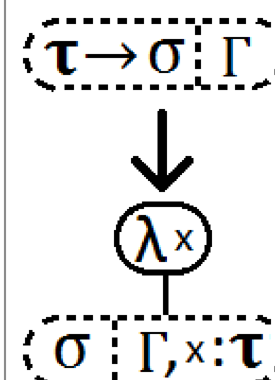


Our *geometric* strategy

- It puts an expanded tree back to the queue with probability $\mathbf{p = q^{depth}}$
- Where **q** is a constant, we used **q = 0.75**
- And **depth** is depth of the expanded node

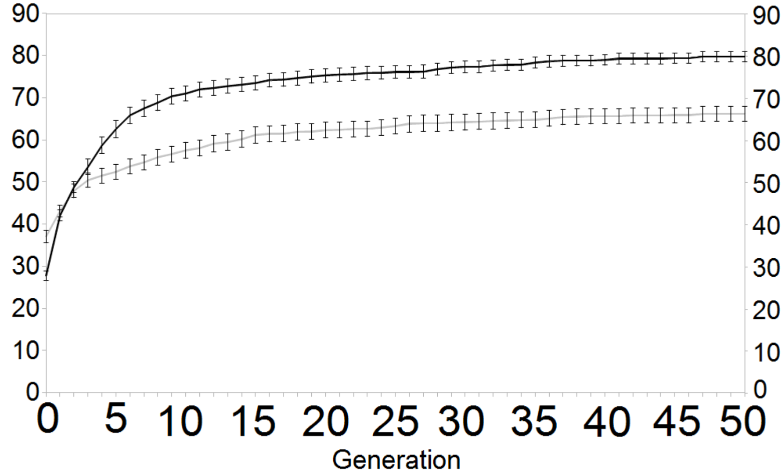


Generalization for simply typed lambda calculus

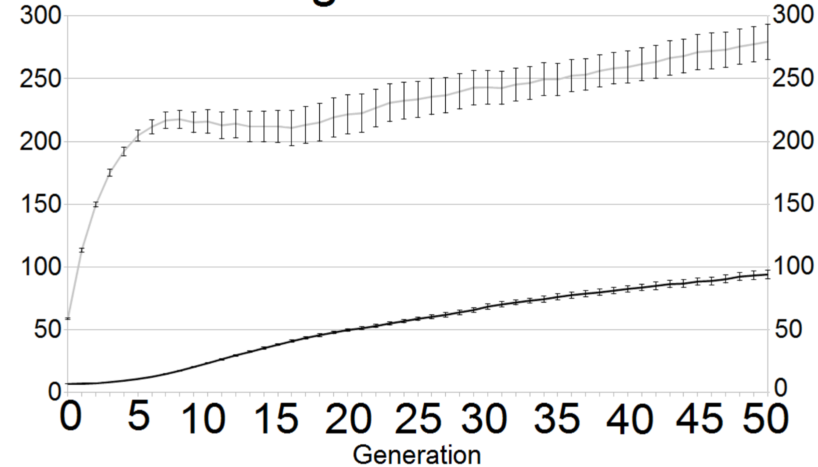
	No types	Types, no contexts	Simply typed lambda calculus	
Unfinished node				
Expansion(s)		 $f : \underbrace{\tau_1 \to \cdots \to \tau_n}_{\text{inputs types}} \to \underbrace{\alpha}_{\text{ouput type}}$	*atomic types:*  $(f : \tau_1 \to \cdots \to \tau_n \to \alpha) \in \Gamma$	*function types:* 

Artificial ant problem

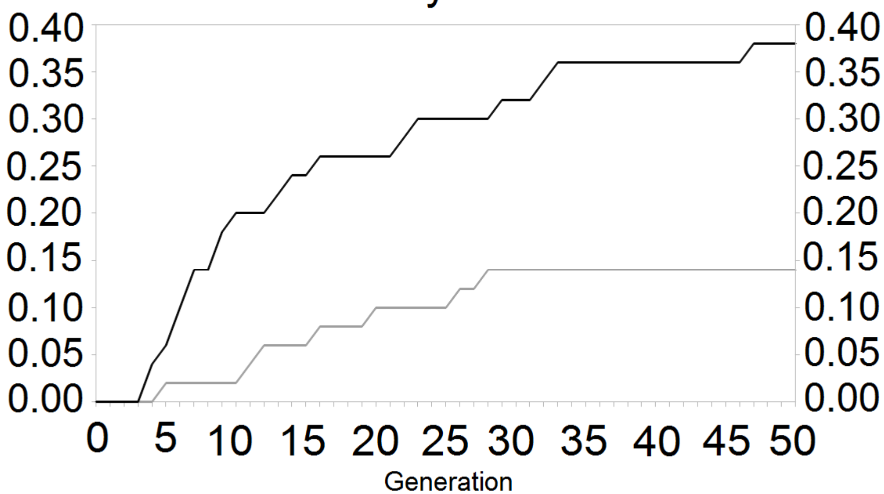
Fitness of the best individual



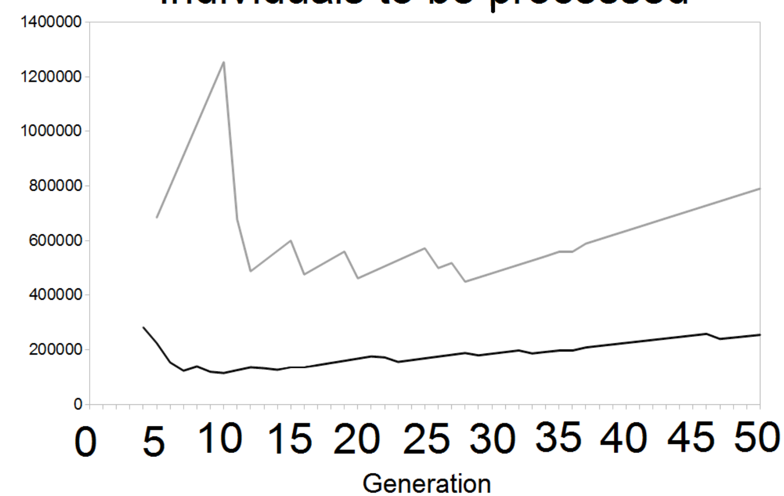
Average term size



Probability of success



Individuals to be processed



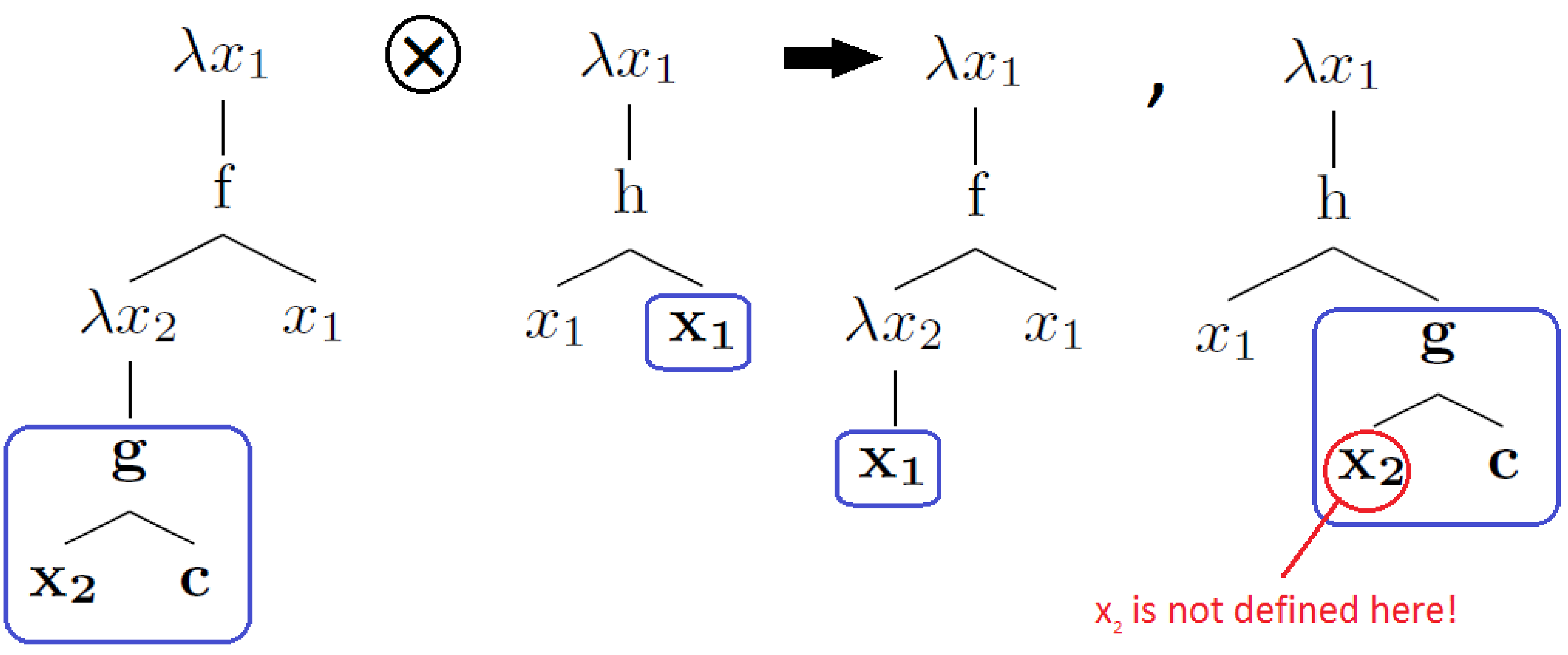
Ramped half-and-half

Geometric

Times: 265 minutes
107 minutes

Crossover operator for lambda terms

- Generalization of simple tree swapping crossover
- We need to swap subtrees with a same type
  - ..but that is simple
- Local variables cause the trouble!



Abstraction elimination

- An algorithm for getting rid of local variables and anonymous function
  - **Input:** an arbitrary lambda term
  - **Output:** equivalent S-expression *(with no local variables or anonymous functions)* that may contain additional new function nodes **S**,**K** and **I** which are defined as:

$\mathbf{S} = \lambda f\, g\, x \,.\, f\, x\, (g\, x)$		"**function**(f,g,x){ **return** f(x, g(x)) }"
$\mathbf{K} = \lambda x\, y \,.\, x$	***i.e.***	"**function**(x,y){ **return** x }"
$\mathbf{I} = \lambda x \,.\, x$		"**function**(x){ **return** x }"

Hybrid crossover

- Each generated term is transformed by abstraction elimination
- So now all terms are typed S-expressions
- So now we only need to swap subtrees with the same type

- *Hybrid* because
  - lambda term representation during generation phase
    - Advantage: reduced search space during generation phase
  - Pure combinator representation during the rest

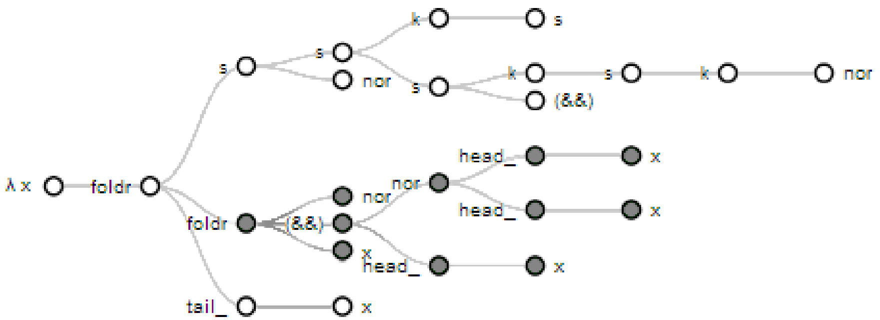
- Possible disadvantage: up to quadratic increase in term size

Unpacking crossover

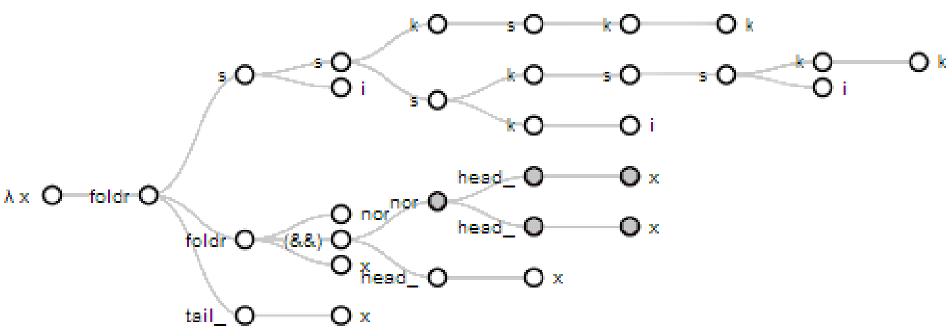
- All terms are kept in small βη-normal form
- ...and transformed right before crossover
- After the tree swapping both children are again normalized

- So the quadratic increase is only temporary

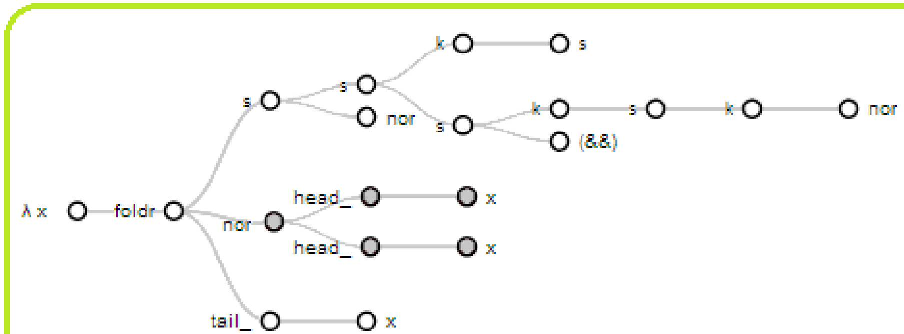
Results



Parent #1, fitness: 0.8125



Parent #2, fitness: 0.5



Child #1, fitness: 1

$$\lambda\, x\ .\ foldr\ (\mathbf{S}(\mathbf{S}(\mathbf{K}\ \mathbf{S})(\mathbf{S}(\mathbf{K}(\mathbf{S}(\mathbf{K}\ nor))) and)) nor)\ (nor\ (head'\ x)\ (head'\ x))\ \ (tail'\ x)$$

$$=_{\beta\eta}$$

$$\lambda\, x\ .\ foldr\ (\lambda\, y\ z\ .\ nor\ (and\ y\ z)\ (nor\ y\ z))\ (nor\ (head'\ x)\ (head'\ x))\ \ (tail'\ x)$$

Which is equivalent to:

$$\lambda\, x\ .\ foldr\ xor\ (not\ (head'\ x))\ \ (tail'\ x)$$

GP approach	$I(M,i,z)$
PolyGP	14,000
Our approach (hybrid)	**28,000**
GP with Combinators	58,616
GP with Iteration	60,000
Our approach (unpacking)	**114,000**
Generic GP	220,000
OOGP	680,000
GP with ADFs	1,440,000

Results comparison