Programación genética

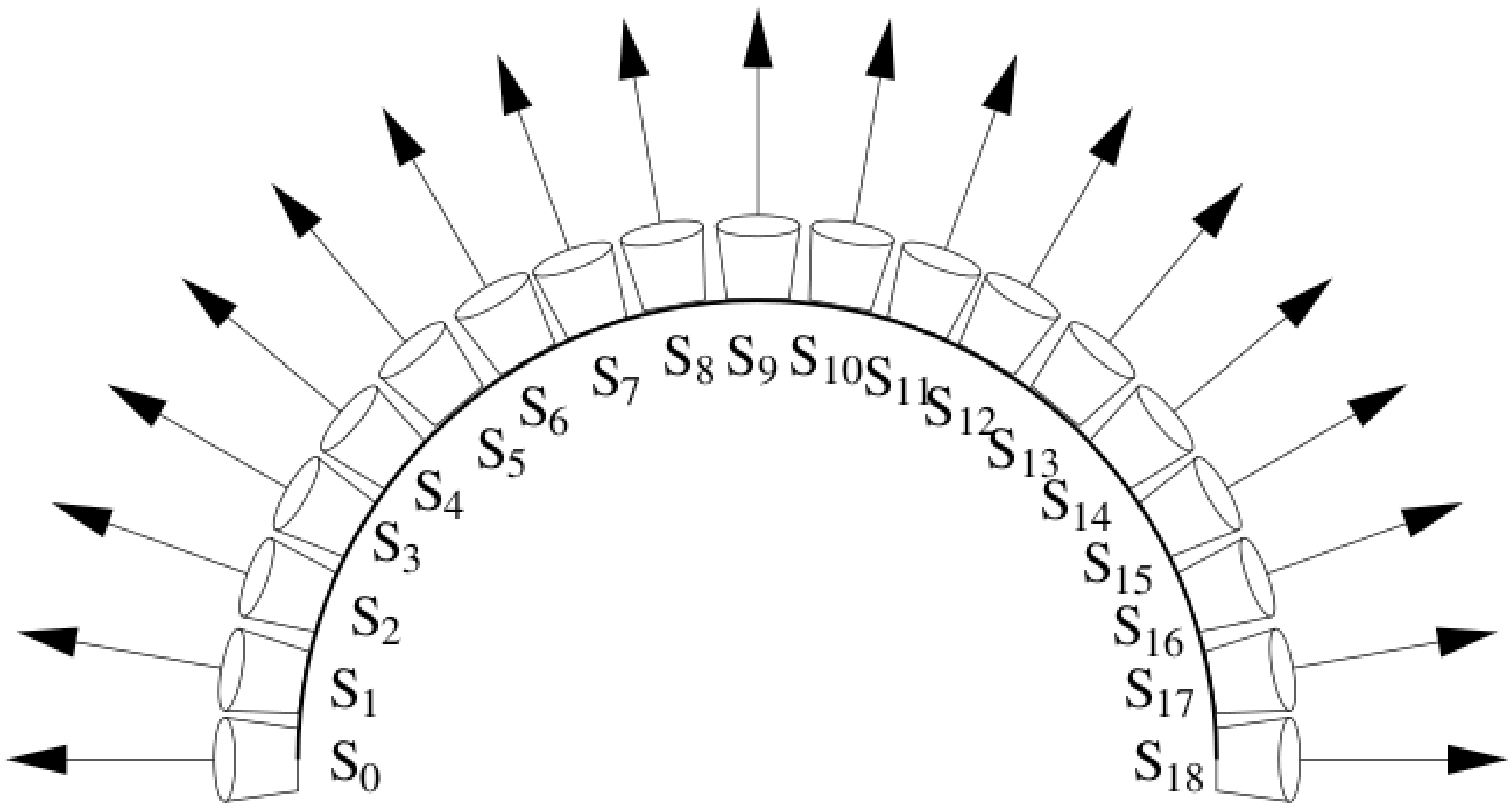
Algoritmos bioinspirados
y computación evolutiva

Ambientes dinámicos

- Algoritmos genéticos
  - Genomas muy largos
  - Diploidía / poliploidía
- Programas genéticos

TORCS

TORCS



TORCS: sensores

α	$[-\pi, \pi]$/rad	orientation of car relative to the current street orientation
distFromStart	$[0, \infty]$/m	distance from start line to current position of car measured along
distRaced	$[0, \infty]$/m	total distance traveled since beginning of race
t_{curLap}	$[0, \infty]$/s	elapsed time on current lap
t_{lastLap}	$[0, \infty]$	time elapsed for last lap
racePos	1, 2, ...	current rank of car in race
damage	$[0, \infty]$/point	total dame incurred to car
fuel	$[0, \infty]$/l	fuel left in fuel tank
gear	$\{-1, 0, 1, \ldots, 6\}$	current gear position (-1: backwards, 0: neutral)
rpm	$[2000 - 7000]$/rpm	rounds per minute of the motor
d_y	$[-1, 1]$	displacement of car from center of track (normalized to 1)
v_x	$[-\infty, \infty]/\frac{\text{km}}{\text{m}}$	velocity of car in track direction
v_y	$[-\infty, \infty]/\frac{\text{km}}{\text{m}}$	velocity of car perpendicular to track direction
$v_{\text{wheel,i}}$	$[0, \infty]/\frac{\text{rad}}{\text{s}}$	velocity of wheel $i \in \{1, 2, 3, 4\}$
S_i	$[0, 100]$/m	dist. to track boundary measured by 19 sensors $i \in \{0, \ldots, 18\}$ as
O_i	$[0, 100]$/m	distance to opponents measured by 18 sensors $i \in \{1, \ldots, 18\}$

TORCS: controles

gas pedal	$[0, 1]$	acceleration
brake pedal	$[0, 1]$	brake (0: don't brake, 1: full brake)
steering	$[-1, 1]$	orientation of steering wheel (-1: maximum left, 1: m
gear	-1, 0, 1,..., 6	shift into gear as specified
meta control	0, 1	meta control flag (0: do nothing, 1: restart race)

Programas como árboles

- `(2+x+y) * (1–sqrt(18/(x+y))) / (((x-y)^2 + 30) * (x^2-y^2))`

$$\frac{(2+x+y)\cdot\left(1-\sqrt{\frac{18}{x+y}}\right)}{\left(\left(x-y\right)^2+30\right)\cdot\left(x^2-y^2\right)}$$

Programas como árboles

- (2+x+y) * (1–sqrt(18/(x+y))) / (((x-y)^2 + 30) * (x^2-y^2))

- ```
  (/ (* (+ 2 x y)
        (– 1 (sqrt (/ 18 (+ x y)))))
     (* (+ (expt (- x y) 2)
           30)
        (- (expt x 2) (expt y 2))))
  ```
  ```

Programas como árboles en R

```
ee <- expression (
      (2+x+y) * (1–sqrt(18/(x+y))) /
      (((x-y)^2 + 30) * (x^2-y^2))    )
as.list (ee[[1]])
 [[1]] →  `/`
 [[2]] →
 (2 + x + y) * (1 - sqrt(18/(x + y)))
 [[3]] →
 (((x - y)^2 + 30) * (x^2 - y^2))
```

Programas como árboles

- `if (a>b) {x<-a;cat(b)} else stop()`

-
```
(if (> a b)
    (progn (setq x a)
           (princ b))
    (error))
```

Programas como árboles en R

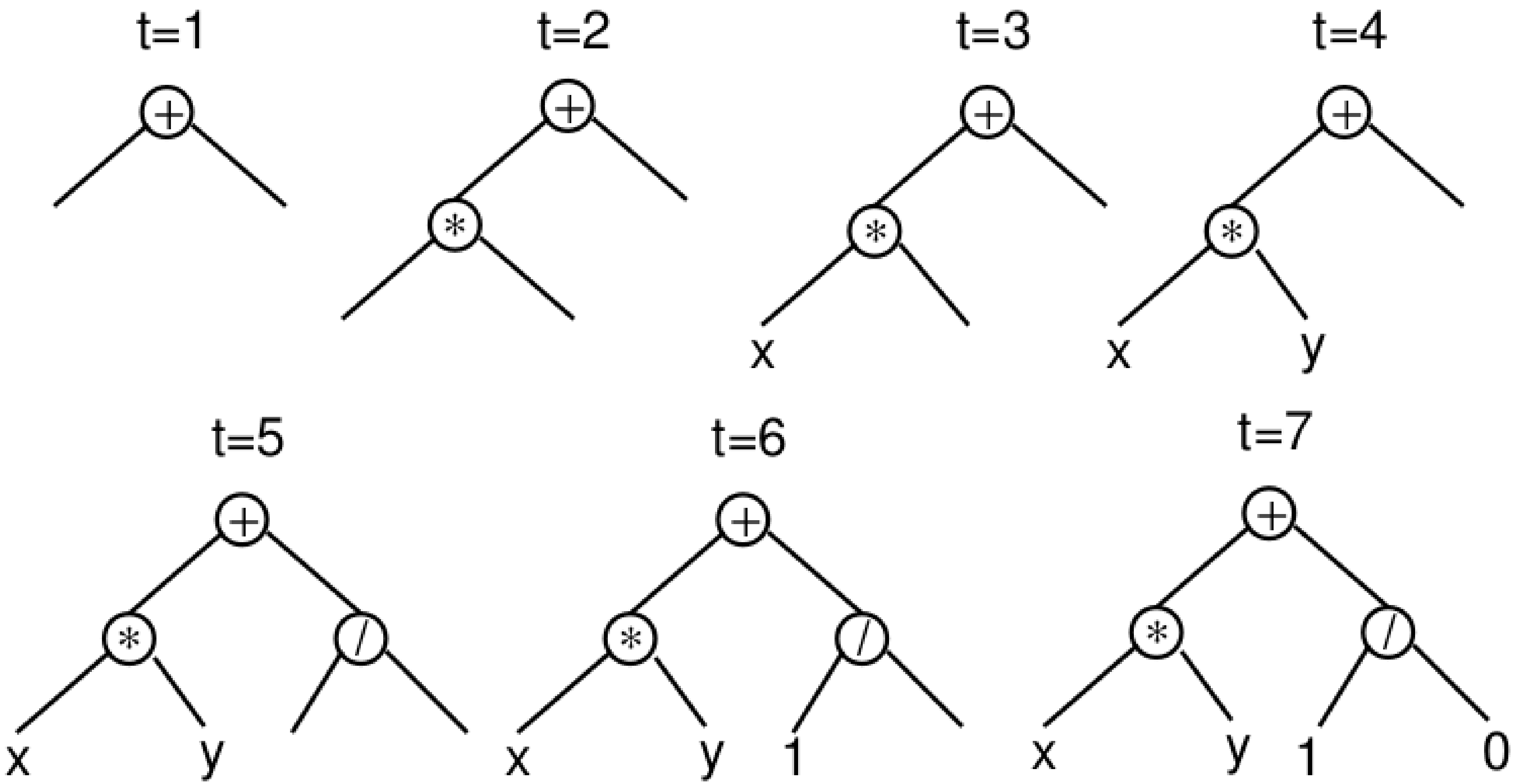
```
ee <- expression (
 if (a>b) {x<-a;cat(b)} else stop() )


as.list (ee[[1]][[3]])
 [[1]] → `{`
 [[2]] → x <- a
 [[3]] → cat(b)
```

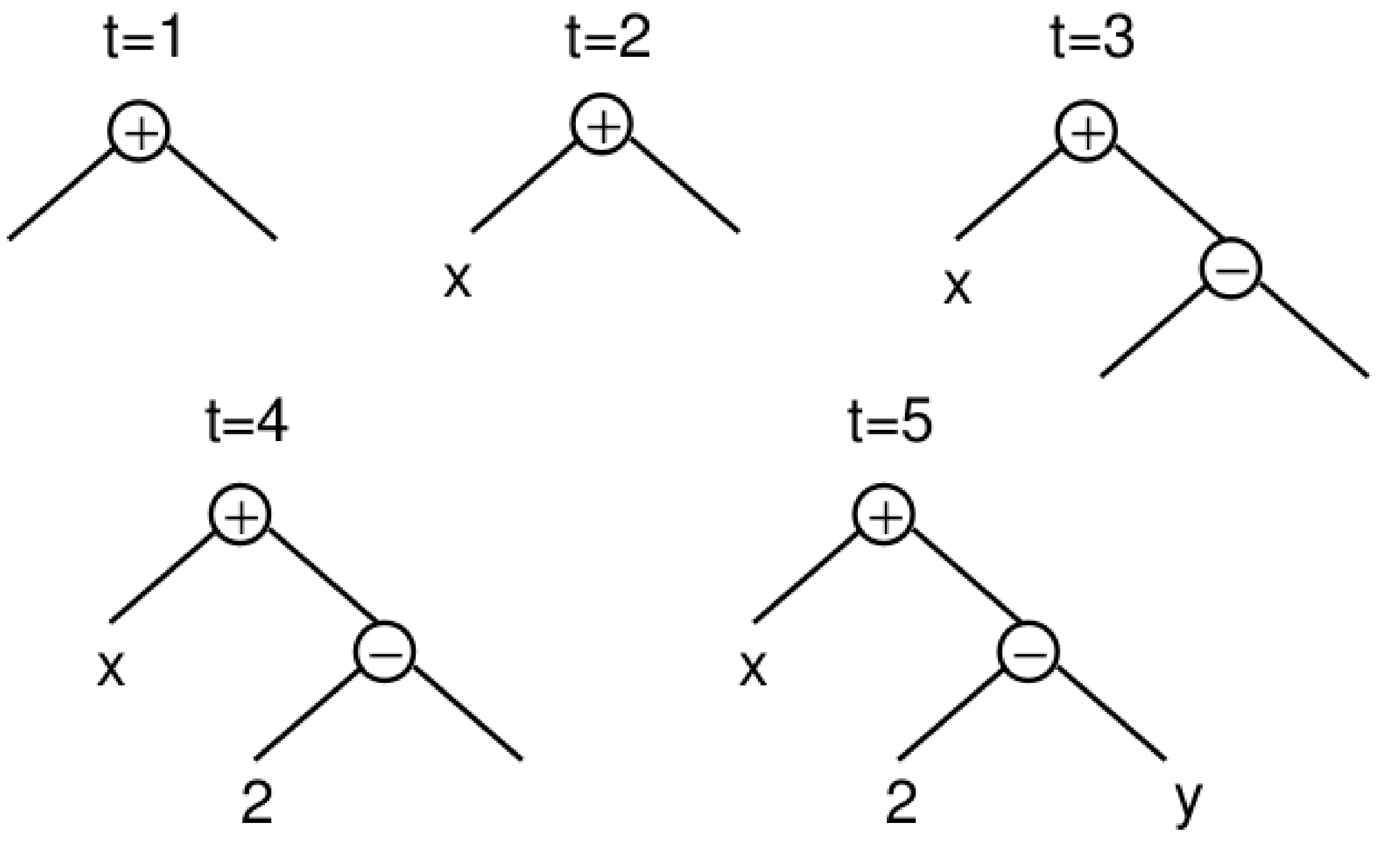
Elementos de un árbol

- Operadores
  - +, –, *, /...
  - Ifelse; ==, not, >...
- Terminales
  - Constantes: 0, 1, π...
  - Aleatorios: runif...
  - Variables: x, y...

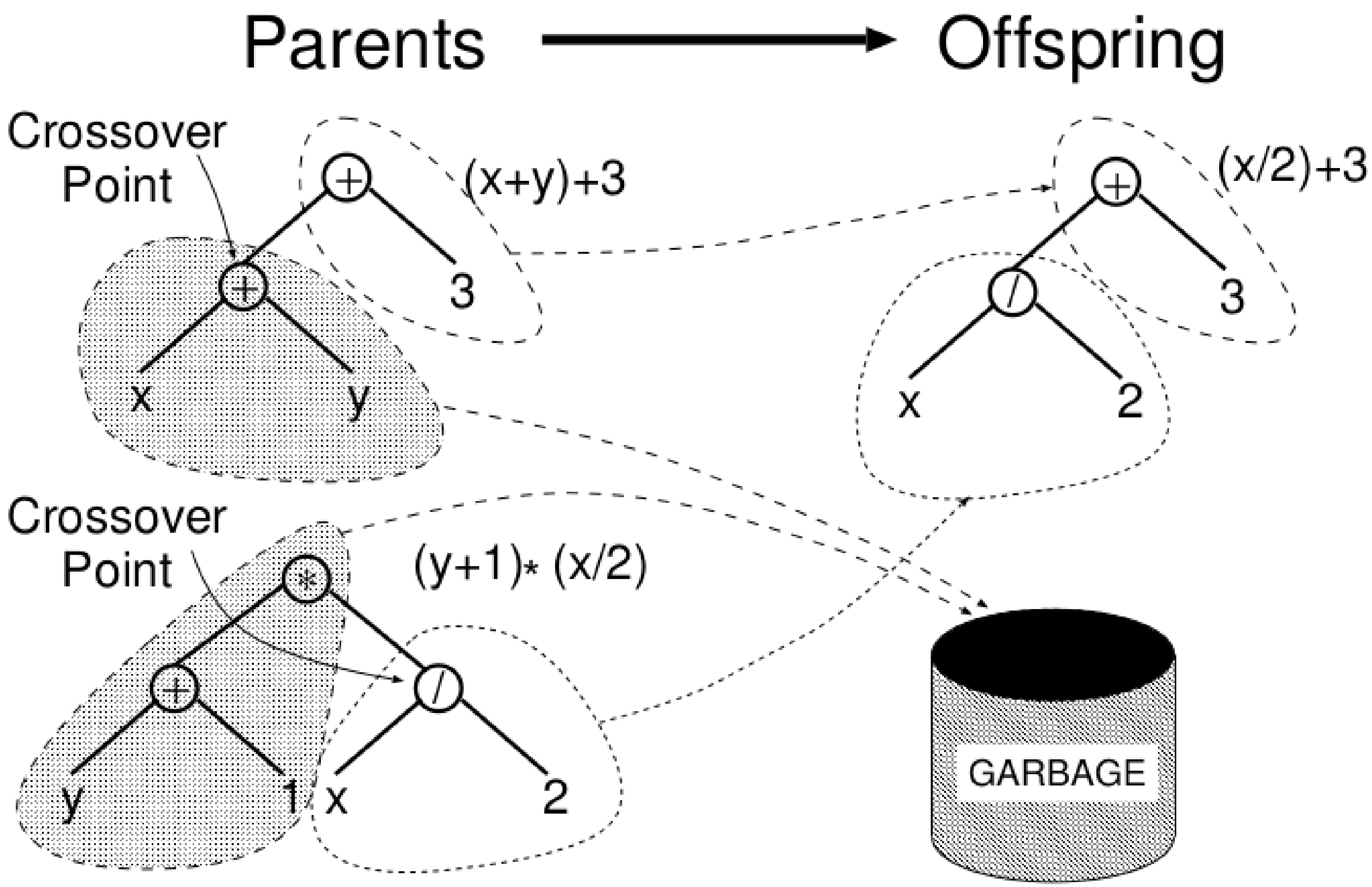
Inicializar población (*full*)



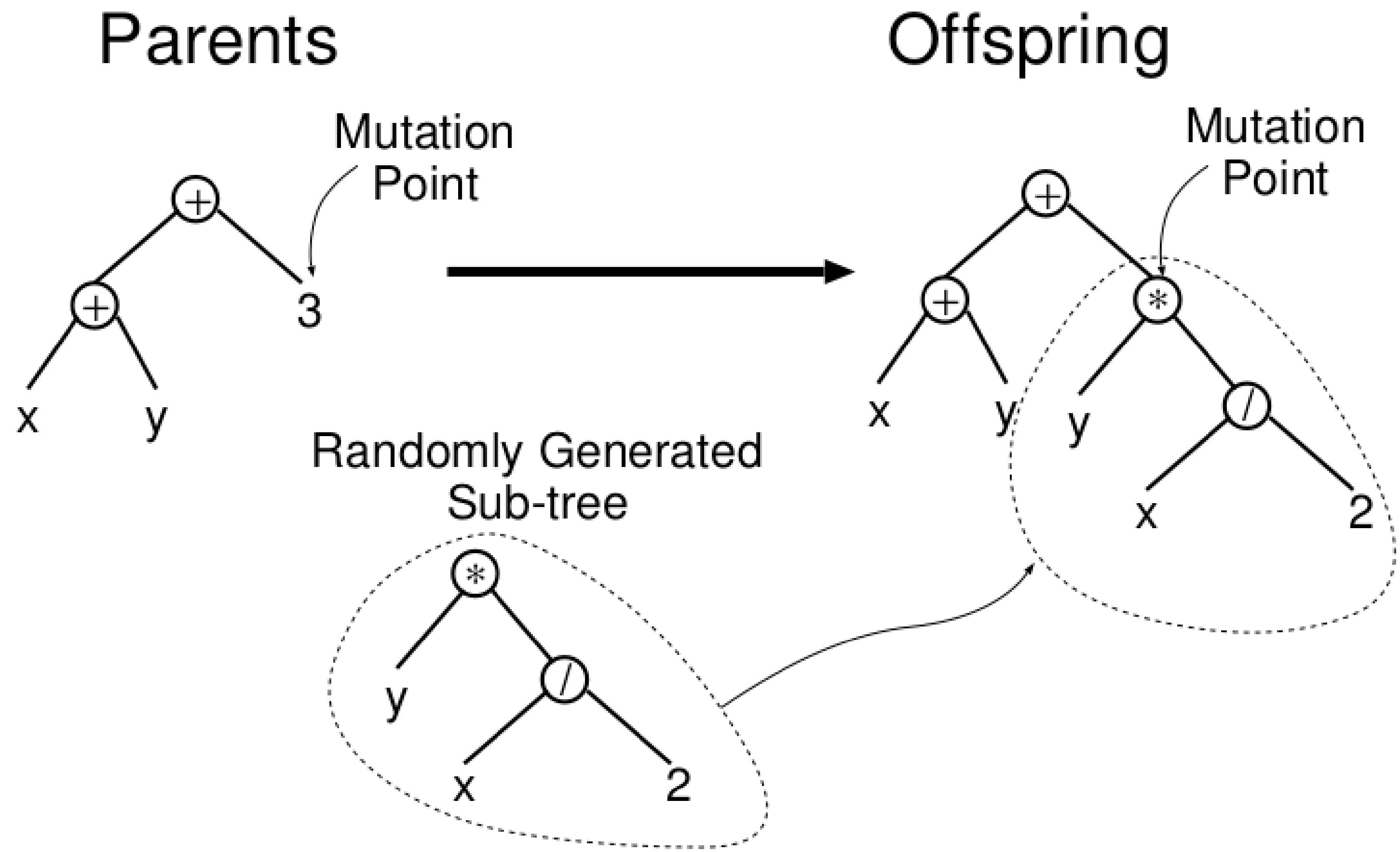
Inicializar población (*grow*)



Recombinación (sobrecruce)

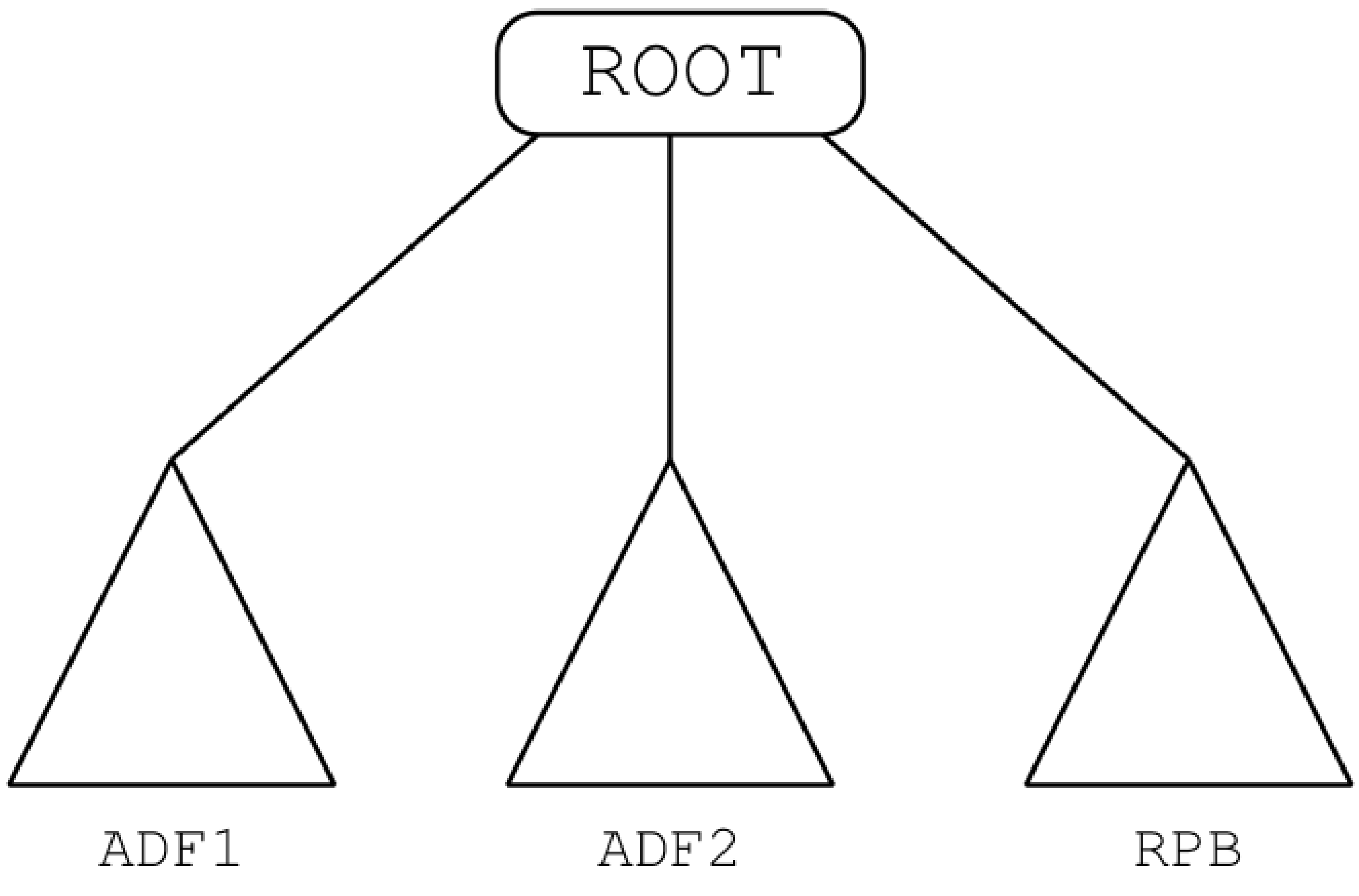


Mutación



Parents
Offspring
Mutation Point
3
x
y
Randomly Generated Sub-tree
y
x
2
Mutation Point
x
y
y
x
2

P.G. avanzada: A.D.F.



P.G. av.: restricciones estructurales

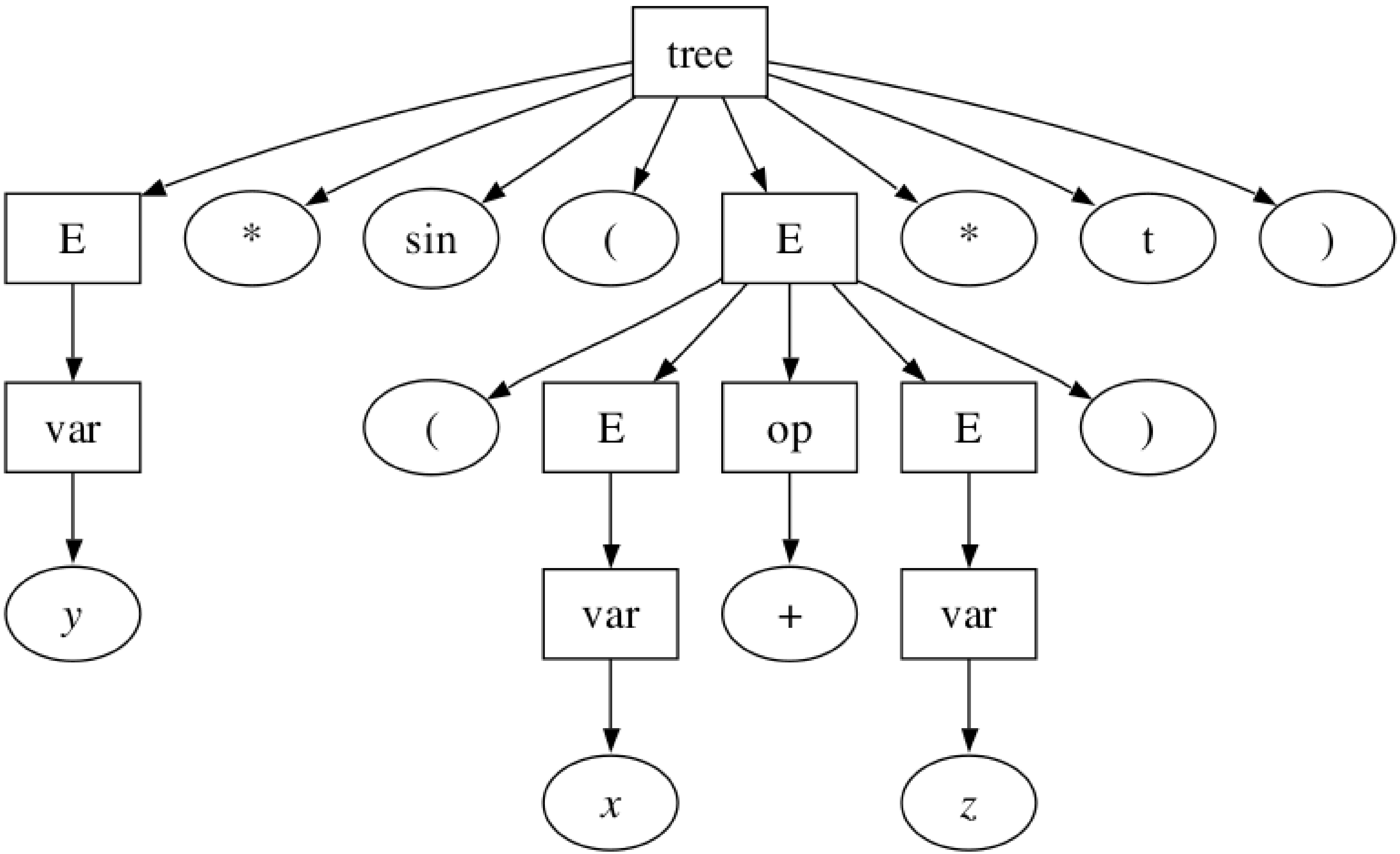
- Estructuras particulares
  - p.ej. Periódicas: a . sen (b . t)
- Tipos estrictos en argumentos
  - p.ej. `ifelse` (<*logical*>, <*numeric*>, <*numeric*>)
  - Disponibles en RGP

P.G. av.: restricciones gramaticales

- Gramática
  - Árbol ::= E . sen (E . t)
  - E ::= var | (E op E)
  - op ::= + | – | . | :
  - var ::= x | y | z

- Recombinación sólo posible entre nodos con el mismo símbolo gramatical (no terminal)

P.G. av.: restricciones gramaticales



P.G. avanzada: PushGP

- Programación autoconstructiva con tipado estricto
- Tipos: booleanos, enteros, coma-deslizante... y árbol de código
- Cada tipo: pila propia
- Soporta recursión y módulos (ADF)
- Un programa (o parte de sí mismo) puede meterse en la pila al evolucionar
- Operadores de recombinación y mutación evolucionan en esa pila

TORCS: árbol del volante

Name	Arguments	Description
ERC1	0	ephemeral random constant with range $[-1, 1]$
ERC150	0	ephemeral random constant with range $[-150, 150]$
c_p	0	constant for hand-crafted proportional controller $c_p = -0.0234$
LR0	0	average difference between left and right track sensors $\frac{1}{2}(S_{15} + S$
abs	1	identity function (should have been absolute value)
+	2	sum of both arguments
-	2	difference of both arguments
*	2	product of both arguments
/	2	protected division

TORCS: árbol de acelerador/freno

Name	Arguments	Description
ERC1	0	ephemeral random constant with range $[-1, 1]$
ERC50	0	ephemeral random constant with range $[-150, 150]$
c_1	0	first constant (used by hand-crafted gas/brake controller)
c_2	0	second constant (used by hand-crafted gas/brake controll
LR1	0	difference between left and right front facing track senso
S_9	0	front facing sensor
v_x	0	velocity of car
abs	1	identity function (should have been absolute value)
+	2	sum of both arguments
-	2	difference of both arguments
*	2	product of both arguments
/	2	protected division

Ejemplín en R

- Objetivo: hallar fórmula para calcular el área de un círculo a partir del radio
- Operadores:

  ```
  .operators. <- c("+","-","*","/")
  ```

  Aridad binaria para todos ellos
- ```
  random.elt <- function (lista)
        sample (lista, 1) [[1]]
  ```
  ```

```
random.form <- function (operators)
    {
        lista <- list (random.elt (operators))
        for (i in 1:2) # aridad
            lista <- c (lista,
                        {
                            random.nr <- runif (1)
                            if (random.nr < .5)
                                list (random.form (operators))
                            else if (random.nr < .75)
                                list (runif (1, 0, 10))
                            else list ("=input=")
                        })
        lista
    }
```

Generar árbol aleatorio

- Profundidad esperada: 2
- Profundidad: no limitada
- Aleatorios entre 0 y 10 (buscamos π)
- “=input=” es una variable (*x*, el radio del círculo)
- Inicialización “grow”
- Probar con

```
escribe.lista (random.form (.operators.))
```

- `Limitaremos profundidad:`

```
random.form <- . . . , max.depth = 4)
```

```
run.form.insegura <- function (form, input)
{
    if (is.atomic (form))
        if (form == "=input=")
            input
        else form
    else
        do.call (form[[1]],
                 lapply (form[-1], run.form.insegura, input))
}
run.form <- function (form, input)
    {
        intento <- try (run.form.insegura (form, input))
        if (inherits (intento, "try-error")) NA else intento
    }
```

Ejecutar un árbol

```
run.form.insegura (
  random.form (.operators.),
  0)  # u otro número

run.form (random.form (.operators.),
        0) # NA en vez de NaN
```

```
create.initial.population <-
  function(operators, size=100)
    lapply (1:size,
            function (i) random.form (operators))

fitness <-
  function (form, fitness.fn, test.input)
    prod (sapply (test.input,
     function (input) {
      output <- run.form (form, input)
      target <- do.call (fitness.fn,
                         list (input))
      difference <- abs (target - output)
      fitness.value <- 1 / (1 + difference)
     }))
```

Población inicial

```
for (i in
      create.initial.population
      (.operators., 10))
{ escribe.lista(i); cat("\n") }
```

Adaptación

```
árbol <- random.form (.operators.)
escribe.lista (árbol)
fitness (árbol,
         function (r) pi * r^2,
         c (0, 1, 2))
# puede ser NA por división por cero
```

Recorriendo las ramas

- `traverse.nodes.example (árbol)`
- `traverse.nodes.infijo (árbol)`

  # para usar con simplificadores algebraicos

  # como Maxima
- `n.nodes (árbol)` # nº nodos (inc. raíz)
- `random.node (árbol)` # evita la raíz
- `replace.node (árbol, 2, 'XXX')`

Recombinación y mutación

- árbol1 <- random.form (.operators.)
- árbol2 <- random.form (.operators.)
- escribe.lista (

  cross.over (árbol1, árbol2, TRUE))
- escribe.lista (

  mutate (árbol, .operators., TRUE))

Evaluar la población

```
población <-
 create.initial.population
   (.operators., 10)
evaluada <- evaluate.population
            (población,
             function (r) pi*r^2,
             C(0,1,2))
evaluada[[1]]$fitness # la mejor
```

```
advance.generation <- function (population, fitness.fn, operators,
                                test.input, max.population = 100)
    {
        epop <- evaluate.population (population, fitness.fn, test.input)
        cat ("Best fitness of current population:",
             epop[[1]]$fitness, "\n")
        res <- list()
        for (plist in head (epop, max.population))
            {
                fitness <- plist$fitness
                form    <- plist$form
                res     <- c (res, list (form))
                if (runif (1) < fitness)
                    res <- c (res, list (if (runif (1) < .9)
                                             cross.over (form,
                                                      random.elt(epop)$form)
                                             else mutate (form, operators)))
                if (runif (1) < 0.02)
                    res <- c (res, list (random.form (operators)))
            }
        res
    }
```

```
population <- create.initial.population (.operators.,
                                         100)
for (i in 1:500) {
        cat("[",i,"] ")
        population <- advance.generation (population,
                                          function(r) pi*r*r
                                          .operators.,
                                          list(0,1,-2))}
best.form <- function ()
    evaluate.population (population,
       function (r) pi * r^2,
       list (0, 1, -2)) [[1]]

traverse.nodes.example(best.form()$form)
traverse.nodes.infijo(best.form()$form) # para Maxima
```

Bibliografía

- A field guide to genetic programming
- On the programming of computers by means of natural selection