

Recent Adventures with Grammar-based Genetic Programming

Dr. Michael O'Neill

Mendel '10

23 June 2010



UCD Natural Computing Research & Applications (NCRA)
<http://ncra.ucd.ie>

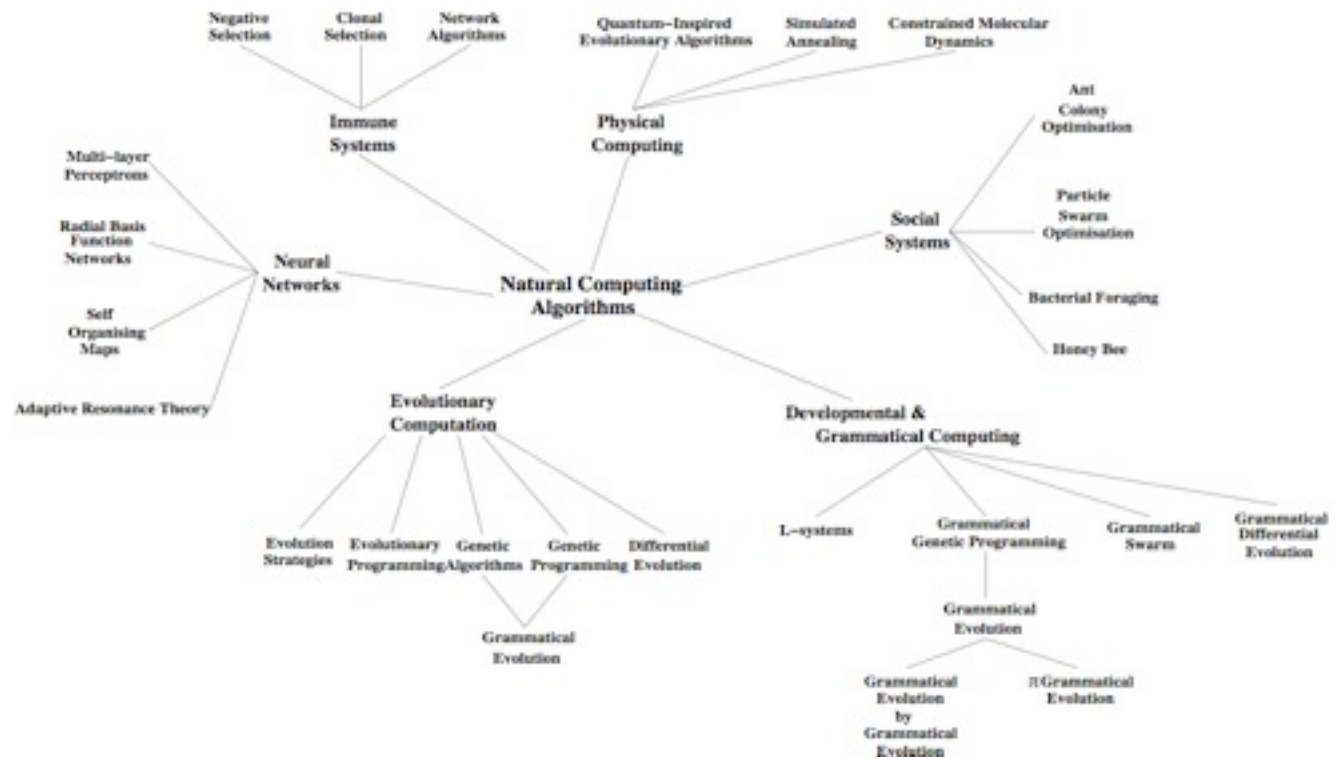
What is NCRA group about?



Inspire Design of *

Natural Processes as Computational Machines

Understanding Natural Processes



Natural Computing Algorithms. Springer (2011).



Team NCRA



~30 researchers

+

Michael

+

Tony

+

€0

4 years

€7M

...

(2006)

(2010)



BIAs



- Develop automated problem solvers
- Solve hard real-world problems
 - e.g. Trading, Prediction, Classification, Model Development, Design...
- Biological organisms inhabit complex, ever-changing environments
- Diverse species and specialisations
- Survival depends on ability to adapt and compete for resources
- Relative performance, being “*good-enough*”



Black Art of EC



- Population-based Search
- Stochastic

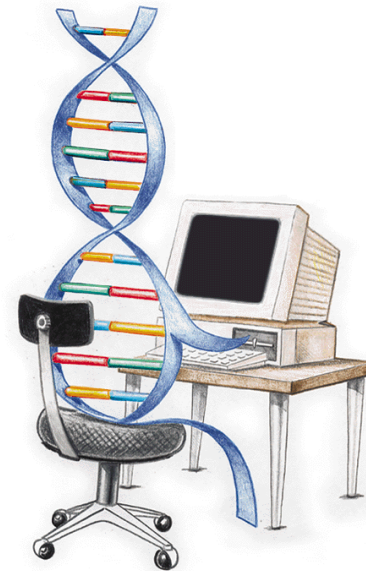
- Find good chromosome representation
- Find good fitness measure
- Design balanced variety generation (search) operators



Genetic Programming



- What is Genetic Programming?
- Automatic Programming?
 - Assemblers
 - Compilers 2GL...
 - Automatic Parallelisation



“Tell the computer what to do, not how to do it.”

Arthur Samuel, 1959



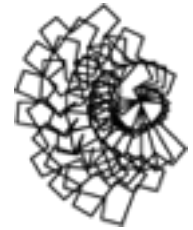
Automatic Programming



- John Koza's (1999) AP Attributes...
 - Start with **high-level problem description** that results in a solution in the form of a computer program
 - Automatically determine the programs **size and architecture**
 - Automatically organise a group of **instructions** so that they may be **re-used** by a program
 - **Problem-independence**
 - **Scalability** to larger versions of the same problem
 - Capability of producing **human competitive results**
 - Evolutionary Automatic Programming/Genetic Programming



Representation



- Individual **is** *OR* represents/encodes a program

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

int main(int argc, char* argv){
    float x=0.0, y=0.0, z=0.0;
    x=atof(argv[1]);
    y=atof(argv[2]);
    z=atof(argv[3]);
    x = 2.0*sin(y) + 4.0*sin(x);
    z = (x*x) + exp(z);
    printf("The answer is: z=%f\n",z);
    return(0);
}
```

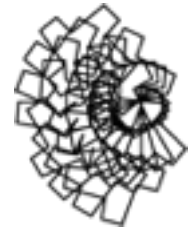
```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

void turnLeft(float degrees);
void turnRight(float degrees);
void moveForward(float distance);

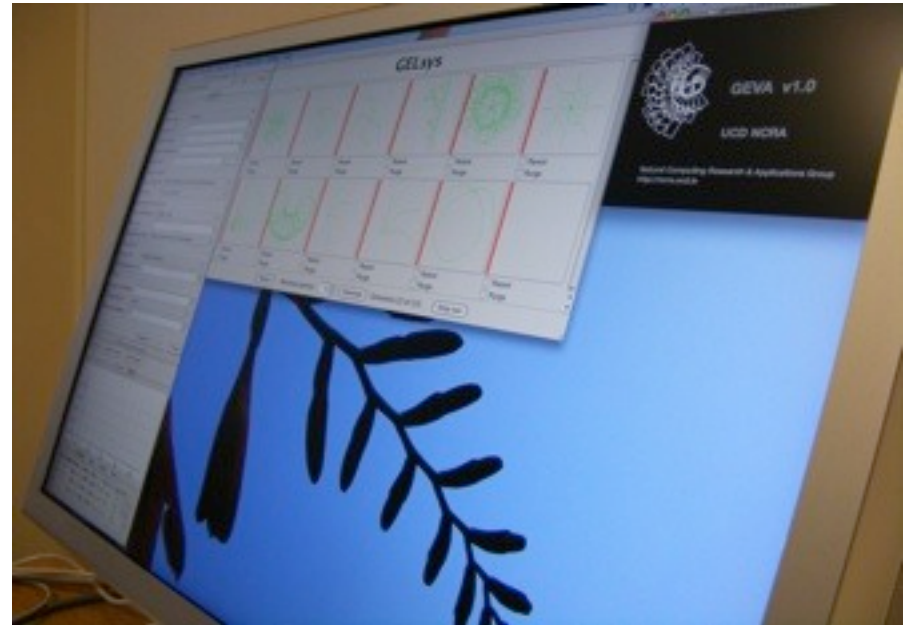
int main(int argc, char* argv){
    turnLeft(90);
    if(sensorValue(0) > 1000)
        moveForward(10);
    else
        turnRight(90);
    return(0);
}
```



Grammatical Evolution



- **Grammatical** Genetic Programming
- Chromosomes
 - Linear
 - Binary/Integer
 - Variable-length
- Genotype-Phenotype Map
- **Bio-inspired**



O'Neill, Ryan. (2003). *Grammatical Evolution*. Kluwer Academic Press.

Brabazon, O'Neill. (2006). *Biologically Inspired Algorithms for Financial Modelling*. Springer

Dempsey, O'Neill, Brabazon. (2009). *Foundations of GE in Dynamic Environments*. Springer.

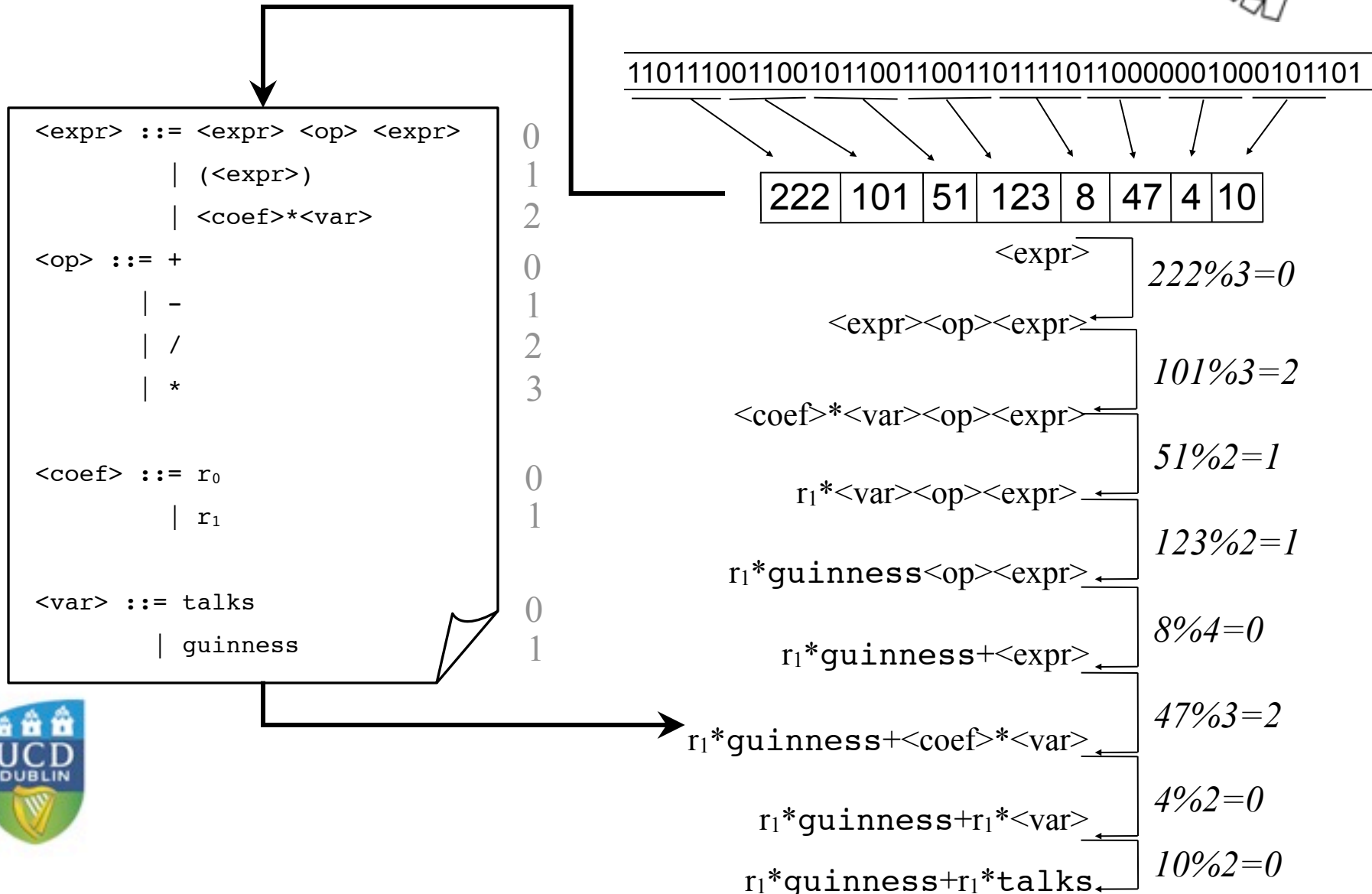
Ryan, O'Neill, Collins (1998). *Grammatical Evolution: Solving Trigonometric Identities*. **Mendel 1998**

GP&EM 10th Anniversary Issue

McKay, Nguyen, Whigham, Shan, O'Neill. (2010). *Grammar-based Genetic Programming - A Survey*. *Genetic Programming & Evolvable Machines* 11(3).



Example - What makes a great conference?



Wrapper



```
<func> ::= <header>
<header> ::= float symbreg(float x) { <body> }
<body> ::= <declarations><code><return>
<declarations> ::= float a;
<code> ::= a = <expr>;
<return> ::= return (a);
```

```
float symbreg(float x){
    float a;
    a= <expr>;
    return(a);
}
```

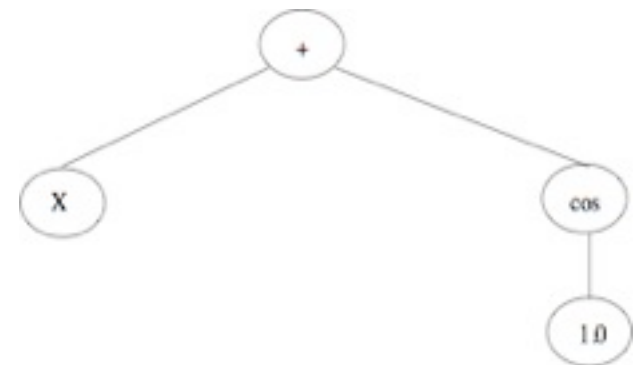
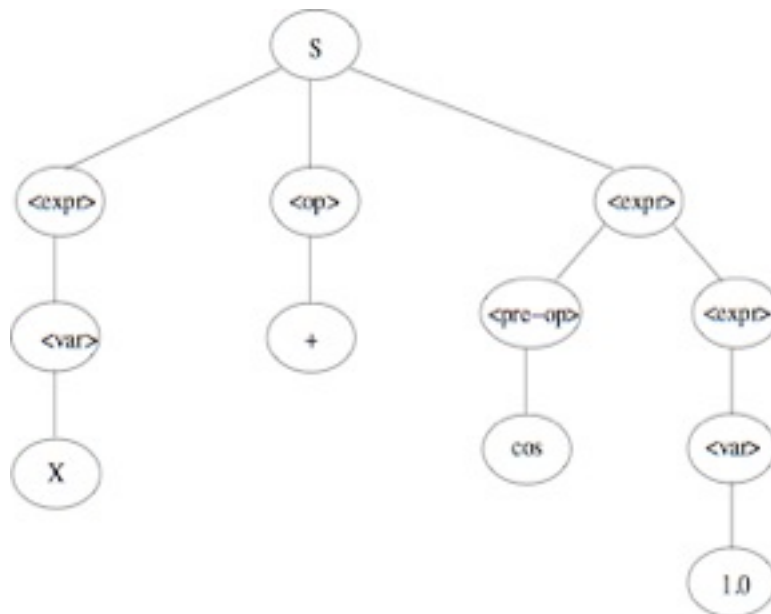
```
<code> ::= <line>;
          | <line>; <code>
<line> ::= ...
```

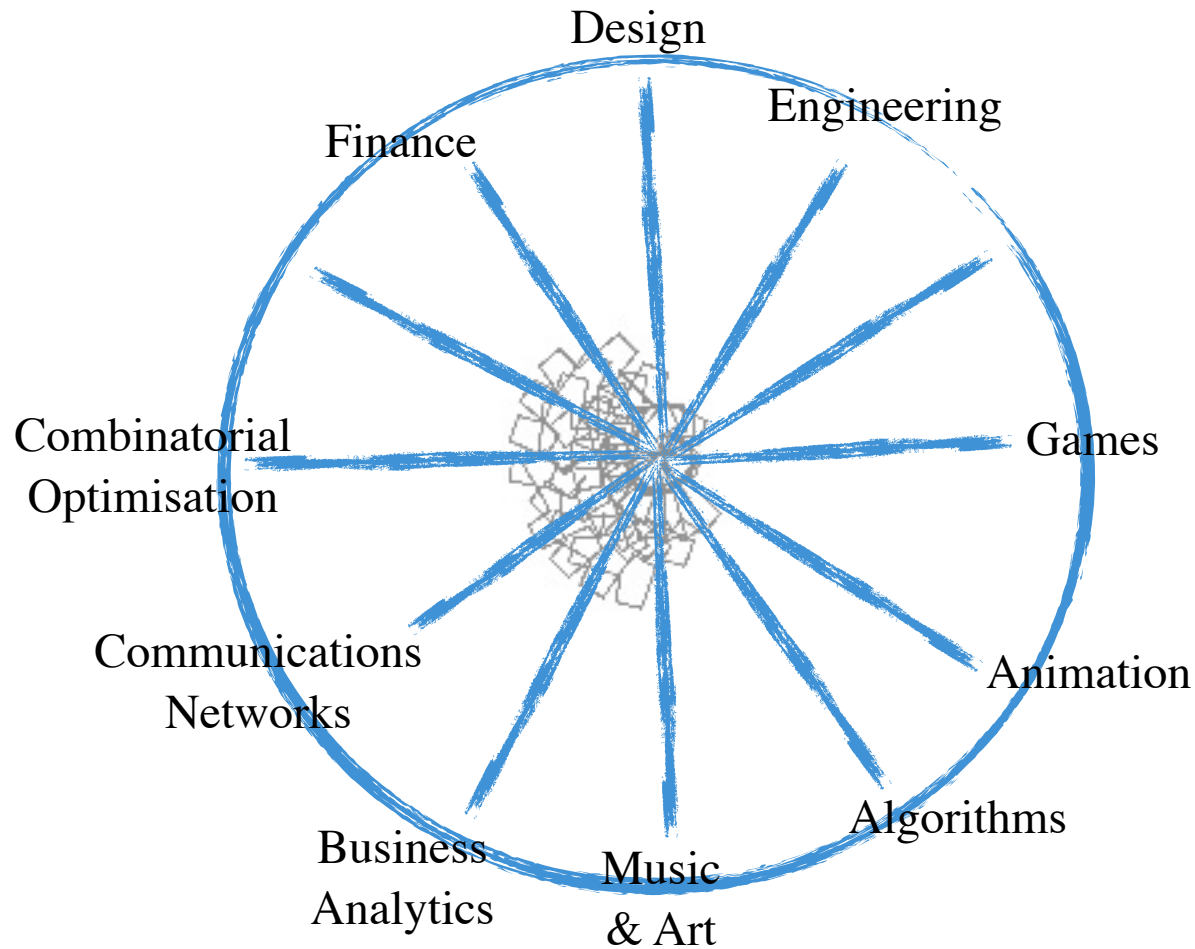


Genetic Operators

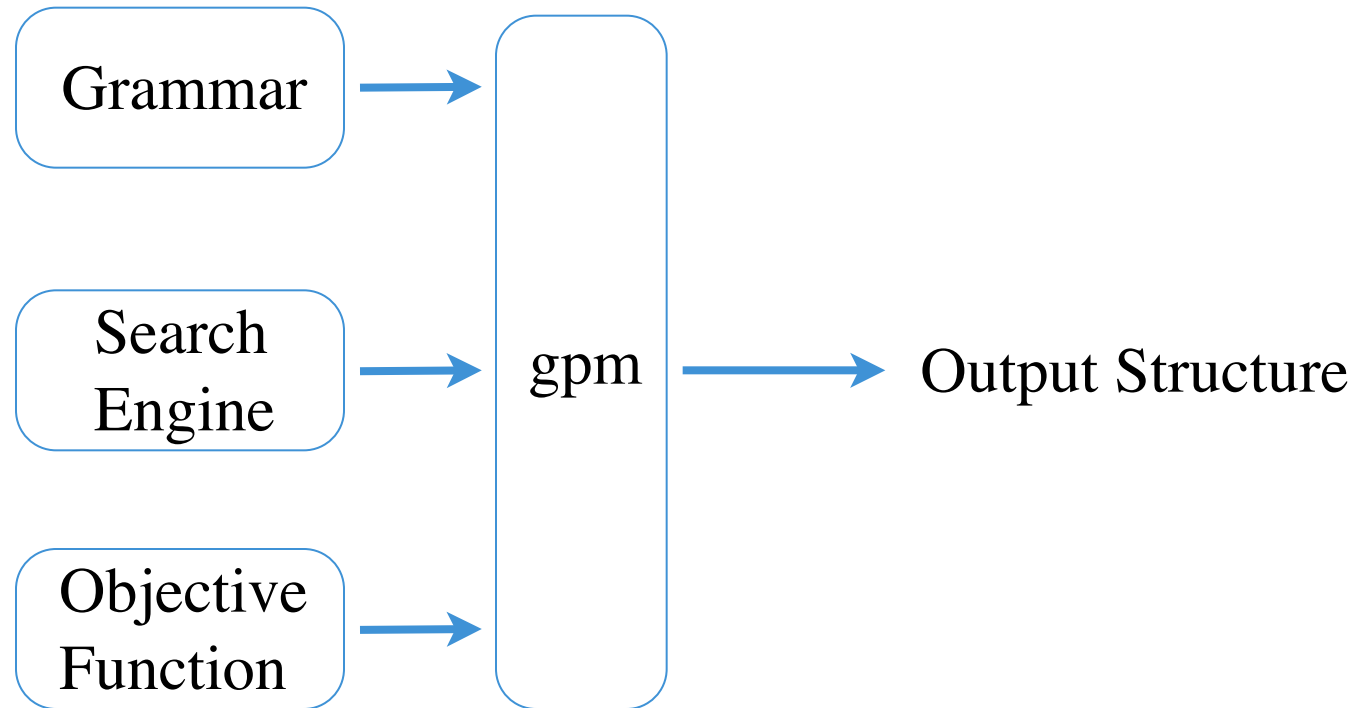


- (Variable-length) Binary/Integer String
- Bit/Codon Mutation
- 1pt Xover
- Duplication
- Tree-based operators





GE/GP Research



- Many important questions to address...



GE/GP Research (Conferences 2010...)



@EvoStar

Cui W., Brabazon A., O'Neill M. *Evolving Dynamic Trade Execution Strategies using Grammatical Evolution*. EvoFIN 2010

Bradley R., Brabazon A., O'Neill M. *Evolving Trading Rule-Based Policies*. EvoFIN 2010

Fagan D., O'Neill M., Galvan-Lopez E., Brabazon A., McGarraghy S. *An analysis of Genotype-Phenotype Maps in Grammatical Evolution*. EuroGP 2010

Nguyen Q.U., Nguyen T.H., Nguyen X.H., O'Neill M. *Improving the Generalisation Ability of Genetic Programming with Semantic Similarity based Crossover*. EuroGP 2010

Byrne J., McDermott J., O'Neill M., Brabazon A. *An analysis of the behaviour of mutation in Grammatical Evolution*. EuroGP 2010

Shao J., McDermott J., O'Neill M., Brabazon A. *Jive: A Generative, Interactive, Virtual, Evolutionary Music System*. EvoMUSART 2010

Galvan-Lopez E., Swafford J.M., O'Neill M. *Evolving a Ms.Pac-man Controller using Grammatical Evolution*. EvoGAMES 2010

@GECCO

Galvan-Lopez E., McDermott J., O'Neill M., Brabazon A. *Towards an Understanding of Locality in Genetic Programming*

Nguyen Q.U., Nguyen X.H., McKay R.I., O'Neill M. *Semantics Based Crossover for Boolean Problems*

@CEC/WCCI

Nguyen Q.U., McKay R.I., O'Neill M., Nguyen X.H. *Self-Adapting Semantic Sensitivities for Semantic Similarity Based Crossover*

McGee R., O'Neill M., Brabazon A. *The Syntax of Stock Selection: Grammatical Evolution of a Stock Picking Model*

McDermott J., O'Neill M., Brabazon A. *Interactive Interpolating Crossover in Grammatical Evolution*

McDermott J., Byrne J., Swafford J.M., O'Neill M., Brabazon A. *Higher-Order Functions in Aesthetic EC Encodings*

Swafford J.M., O'Neill M. *An Examination on the Modularity of Grammars in Grammatical Evolutionary Design*

Byrne J., McDermott J., Galvan-Lopez E., O'Neill M. *Implementing an Intuitive Mutation Operator for Interactive Evolutionary 3D Design*

Murphy E., O'Neill M., Galvan-Lopez E., Brabazon A. *Tree-Adjunct Grammatical Evolution*

Galvan-Lopez E., Fagan D., Murphy E., Swafford J.M., Agapitos A., O'Neill M., Brabazon A. *Comparing the Performance of the Evolvable PiGrammatical Evolution Genotype-Phenotype Map to Grammatical Evolution in the Dynamic Ms. Pac-Man Environment*

Galvan-Lopez E., McDermott J., O'Neill M., Brabazon A. *Defining Locality in Genetic Programming to Predict Performance*

Bradley R., Brabazon A., O'Neill M. *Objective Function Design in a Grammatical Evolutionary Trading System*

Cui W., Brabazon A., O'Neill M. *Evolving Efficient Limit Order Strategy using Grammatical Evolution*

Fagan D., Nicolau M., O'Neill M., Galvan-Lopez E., Brabazon A. *Investigating Mapping Order in IIGE*

@PPSN

Agapitos A., O'Neill M., Brabazon A. *Evolutionary Learning of Technical Trading Rules without Data-mining Bias*

McDermott J., Galvan-Lopez E., O'Neill M. *GP Locality with Binary Decision Diagrams as Ant Phenotypes*

Nguyen Q.U., Nguyen X.H., O'Neill M., McKay B. *The Role of Syntactic and Semantic Locality of Crossover in Genetic Programming*



Open Issues in GP

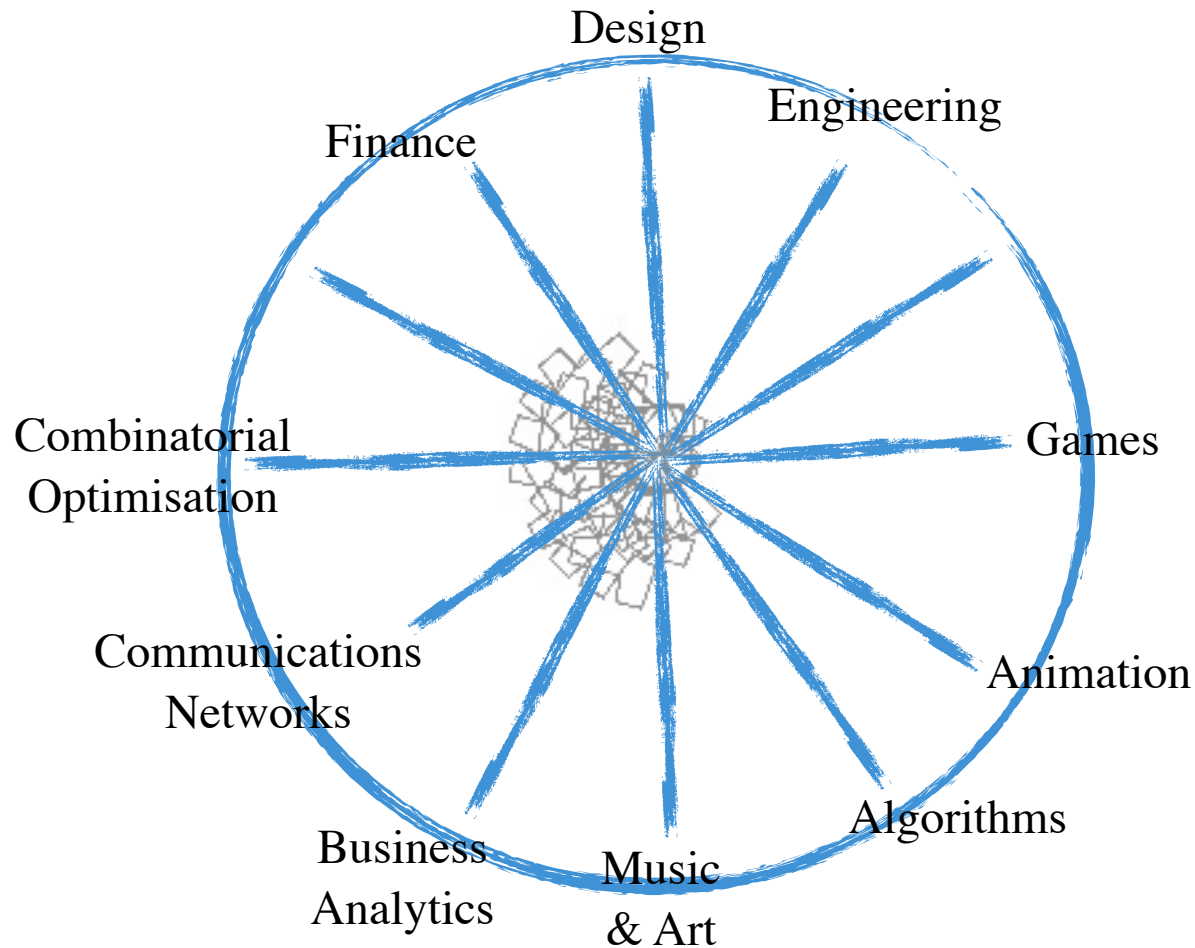


O'Neill, Vanneschi, Gustafson, Banzhaf. (2010). *Open Issues in Genetic Programming*. Genetic Programming & Evolvable Machines, 11(3).

GP&EM 10th Anniversary Issue

- Identifying appropriate Representations
- Fitness Landscapes & Problem Difficulty
- Static vs. Dynamic Problems
- The Influence of Biology
- Open-ended Evolution
- Generalization
- Benchmarks
- Modularity
- Complexity of GP
- Misc....
 - Halting, AI Ratio, Bio, Constants, Theory, Distributed Models, Usability...





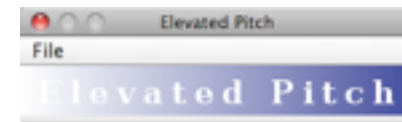
Applications - Art & Music



O'Neill & Brabazon (2008)



Reddin, McDermott, Brabazon, O'Neill (2009)



Welcome to Elevated Pitch

1. Select your preferences from the drop down lists below (or leave random) and click generate.
 2. Wait (~15 seconds) until the generate button pops out.
 3. Change the melodies to suit your taste.
 4. Save, playback and enjoy the output!
- Once you're finished, click Exit.

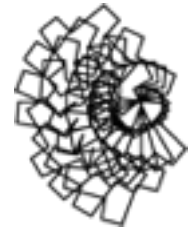


Nicolau & Costelloe (2010)

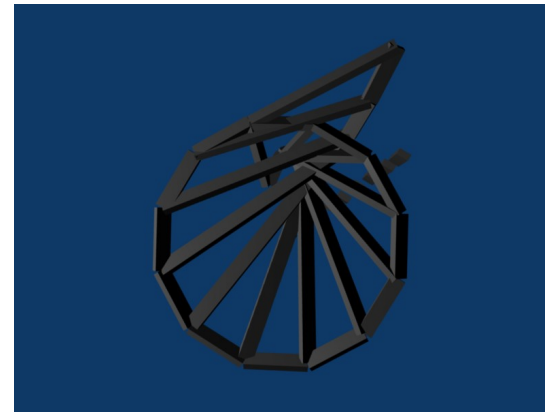
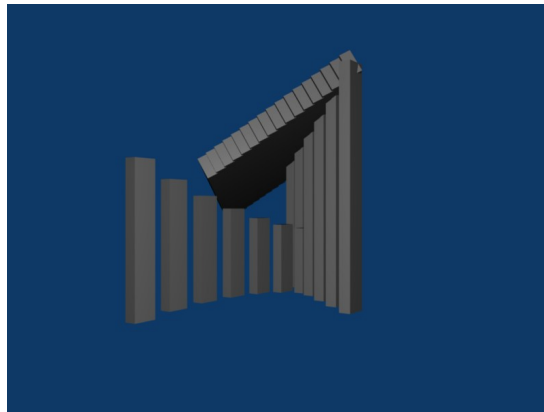
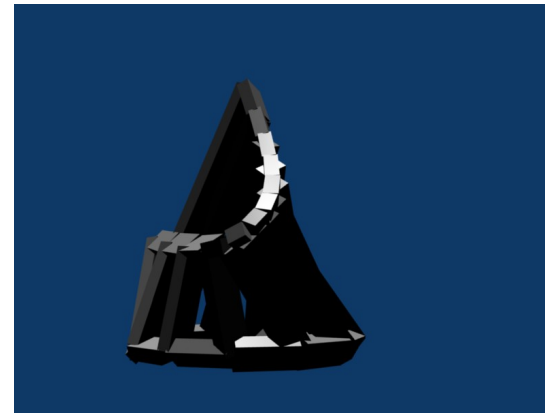
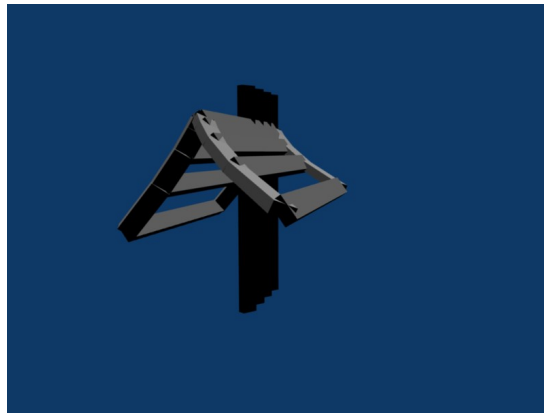


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Applications - Architecture



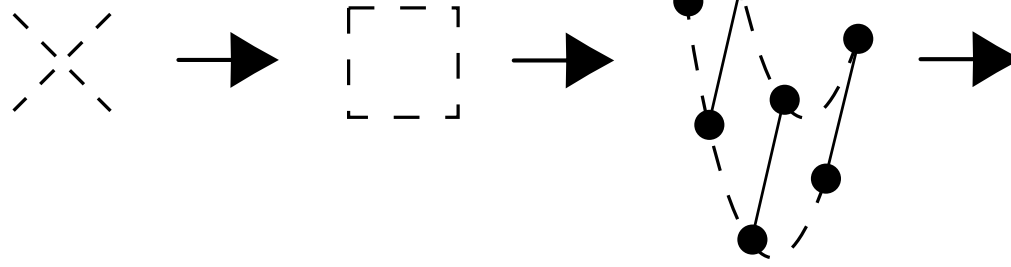
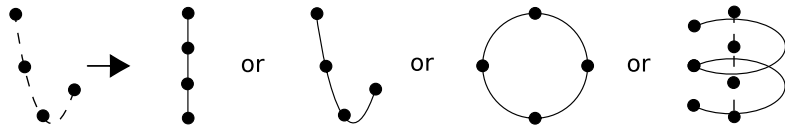
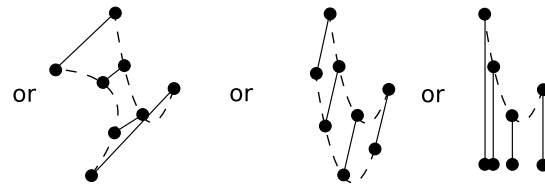
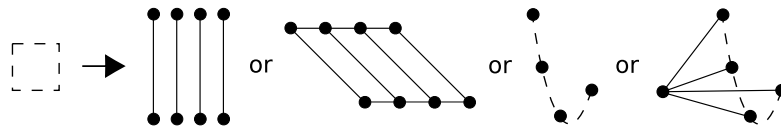
Evolutionary Architecture with Shape Grammars
O'Neill et al (2009 & 2010)



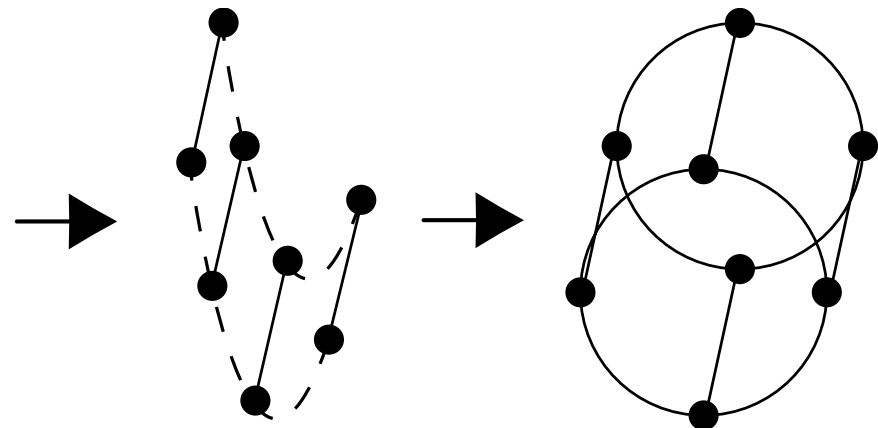
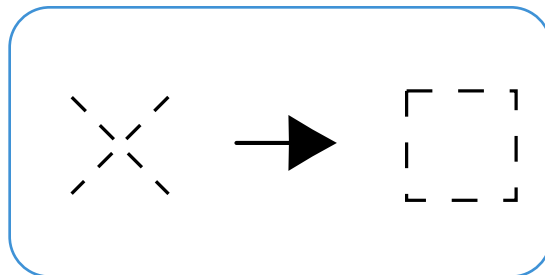
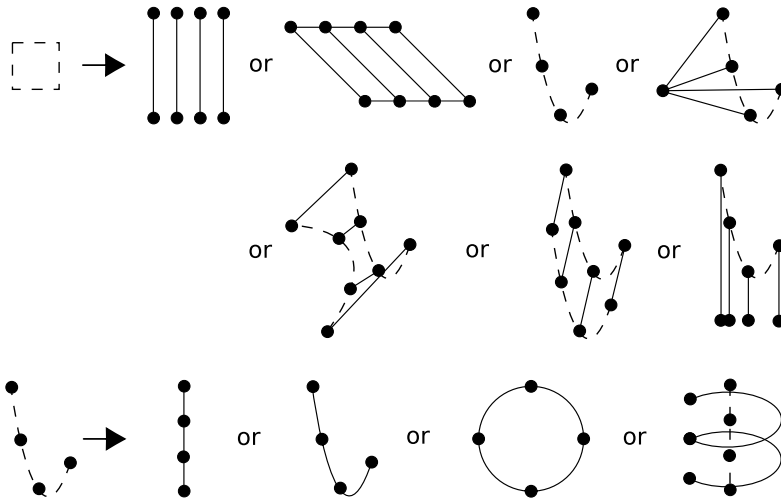
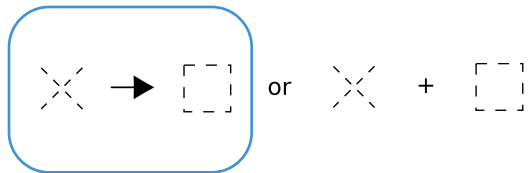
Example derivation



$$\times \rightarrow \square \text{ or } \times + \square$$



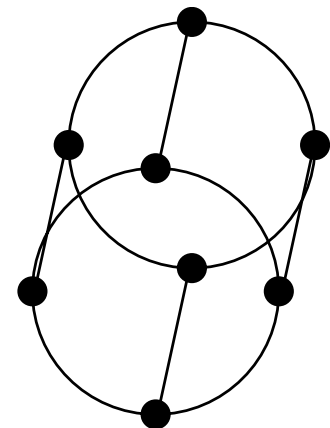
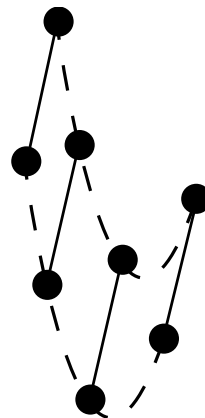
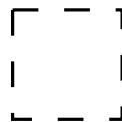
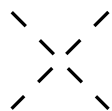
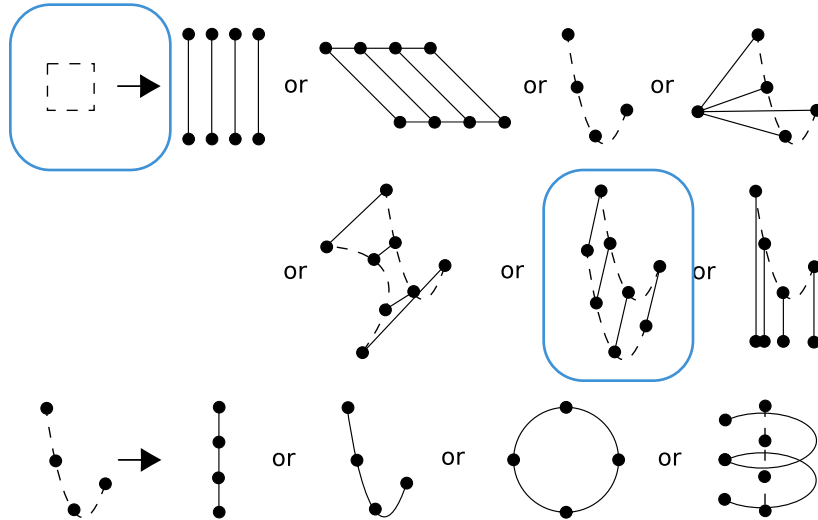
Example derivation



Example derivation



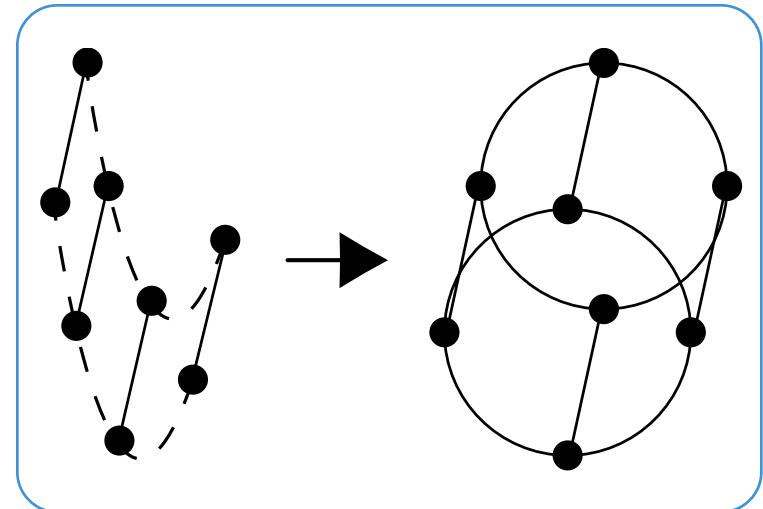
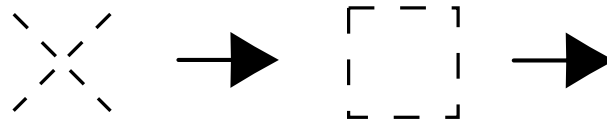
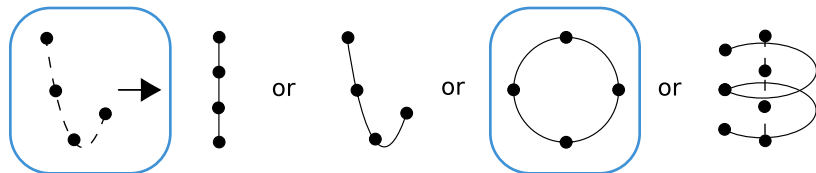
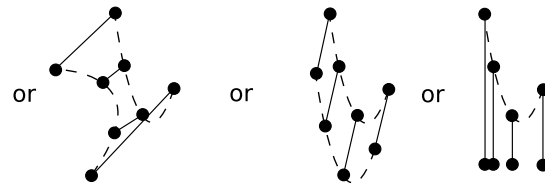
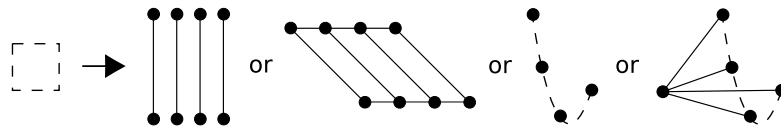
$$\times \rightarrow \square \text{ or } \times + \square$$



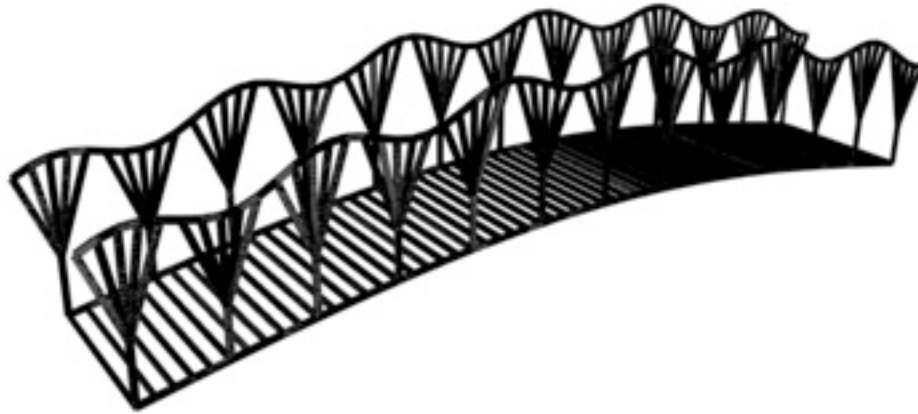
Example derivation



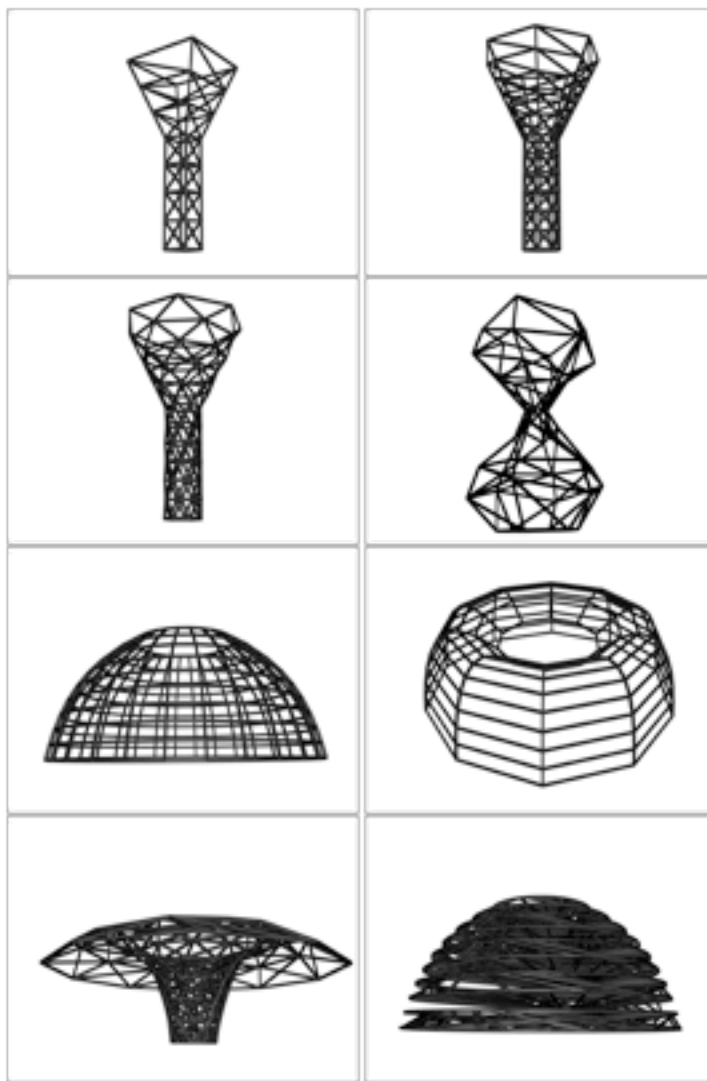
$$\times \rightarrow \square \text{ or } \times + \square$$



Results



Results



James McDermott in new
collaboration with MIT CSAIL
(Sep 2010)



Applications - Finance



www.fmc-cluster.org



GEVA - "Play with GE"



O'Neill, Hemberg, Gilligan, Bartley, McDermott, Brabazon. (2008). *GEVA: Grammatical Evolution in Java*. SIGEVolution, 3(2):17-23.



- <http://ncra.ucd.ie/geva>
- v1.2 release imminent





Call for Papers

2011 Genetic and Evolutionary Computation Conference

Tuesday – Saturday July 12–16, 2011 Dublin, Ireland

Largest Conference in the Field of Genetic and Evolutionary Computation

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20th International Conference on Genetic Algorithms (ICGA) and the

16th Annual Genetic Programming Conference (GP)

www.sigevo.org/gecco-2011



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Important Dates

- * **Submission deadline: January 26, 2011**
- * Notification of paper acceptance: March 23, 2011
- * Camera-ready submission: April 18, 2011
- * Workshop and tutorial proposals submission: November 8, 2010
- * Notification of workshop and tutorial acceptance: November 29, 2010
- * GECCO-2011 Conference: July 12–16, 2011

Review Process

Each paper submitted to GECCO will be rigorously reviewed, in a double-blind review process, meaning that reviewers should not be able to infer the identities of the authors of the papers under review, and, of course, that authors will not know the identities of their reviewers.

Each submitted paper will be evaluated by one of at least 15 separate and independent program committees specializing in various aspects of genetic and evolutionary computation. These committees make their own final decisions on submitted papers for their areas, subject only to conference-wide space limitations and procedures.

Review criteria include significance of the work, technical soundness, novelty, clarity, writing quality, and sufficiency of information to permit replication, if applicable.

How to Submit a Paper

Meet the submission deadline (January 26, 2011) and submit substantially new work. GECCO allows submissions of material that is substantially similar to a paper being submitted contemporaneously for review in another conference. However, if the submitted paper is accepted by GECCO, the authors agree that substantially the same material will not be published by another conference in the evolutionary computation field. Material may be later revised and submitted to a journal, if permitted by the journal.

Visit www.sigevo.org/gecco-2011

For detailed instructions, including categories, keywords, and formatting requirements, visit <http://www.sigevo.org/gecco-2011>. Be sure to check the web page for changes that may appear as the paper submission deadline approaches.

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Accept author agreement

By submitting a paper, the author(s) agree that, if their paper is accepted, they will:

- * Submit a final, revised, camera-ready version to the publisher by Monday, April 18, 2011
- * Register at least one author to attend the conference by Monday, May 2, 2011
- * Attend the conference (at least one author)
- * Present the accepted paper at the conference

More Information

Visit www.sigevo.org/gecco-2011 for information about deadlines, student travel grants, hotel reservations, student housing, the graduate student workshop, the latest list of topics, late-breaking papers, and more. For matters of science and program content, contact Conference Chair Pier Luca Lanzi at lanzi@elet.polimi.it. For general help and administrative matters contact GECCO Support at gecco2011@sigevo.org

About the Conference Venue

Dublin is the lively capital of Ireland and the perfect GECCO destination. It is served by several low-cost airlines, offering a wide range of flight deals, and provides several accommodation options. The social event will take place at Ireland's No. 1 international visitor attraction, the Guinness Storehouse. More information at <http://www.visitdublin.com>



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Questions?



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