Recent Adventures with Grammar-based Genetic Programming

Dr. Michael O’Neill

Mendel ‘10
23 June 2010
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

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

```c
#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);
}
```

```c
#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**


GP&EM 10th Anniversary Issue

Example - What makes a great conference?
Wrapper

\[
\text{float symbreg(float x) \{ } <\text{body}> \}
\]
\[
<\text{body}> ::= <\text{declarations}><\text{code}><\text{return}>
\]
\[
<\text{declarations}> ::= \text{float a;}
\]
\[
<\text{code}> ::= \text{a = <expr>;}
\]
\[
<\text{return}> ::= \text{return (a);}
\]

\[
\text{float symbreg(float x)\{}
\quad \text{float a;}
\quad a= <\text{expr}>;
\quad \text{return(a);}
\}
\]

\[
<\text{code}> ::= <\text{line}>;
\quad | <\text{line}>; <\text{code}>
\]
\[
<\text{line}> ::= ... 
\]
Genetic Operators

- (Variable-length) Binary/Integer String
- Bit/Codon Mutation
- 1pt Xover
- Duplication
- Tree-based operators
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
Byrne J., McDermott J., O’Neill M., Brabazon A.  *An analysis of the behaviour of mutation in Grammatical Evolution*.  EuroGP 2010

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

@CEC/WCCI
Nguyen Q.U., Nguyen X.H., McKay R.I., O’Neill M.  *Semantics Based Crossover for Boolean Problems*

@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 Genetic Programming


- 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)

Nicolau & Costelloe (2010)

Reddin, McDermott, Brabazon, O’Neill (2009)
Applications - Video Games

Miss PacMan
&
ToriBash (Jonathan Byrne...later in Mendel 2010)

GameBrains
http://www.ndrc.ie
Applications - Architecture

Evolutionary Architecture with Shape Grammars
Example derivation

\[ \times \rightarrow [\ ] \text{ or } \times + [\ ] \]

[Diagrams of various structures and transformations]
Example derivation

\[
\begin{align*}
\times & \rightarrow \boxed{} \\
\boxed{} & \rightarrow \begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\begin{array}{c}
\text{or} \\
\text{or} \\
\text{or} \\
\end{array} & \rightarrow \\
\Rightarrow & \rightarrow \\
\Rightarrow & \rightarrow
\end{align*}
\]
Example derivation

\[ \times \rightarrow \begin{array}{c} [\quad] \text{ or } \begin{array}{c} [\quad] \end{array} + [\quad] \end{array} \]
Example derivation

\[ \times \rightarrow \begin{array}{c}
\text{[ ]} \\
\text{or}
\end{array} \quad \text{or} \quad \begin{array}{c}
\times \\
\text{+}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \]

\[ \begin{array}{c}
\text{[ ]} \\
\rightarrow
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \]

\[ \begin{array}{c}
\text{[ ]}
\rightarrow
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \quad \begin{array}{c}
\text{or}
\end{array} \begin{array}{c}
\text{[ ]}
\end{array} \]

Results
Results

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

www.fmc-cluster.org
GEVA - “Play with GE”


• http://ncra.ucd.ie/geva
• v1.2 release imminent
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.

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.

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.visitedublin.com
Thank You...

Leader
Dr. Michael O'Neill

Manager
Ms. Irene Moore

PI Members
Prof. Anthony Brabazon
Prof. Gregory Connor
Prof. John Cotter
Dr. David Edelman
Prof. Paolo Guasoni
Dr. Sean McGarraghy
Dr. Ciaran McNally
Dr. Conall O'Sullivan
Elizabeth Shotton

Senior Research Associate
Dr. Miguel Nicolau

Postdoctorate Researchers
Dr. Alexandros Agapitos
Dr. Edgar Galvan-Lopez
Dr. James McDermott
Dr. Tom Conlon

Postgraduate Researchers
Robert Bradley
Jonathan Byrne
Wei Cui
Jing Dang
David Fagan
Kai Fan
Lena Golubovskaja
Erik Hemberg
Richard McGee
Eoin Murphy
James Murphy
Uy Quang Nguyen
Patrick O'Sullivan
Sébastien Piccand
Tiberiu Simu
John Mark Swafford
Zheng Yin

Visiting Researchers
Michael Fenton