Evolution and Co-Evolution of Computer Programs to Control Independently-Acting Agents

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Outline

- Introduction
- Genetic Programming Paradigm
- 3 examples
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  - Differential Game
  - Co-Evolution Game

Introduction

For some particular problems, genetic programming paradigm can genetically breed the fittest computer program to solve these problems.

Genetic Programming Paradigm:

- Using hierarchic genetic algorithm by specifying:
  - The structures
  - The search space
  - The initial structure
  - The fitness function

Genetic Programming Paradigm: (Cont)

- The operation that modify the structure

  - the fitness proportionate reproduction

  - the crossover(recombination)
- The state of the system
- Identifying the results and termination the algorithm
- The parameters that control the algorithm

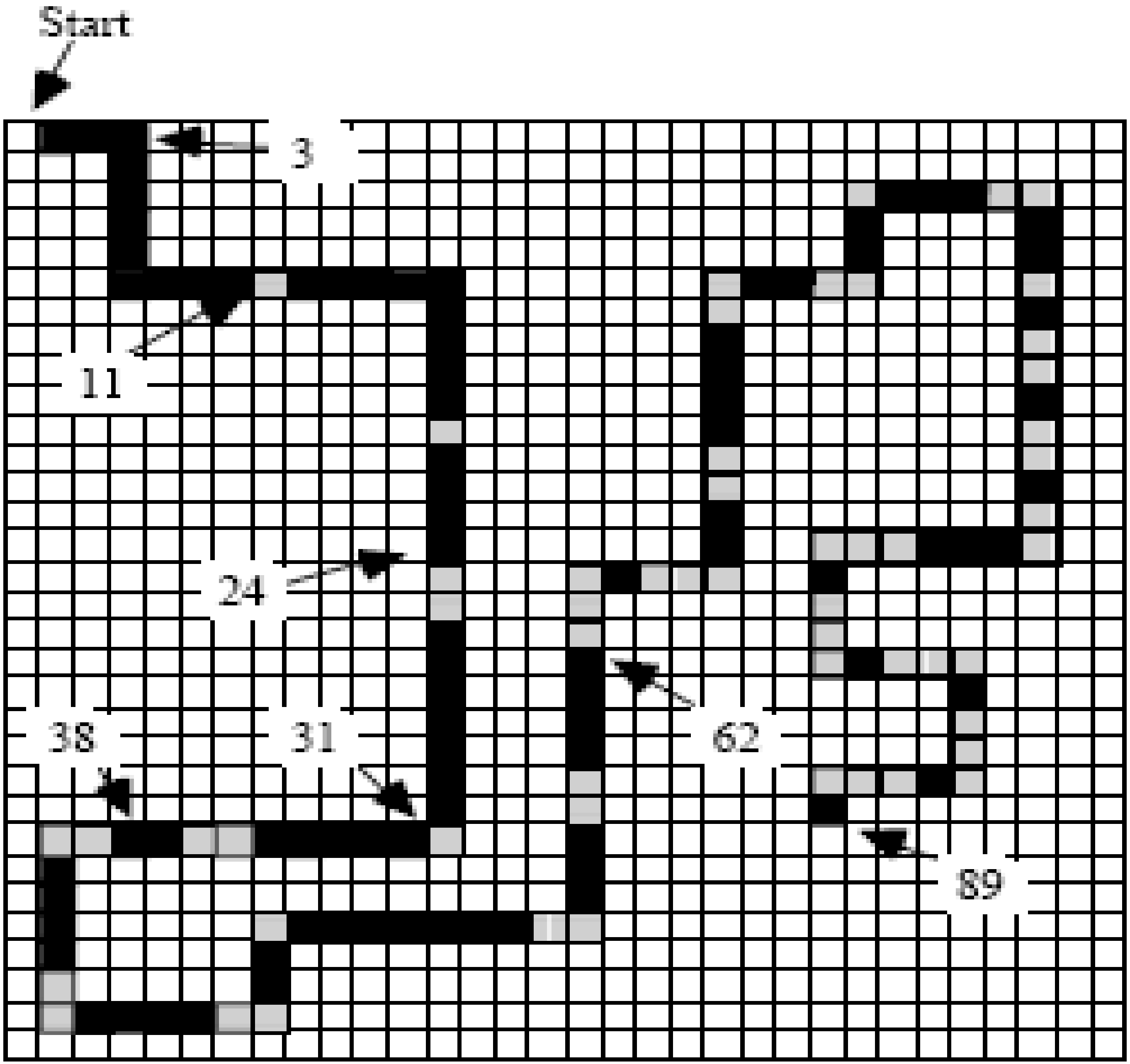
Artificial Ant Trail

- Case:

  A toroidal grid plane with 32*32 cells on which a winding trial consists of 89 stones, where there are single, double, and triple missing stones on the trail.

- Objective:

  To traversal the winding stone trail within certain time steps(400).


Start
3
11
24
38
31
62
89

- Capacity of the ant:

  move forward (advance)

  turn left

  turn right

  sense the contents of it facing

- Function set:

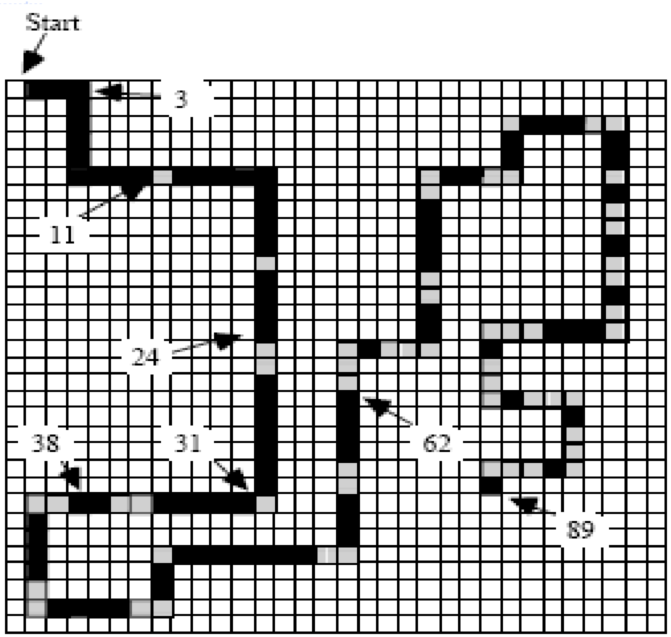
  F = { IF-SENSOR, PROGN}

- Terminal set:

  T = { ADVANCE, TURN-LEFT, TURN-RIGHT}

An individual of S-expression of 7th generation:

```
(IF-SENSOR (ADVANCE)
           (PROGN (TURN-RIGHT)
                  (IF-SENSOR (ADVANCE) (TURN-LEFT))
                  (PROGN (TURN-LEFT)
                         (IF-SENSOR (ADVANCE) (TURN-RIGHT))
                         (ADVANCE)))).
```



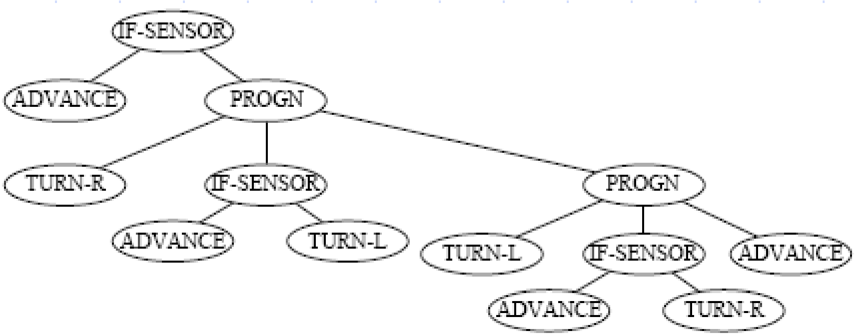
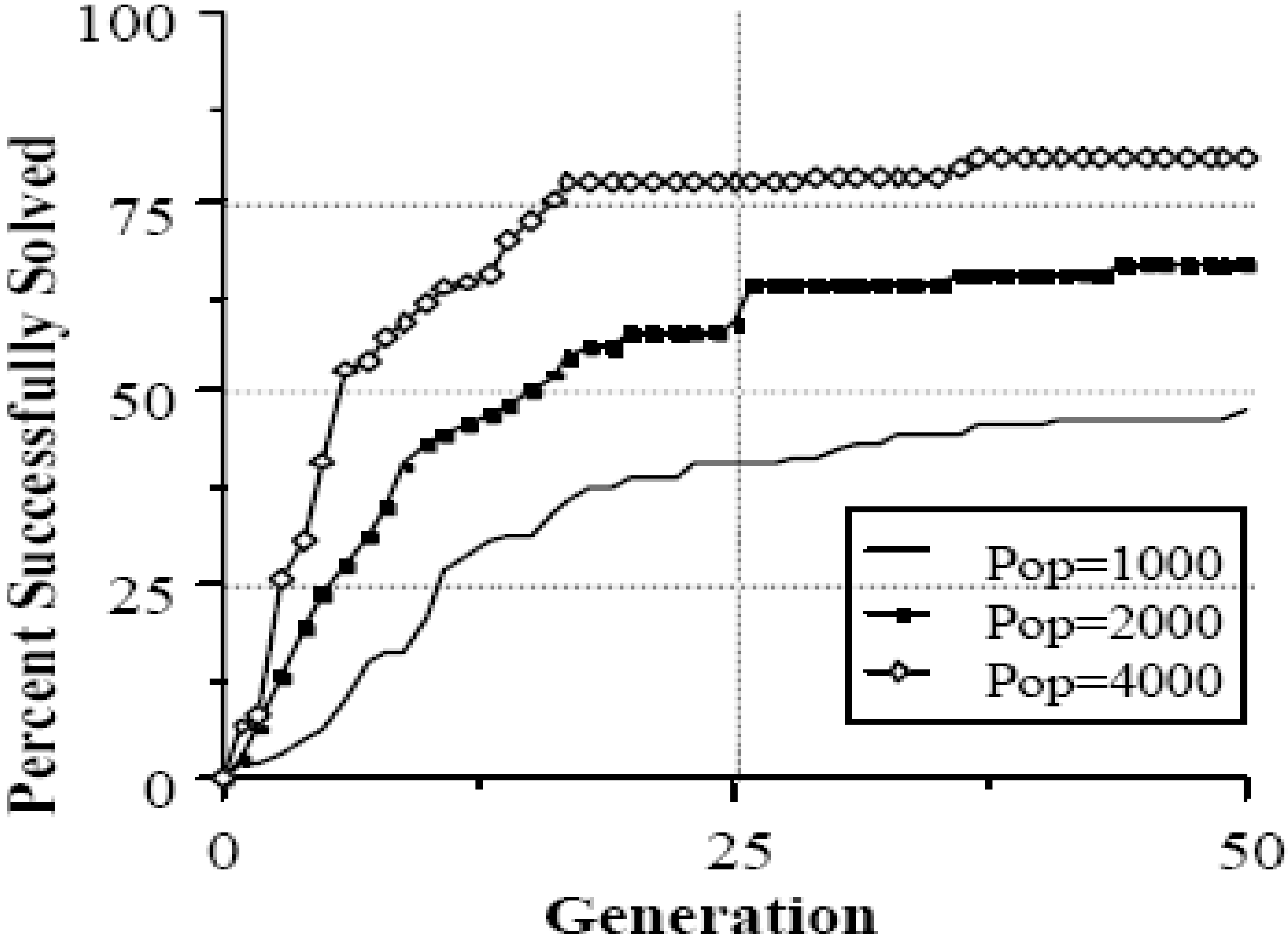


Figure. 1 Artificial Ant Solution

It is the exactly the solution for the problem!

Artificial Ant-Santa Fe Trail



Differential Pursuit Game

- Case:

  Two-person, competitive, zero-sum, simultaneous-moving, complete-information game in which a fast pursuing player P is trying to capture a slower evading player E.

Differnetial Pursuit Game (Cont)

- Objective:

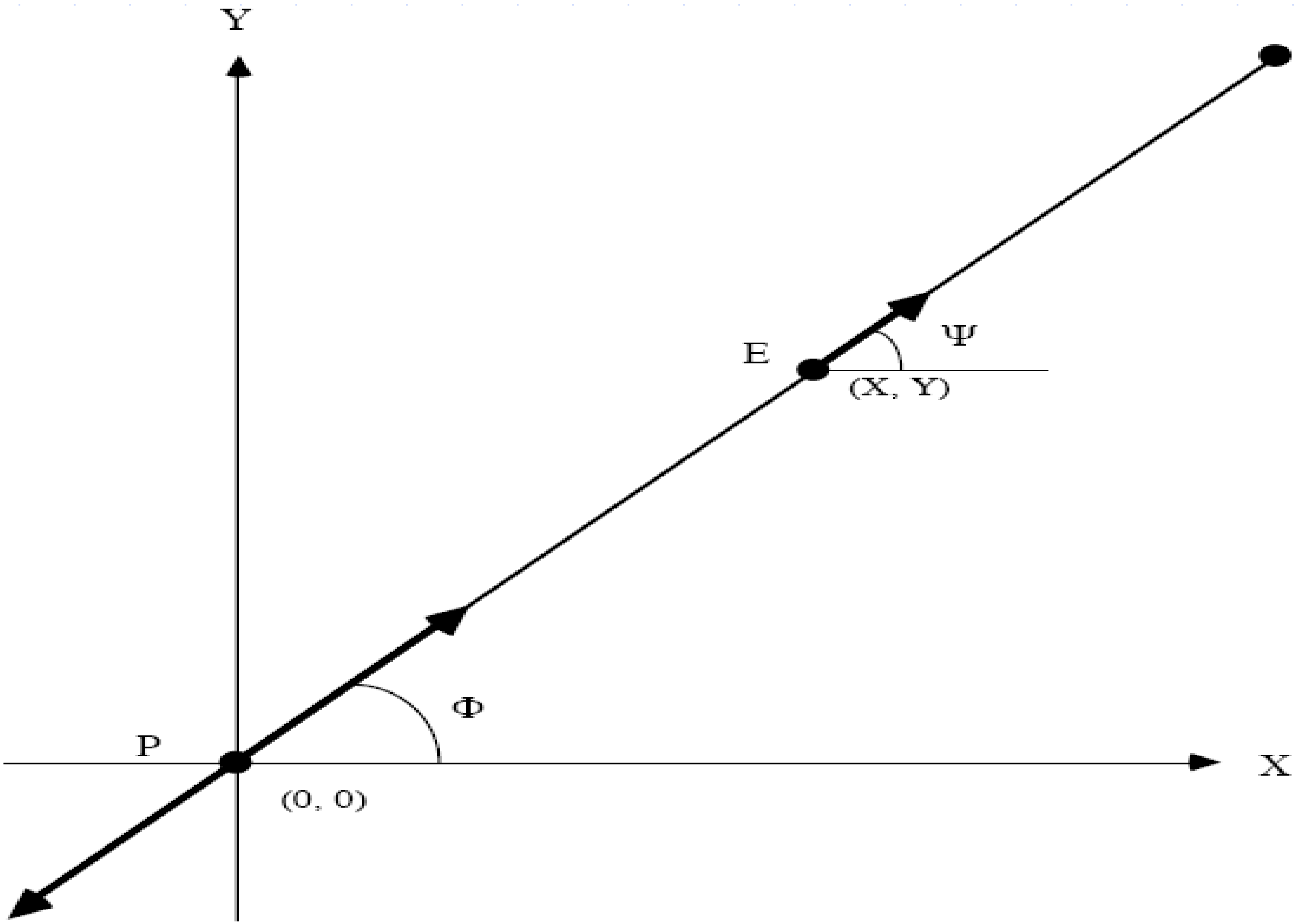
  To find an optimal strategy for one player when the environment (fitness function) consists of an optimal opponent.

- control variable:

  at each time step, the choice for each players is the select a value of their control variable.

  Pursuer: Φ

  Evader: Ψ

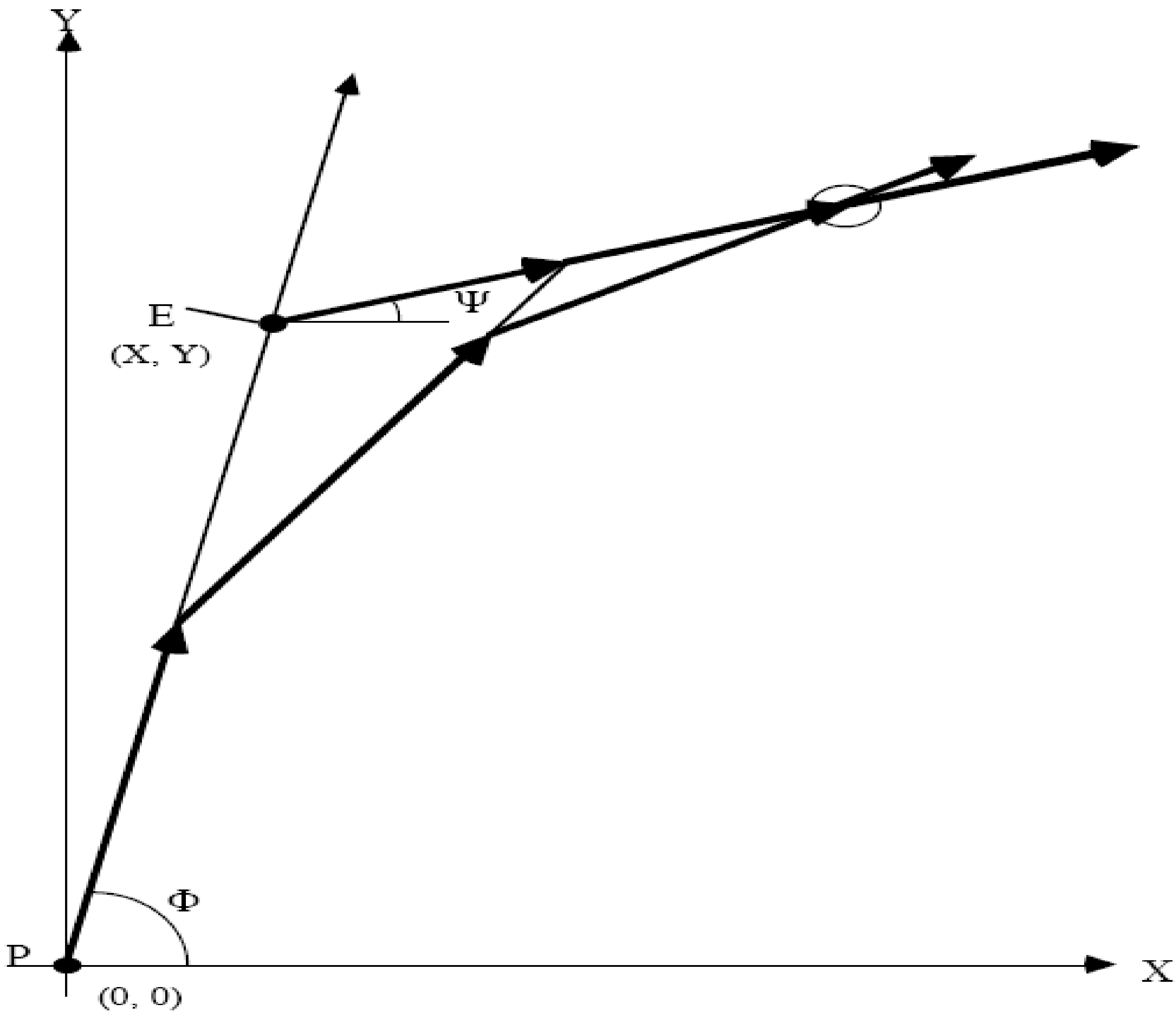


The state transition equations for the evader E are as follows:

$$x(t+1) = x(t) + w_e \text{Cos } \psi - w_p \text{Cos } \phi$$

$$y(t+1) = y(t) + w_e \text{Sin } \psi - w_p \text{Cos } \phi \; .$$

Wp*sinΦ



Y
E
(X, Y)
Ψ
Φ
P
(0, 0)
X

- The function set:

  F = { +, -, *, %, EXP}

- The terminal set:

  T= { X,Y,R}

  R- ephemeral random constant

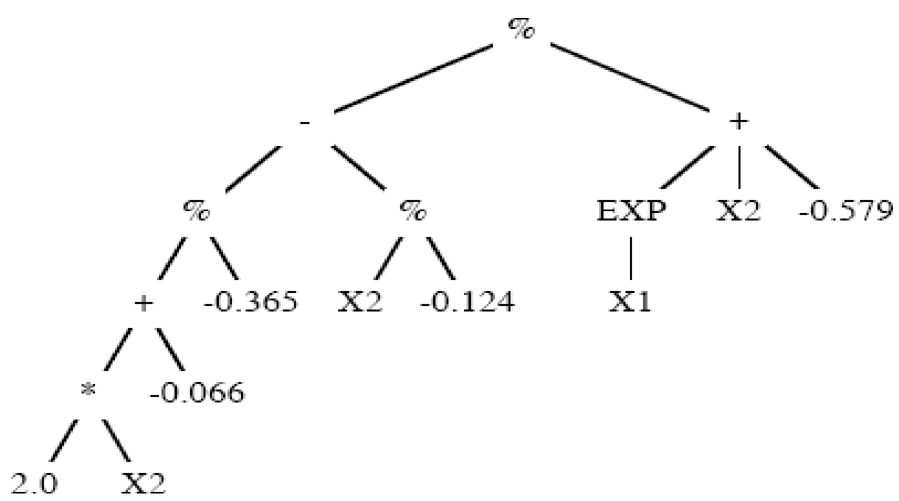
  (-1.0 ~ +1.0)

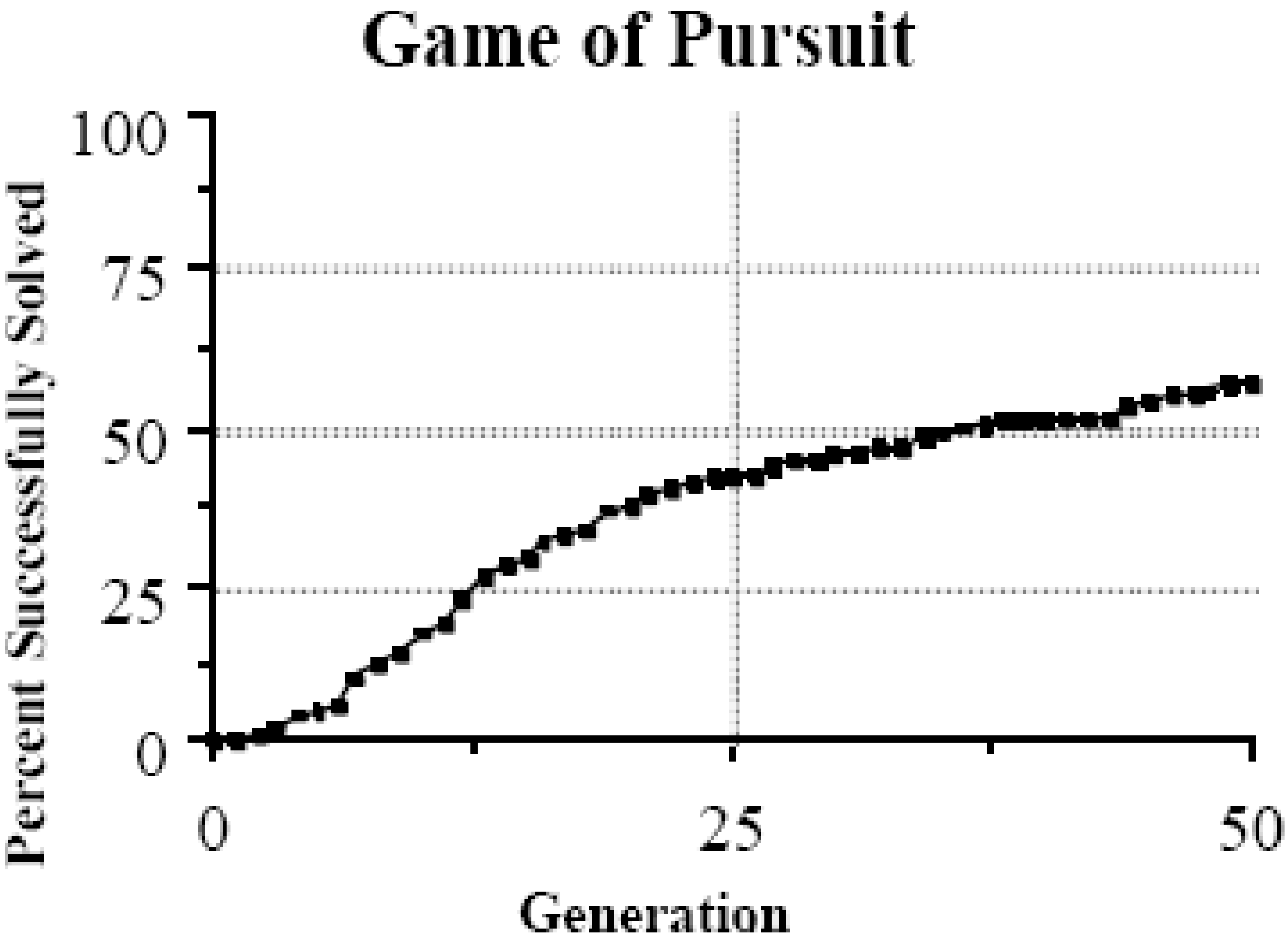
In 17th generation, a pursuer (the S-expression as following)can capture the evader in 10/10.

S-expression:

```
(% (- (% (+ (* 2.0 X2) -0.066) -0.365) (% X2 -0.124))
   (+ (EXP X1) X2 -0.579)).
```

S-expression can be depicted graphically as:





Size of the population=500

Co-Evolution Of A Game Strategy:

- Definition for co-evolution:

  All species are simultaneously co-evolving in a given physical environment

- Example:

  A plant and inserts

- Case:

  This is a two player, competitive, complete information, and zero-sum game in which the players make alternating moves(go-left or go-right).

Objective:

to simultaneously co-evolve strategies for both players.

- The function set:

  F = { CXM1, COM1, CXM2, COM2}

- The terminal set:

  T= { L,R}

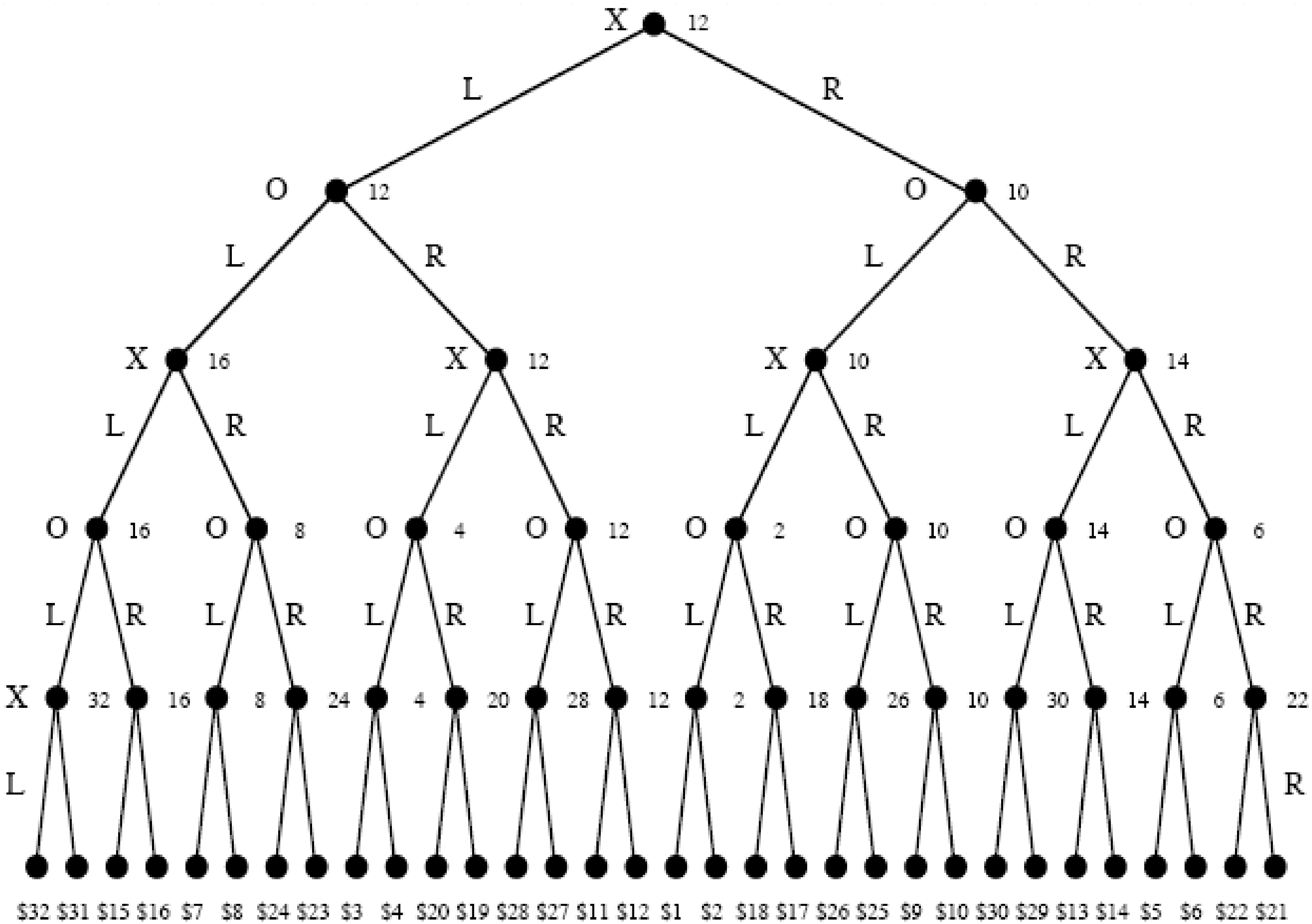
- variables: XM1,XM2,XM3,OM1,OM2

  store the historical

  information of X or O.

  consist three values: L, R ,and U.

- Procedures:
  - Both populations start as random compositions of the available functions and terminals.
  - The entire second population servers as the environment for testing the performance of each particular individual in the first population.
  - At the same time, the entire first population servers as the environment for testing the performance of each particular individual in the second population.



X 12
L R
O 12
O 10
X 16
X 12
X 10
X 14
O 16
O 8
O 4
O 12
O 2
O 10
O 14
O 6
X 32 16 8 24 4 20 28 12 2 18 26 10 30 14 6 22
$32 $31 $15 $16 $7 $8 $24 $23 $3 $4 $20 $19 $28 $27 $11 $12 $1 $2 $18 $17 $26 $25 $9 $10 $30 $29 $13 $14 $5 $6 $22 $21

A best game-playing strategy for player X in 6 generation, the minimax strategy for O servers as the environment.

(com2 (com1 (com1 L (com2 L L L)

(cxm1 L R L))

(cxm1 L L R)) L R)

L (com1 L R R)).

This strategy simplifies to:

(com2 (com1 L L R) L R)

- If the player O has been playing its minimax strategy, this S-expression will cause the game to finish at the endpoint with the payoff of 12 to player X, which is the optimal solution.

- If the player O was not playing its minimax strategy, this S-expression will cause the game to finish at the endpoints with the payoff of 32,16,or 28 to player X.

A best game-playing strategy for player in generation 9, the minimax strategy for X servers as the environment.

(cxm2 (cxm1 L (com1 R L L) L)

(com1 R L (cxm2 L L R))

(com1 L R (cxm1 L R

(cxm2 R (com1 L L R) (com1 R L R)))).

Can be simplified:

(cxm2 (cxm1 # R L) L R)

Thanks !