UCD CASL

Complex & Adaptive Systems Laboratory

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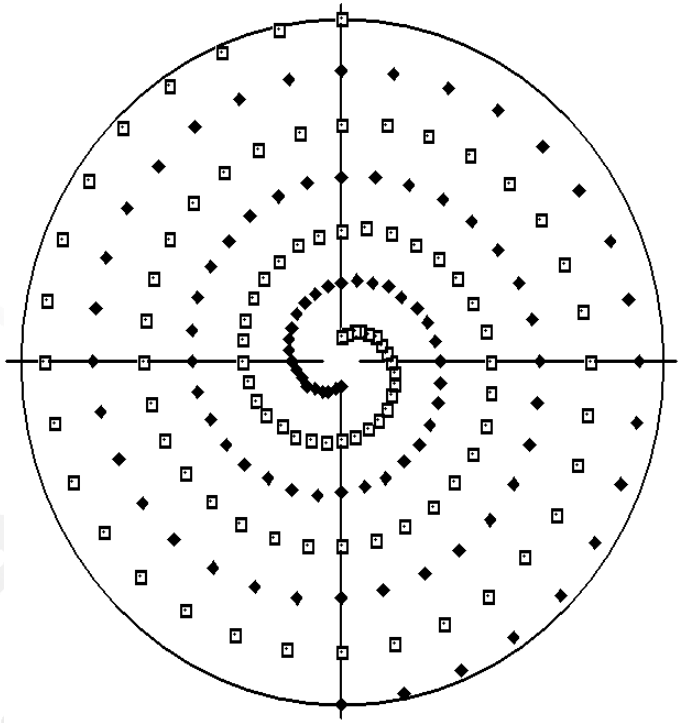
Genetic Programming II

COMP30290 Natural Computing
COMP41190 Natural Computing and Applications

GP - Classification

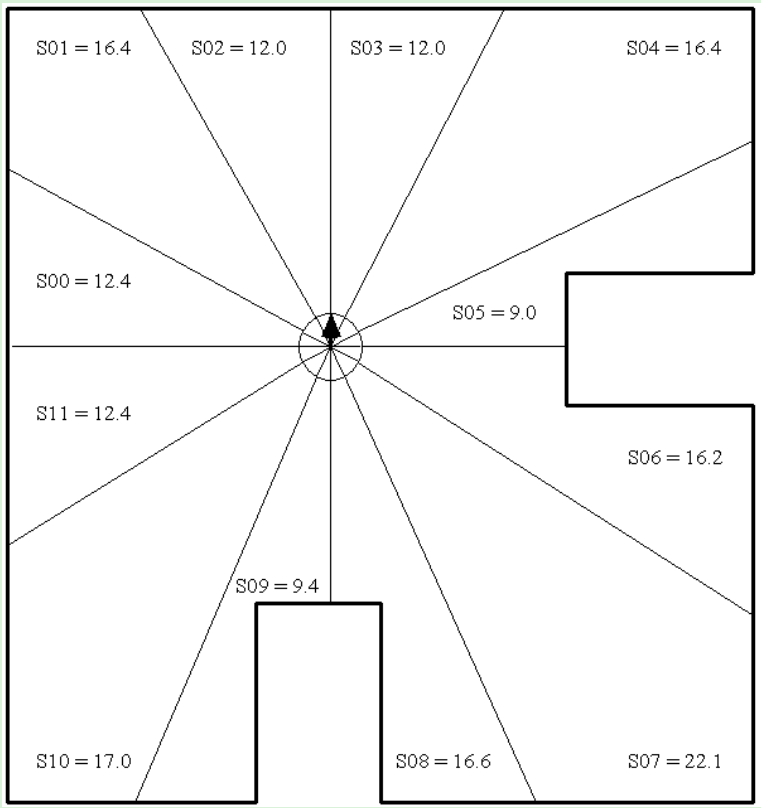


Objective	Create a program to classify a given point in the $x\|y$ plane to the black or white spiral
Terminal Set	$T = x, y,$ random-constants
Function Set	$F = +, -, \times, \%, IFLTE, \sin, \cos$
Fitness	The number of correctly classified points $(0 - 194)$
Parameters	$M = 10,000, G = 51$
Termination	An individual program scores 194

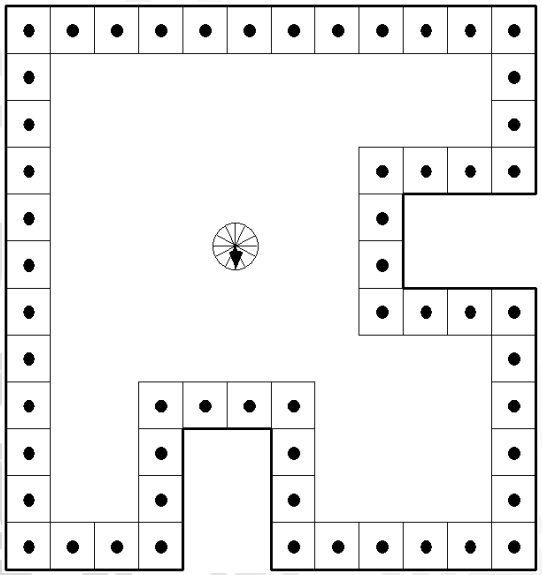
GP - Navigation

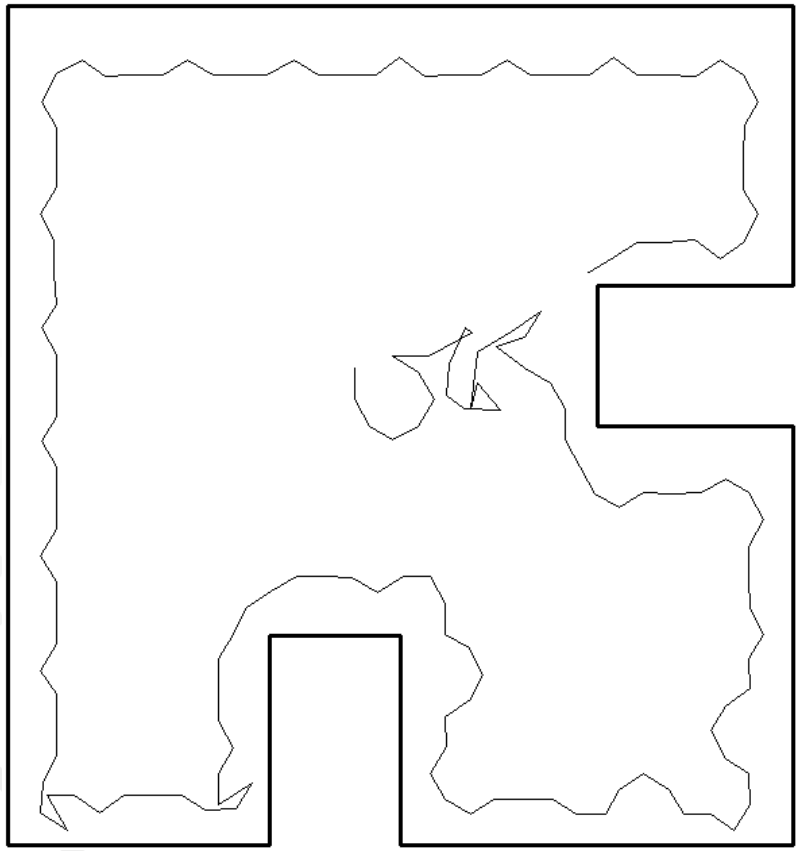
Wall Follower

- 12 sonar sensors, distance in feet;
- Additional STOPPED sensor;
- Actions:
  - forward(1ft)
  - backward(1.3ft)
  - right(30deg)
  - left(30deg)
  - stop;
- Fitness: hit all 56 tiles within `EDG` distance of wall;
- 400 time steps available;
- `EDG` = 2.3ft, `MSD` = 2.0ft, `SS`;
- Function set: `IFLTE`, `PROGN2`;
- Closure!



GP - Navigation



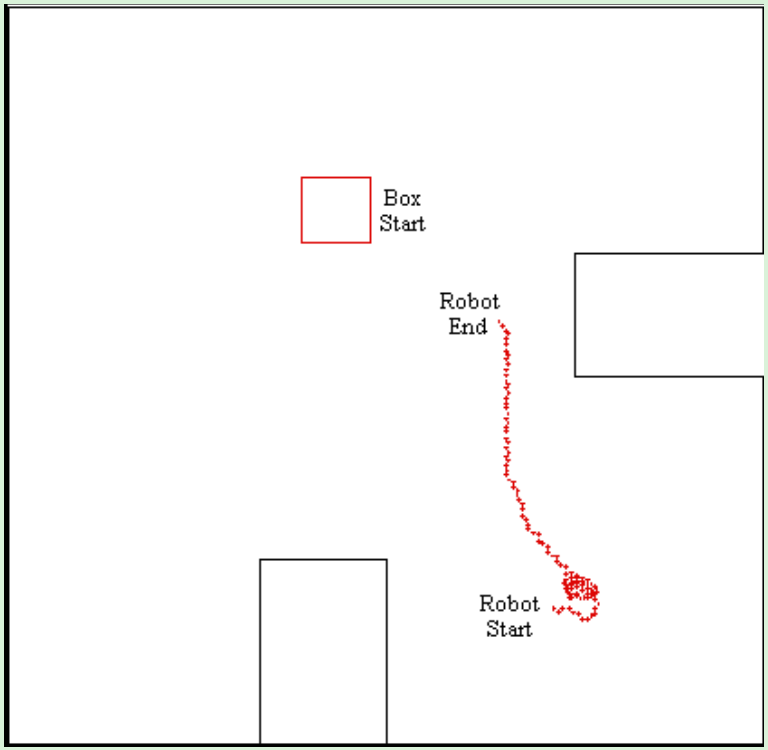


Best generation = 57

GP - Navigation

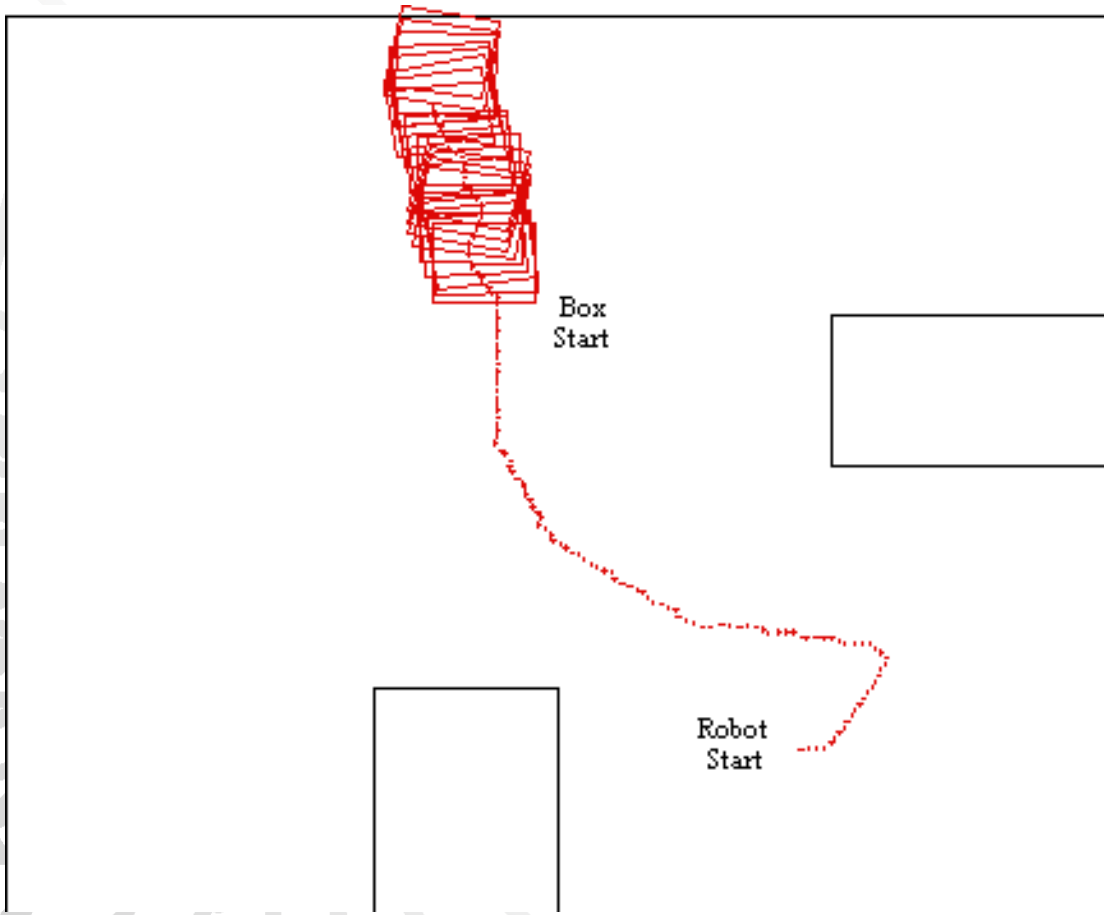
Box Pusher

- Find box in middle of room, and move to edge;
- Robot pushes box:
  - Unless force applied correctly, box will rotate!
- Similar function and terminal set as before;
- 4 fitness cases: different robot start positions.



Generation 0 (best)

GP - Navigation



Best generation = 45 (fitness case 1)

GP - Example Problems

Toy Problems

- Symbolic Regression;
- Artificial Ant;
- Intertwined Spirals;
- Broom Balancer;
- Block Stacking;
- Cellular Automata;
- Image Compression;
- Box Mover;
- Boolean Function Learning;
- ...

Applications

- Human Competitive non-patent results;
- 20^{th} Century Patents;
- 21^{st} Century Patents;
- New Patented Inventions.

GP 1987-2002

System	Dates	Speed up	HC Results	Problem Category
Serial LISP	1987-1994	1 (base)	0	Toy Problems
64 transputer	1994-1997	9	2	human-competitive results not patent related
64 PowerPC	1995-2000	204	12	20^{th} Century Patented Inventions
70 Alpha	1999-2001	1,481	2	20^{th} Century Patented Inventions
1,000 Pentium II	2000-2002	13,900	12	21^{st} Century Patented Inventions
4-week runs on Pentium IIs	2002-2003	130,000	2	Patentable new inventions

Human-Competitive Results (non-Patent)

Transmembrane segment identification problem for proteins
Motifs for DEAD box family and manganese superoxide dismutase family of proteins
Cellular automata rule for Gacs-Kurdyumov-Levin (GKL) problem
Quantum algorithm for the Deutsch-Jozsa early promise problem
Quantum algorithm for Grovers database search problem
Quantum algorithm for the depth-two AND/OR query problem
Quantum algorithm for the depth-one OR query problem
Protocol for communicating information through a quantum gate
Quantum dense coding
Soccer-playing program that won its first two games in the 1997 Robo Cup competition
Soccer-playing program that ranked in the middle of field in 1998 Robo Cup competition
Antenna designed by NASA for use on spacecraft
Sallen-Key filter

20^{th} Century Patents

Campbell ladder topology for filters
Zobel M-derived half section and constant K filter sections
Crossover filter
Negative feedback
Cauer (elliptic) topology for filters
PID and PID-D2 controllers
Darlington emitter-follower section and voltage gain stage
Sorting network for seven items using only 16 steps
60 and 96 decibel amplifiers
Analog computational circuits
Real-time analog circuit for time-optimal robot control
Electronic thermometer
Voltage reference circuit
Philbrick circuit
NAND circuit
Simultaneous synthesis of topology, sizing, placement, and routing

21st Century Patents

Low-voltage balun circuit
Mixed analog-digital variable capacitor circuit
High-current load circuit
Voltage-current conversion circuit
Cubic function generator
Tunable integrated active filter

Alternative Representations

Representations

- Various explored since trees;
- Graphs (PADO);
- Linear (Friedberg, Cramer, CGP and DGP);
- Grammars:
  - Tree-based (G^3P);
  - Linear (GADS, GE).

Alternative Representations

Grammars

- Backus Naur Form (BNF);
- BNF Grammar a 4-tuple $< T, N, P, S >$:
  - T: Terminal Set;
  - N: Non-terminal Set;
  - P: Set of Production Rules;
  - S: Start Symbol (a member of N).

BNF Example

T = {sin, cos, tan, log, +, -, /, *, X, (,)}

S = <expr>

N = {<expr>, <op>, <pre-op>, <var>}

P =

<expr> ::= (<op> <expr> <expr>)
| (<pre-op> <expr>)
| <var>

<op> ::= + | - | / | *

<pre-op> ::= sin | cos | tan | log

<var> ::= x

DGP

Developmental GP

- Wolfgang Banzhaf;
- Linear, fixed-length, binary chromosomes!;
- Genotype-Phenotype Mapping;
- Binary Codes for each Symbol in function and terminal sets;
- n-bit code - a codon.

DGP

```
<expr> ::= (<expr> <op> <expr>) | <var>
<op> ::= + | *
<var> ::= a | b
```

Developmental GP

Codon	Symbol
000	a
001	b
010	$+$
011	$*$
100	a
101	b
110	$+$
111	$*$

- 000010101 represents $a + b$;
- Repair illegal raw sequences:
  - Editing.
- Determine legal symbol set;
- Determine minimal distance set;
  - Symbol with lowest int values used.

DGP

```
<expr> ::= (<expr> <op> <expr>) | <var>
<op> ::= + | *
<var> ::= a | b
```

Developmental GP

Codon	Symbol
000	a
001	b
010	$+$
011	$*$
100	a
101	b
110	$+$
111	$*$

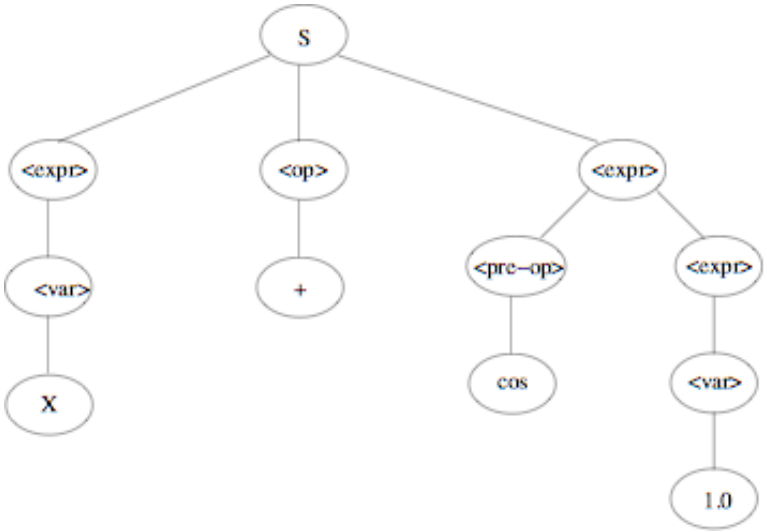
- 000 001 011 gives $ab*$;
- a is ok, b is illegal:
  - Look up <op> in grammar;
  - Nearest to b (001) is $*$ (011).
- $a * *$:
  - Second $*$ illegal;
  - Look up <var>;
  - Closest to 011 is b (001);
  - $a * b$.

G^{3}P

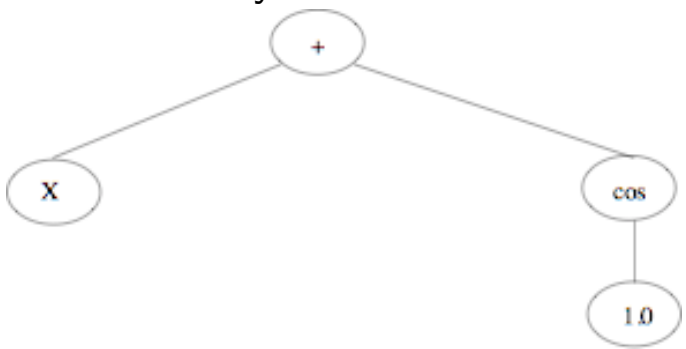
- Grammar Guided Genetic Programming;
- Use Derivation Trees:
  - Crossover: match NT symbol (no match, no XO);
  - Mutation: Replace with random derivation sequence.

```
<expr> ::= <expr> <op> <expr>
         | <pre-op> <expr>
         | <var>
<op> ::= + | *
<pre-op> ::= sin | cos
<var> ::= 1.0 | x
```

Derivation Tree



Syntax Tree



Project Proposal

(Maximum Length 2 Pages, Minimum Font Size 12)

Author Name :
Author ID:

Project Title :

Abstract (*max 100 words*):

I. What is the question that this proposal addresses?

II. Why is this problem significant?

III. How will the question be addressed? (*i.e. Briefly describe the experimental methods that you plan to use and Timelines.*)