Evolving a Logo Design using Grammatical Evolution

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Abstract

We present an application of Grammatical Evolution to the exploration of Lindenmayer systems. The resulting L-systems are expressed in the Postscript language, and as such a Postscript grammar was provided as input to the Grammatical Evolution algorithm.

The system takes the form of an interactive evolutionary algorithm, with a human-in-the-loop acting as the fitness function for the generated L-systems.

The motivation for this research was to evolve a logo for the UCD Natural Computing Research & Applications group, and to this end the study was a success.

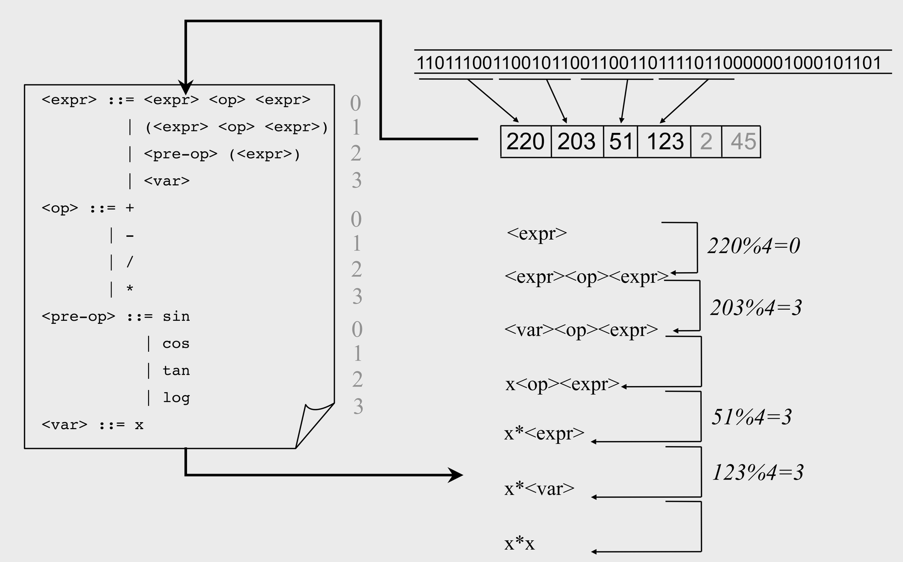
Background

Evolutionary Computation has demonstrated much potential for Evolutionary Design (ED) producing solutions that are competitive, and even superior to those developed by human experts resulting in patentable inventions [1][2][3].
As such, the real world application domain of Design (in particular Analog Circuit Design [1]) has been a proving ground for the abilities of an artificial evolutionary process and has arguably led to the first routinely, human-competitive form of Machine Learning. ED is a challenging domain as it is often dynamic in nature due to the ever changing preferences of the human users that judge the aesthetic qualities of a design during evolution.

The combination of an EA coupled to a Grammatical, Developmental Representation (*Design Language*) is a particularly powerful and novel departure in recent years [4]. Research at this nexus of EC and a Grammatical Representation include GENRE and Genr8 amongst others [4][6][7][8][9]. As is the case in this study much of this research in grammar-based Genetic Programming and in more traditional approaches to Genetic Programming (e.g., [10]) has been undertaken using L-systems.

Aristid Lindenmayer developed what are now known as L-systems in 1968 to model the development of cells [11]. The L-systems are a form of grammar, similar to Chomsky grammars, with the difference that Lindenmayer grammars can apply production rules in parallel. There have been a number of applications of genetic programming approaches to the generation of various types of L-systems most notably the Hemberg-Extended Map L-systems for 3-D surface generation [6], and using Grammatical Evolution to design fractal curves with a specific dimension [12]. A convenient way to generate and display L-systems is to use the Postscript language, and in this study we use Grammatical Evolution [13] to evolve Postscript programs that represent aesthetically pleasing 2-D L-systems.

Methods



Grammatical Evolution

Grammatical Evolution (GE) is an evolutionary algorithm that can evolve computer programs in any language [13][14][15][16][17][18], and can be considered a form of grammar-based genetic programming. Rather than representing the programs as parse trees, as in GP [19][20][21][22][1], a linear genome representation is used. A genotype-phenotype mapping is employed such that each individual's variable length binary string, contains in its codons (groups of 8 bits) the information to select production rules from a Backus Naur Form (BNF) grammar. The grammar allows the generation of programs in an arbitrary language that are guaranteed to be syntactically correct, and as such it is used in the generative sense. The user can tailor the grammar to produce solutions that are purely syntactically constrained, or they may incorporate domain knowledge by biasing the grammar to produce very specific forms of sentences.

The grammar is used in a developmental process to construct a program by applying production rules, selected by the genome, beginning from the start symbol of the grammar. In order to select a production rule in GE, the next codon value on the genome is read, interpreted, and placed in the following formula:

```
Rule = c % r
```

where `c` is the codon integer value, `r` is the number of rule choices for the current non-terminal, and `%` represents the modulo operator.

```
pxpxpxpxpxpx
Postscript Header:
%!PS
/order 3 def                        %set the systems order
/START { X } def                    %start definition of X
/X {                                %let evolution fill in
dup 0 ne                            %the rest
{1 sub

Postscript Footer:
/F {                                %define F - draws a line
0 eq { 10 0 rlineto } if
} bind def
/- { rotangle neg rotate } bind def %rotation angle specified
/+ { rotangle rotate } bind def     %by evolution
/paperx 8.5    72 mul def
/papery 11     72 mul def
/xx paperx 0.3 mul def
/yy 400 def
/thick 25 def
/factor { pop 2 } def
1 setlinejoin
1 setlinecap
newpath
xx yy moveto                        %centers in page, roughly
thick 1 1 order { factor div } for dup scale
90 rotate                           %initial angle
order START
stroke
showpage
```

Postscript Logo Design Grammar

To evolve a logo design for the UCD Natural Computing Research & Applications group we wished to use a bio-inspired process that would complement the philosophy of the group. We also wished that the design itself would reflect the natural world to some extent. As L-systems were originally adopted to model cell growth and plant development we considered this developmental language appropriate. The input grammar adopted in this study is presented below, and contains the rules to generate an L-system grammar. The L-system must then be expanded to produce a design that can be evaluated by the human user.

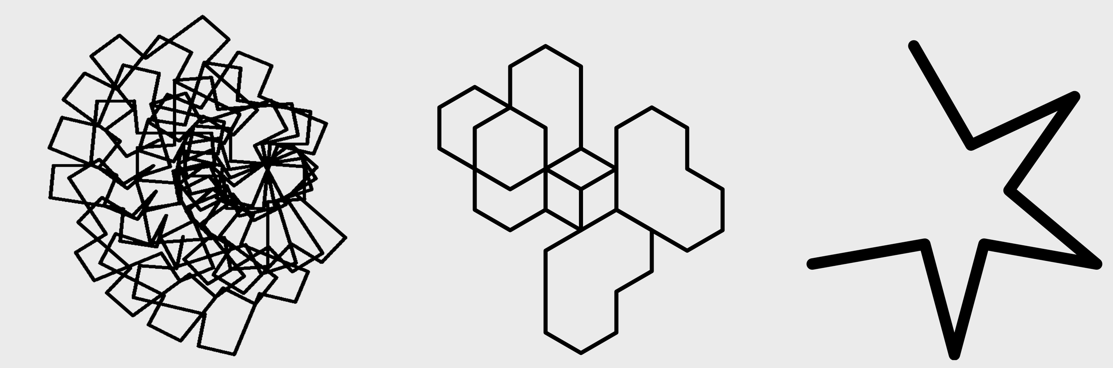
```
<lsys> ::= <numrepeats> "{dup} repeat" <rules>"} \n
           if pop \n
           } def \n
           /rotangle"<rotangle> " def \n"

<rules> ::= <rules> <rules> <rules> <rules>
         l <Fcomplex>
         l <Xcomplex>
         l <fun>
         l <rotateop>

<rotateop> ::= + l -

<fun> ::= F l X

<Fcomplex> ::= <rotateop> F
           l <rotateop> F <rotateop> F

<Xcomplex> ::= <rotateop> X
           l <rotateop> X <rotateop> X

<rotangle> ::= 5 l 10 l 15 l 20 l 25 l 30
           l 35 l 40 l 45 l 50 l 55 l 60
           l 65 l 70 l 75 l 80 l 85 l 90

<numrepeats> ::= ?
```

The grammar generates an L-system coded in the Postscript language [27][28]. All the evolved grammars in this study take the form:

```
S -> X
X -> ?
```

where the angle of rotation of the turtle graphic `rotangle` is evolved according to the non-terminal <rotangle>, and the `order` (depth of expansion of the L-system) of the system is 3 by default, however, the interesting L-systems evolved in this study were allowed to divide further and are presented later on. To complete a valid postscript file the header and footers presented (left) are used to wrap the evolved L-System. A number of PostScript operators are provided including `dup` and `pop` which duplicate and pop the top item on the stack respectively, the conditional operators `if` and `ne` (not equals). The forward slash, `/`, is used to denote user-defined variable and procedure names along with the definition operator (`def`). `rlineto`, `newpath` and `moveto` are path construction operators that create a path, clear the current path and move to a specific cartesian coordinate respectively. The painting operator `stroke` is used to paint the current path with the current color and line width. `F` is a user-defined procedure that creates a path for a line, and the evolved procedure `X` determines how `F`'s are combined and rotated during the expansion of the L-system.

Results



Conclusions

We presented an application of Grammatical Evolution to the exploration of L-systems expressed in Postscript. The use of this approach resulted in the discovery of a logo for the UCD Natural Computing Research & Applications group.

Future work will include the continued development of Grammatical Evolution in the context of interactive Evolutionary Computation for the exploration of designs. In particular, Shape Grammars have proven a successful tool to capture the essence of many designs including Coffee Makers, Cars and Harley Davidson Motorbikes [29][30][31][32][33][34][35]. We are examining their potential for combination with evolutionary search using GE.

Research we have undertaken in addressing the fitness evaluation bottleneck for interactive evolutionary computation during sound synthesis [36] also has relevance to evolutionary design with GE. We are investigating the extension of the sweeping interface to GE to allow interpolation between individuals at different levels of granularity.

An implementation of Grammatical Evolution in Java, GEVA, is available to download from http://ncra.ucd.ie/geva and includes a demonstration of the interactive evolution of L-systems.

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