L2 Designer
Language and Tool for Generative Art

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Abstract: We propose a new formal grammar (*L2 language*) and its implementation in JavaScript tool (*L2 Designer*). The L2 language allows us to create formal definition of the hierarchy of L-systems encapsulated in L-scripts. The L2 Designer enables creation of initial L-system, its modifications based on genetic programming and iterative evolution, and graphical interpretation. We provide an example of L2 program and we illustrate possibilities of L2 Designer on a case study which was inspired by an artistic decorative floral pattern.

1 INTRODUCTION

Lindenmayer systems (L-systems) are formal grammars with parallel rewriting mechanism that were originally developed for modelling and visualization of the growth process of various types of algae (Lindenmayer, 1968). Later they were applied in the field of computer graphics. The best known graphical interpretation of L-systems is based on usage of a relative cursor upon a Cartesian plane (turtle graphics). The L-systems are frequently used in combination with evolutionary techniques, e.g. (Hornby, 2001) presents a parametric L-system for drawing virtual creatures for computer animations.

In this contribution we explore the emergence phenomena growing from combination of L-systems, genetic programming and interactive evolution, especially we are interested in its application in generative art and artificial creativity. We were inspired by shape grammars that also originate from the theory of formal grammars: it was shown that even simple rules of shape grammars produce complex results (Stiny, 1994), moreover (Chakrabarti et. al., 2011) applied shape grammars in design.

The key issue in our research area is the definition of the fitness function. Artificial neural networks or design principles measurements are well-applicable techniques (Galanter, 2012), for relevant results see e.g. (Ashlock and Bryden, 2004), (McCormack, 2003), (McCormack, 2008) or (Bergen and Ross 2013).

The graphical interpretation of L-system: strongly depends on its definition, because even minor changes of parameters lead to completely different and surprising results. Here the evolutionary techniques help to search the large space of parameters and to modify production rules.

Current implementations of the L-system theory are based on extensions of general purpose programming languages. From the technical point of view, languages such as L+C (Karwowski and Prusinkiewicz 2003), L-Py (Boudon et al. 2012) or XL (Kniemeyer and Kurth, 2008) are complex and their implementations are platform dependent. Our intention is to provide easy-to-use tool for partly interactive creation of various types of graphical outputs. On the contrary, our tool does not make user to directly write production rules, in fact the user does not need to know the grammar of the L-system at all.

In following sections of this paper we propose a new formal language (*L2 language*) which is easy to parse to the tree representation. Then we provide a plaftorm independent tool (*L2 Designer*) which enables specification of L-systems within L2 language, with its subsequent evolution based on genetic programming. Finally, the graphical interpretation of outputs is presented.

2 L2 LANGUAGE

L2 language is designed for defining stochastic context free parametric L-systems grammars. In contrast to L+C or L-py, L2 does not include anything else but features that we need for the purpose of the definition of L-system. As well as L+C, L2 supports the advanced properties of L-systems:

- *Sub-L-systems* – it is possible to divide large L-systems into smaller reusable parts,
- *Interpretation production rules* – it lets us separate topology of the L-system from its representation, therefore the application of genetic programming operators is easier.

For detail specification of L2 language, see (L2 Documentation, 2015). Here we provide a sample code. Its explanation and interpretation is shown below.

Example 1: L2 sample code.

```
1    alphabet Turtle2D {
2      F, f, L, R, PU, PS
3    };
4    $black = __rgb(0,0,0,255);
5    lscript BranchingLScript {
6      lsystem Bloom(F(0.01), 3)
7       using Turtle2D {
8       $angle = 90;
9       $colorA = __rgb(255,100,0,200);
10      $colorB = __rgb(150,50,50,200);
11      F(a) -->
12       F($a) L($angle) F($a) A($a);
13      F(a) -->
14       F($a) R($angle) F($a) A($a);
15      F(a) -h>
16       F($a, 0.003, __rgb(0,0,0,0));
17      A(a) -h>
18       [ F(0.0001, $a * 1.5 *
19   __random(), $colorA) ] |
20       [ F(0.0001, $a * 1.5 *
21   __random(), $colorB) ];
22     };
23     lsystem Branching(G(0.1), 4)
24   using Turtle2D {
25      $ratio = 0.9;
26      $angle = 60;
27      $anglePrec = 50;
28      $stroke = 0.003;
29      G(a) -->
30       F($a) [ L($angle)
31       G($ratio * $a)B($a) ]
32       [ R($angle) G($ratio * $a)
33       B($a) ];
34      L(a) -h>
35       L($a - $anglePrec * 0.5);
36      R(a) -h>
37       R($a - $anglePrec * 0.5);
38      F(a) -h>
39       F($a, $stroke, $black)
40       [sublsystem Bloom(F($a / 10),
41       6)];
42     };
43     main call Branching();
44   };
45   derive BranchingLScript;
```

As shown in Example 1, the L2 program consists of three main parts:

- *Alphabet* - a set of symbols (line 1),
- *L-script* encapsulating L-systems (line 5),
- *L-system* - the unit defining production rules, default axiom and default number of derivations (lines 6, 23).

The user can add variables (line 4). Variable names start with symbol **$**. The L-script contains the main L-system (line 43). Start of the derivation of the L-script is done by *derive* statement (line 45) resulting in string of the modules.

BranchingLScript contains a definition of two L-systems called *Branching* and *Bloom* (lines 6–22, 23–42). The heading of the L-system consists of:

- name,
- default axiom,
- default number of derivations,
- alphabet.

The body of L-systems includes the list of productions. For the L-system productions we use either the --> operator (line 11) or the *–h>* for interpretation rules (line 15). The replacement string on the right side of the production rule can contain *sublsystem* statement (line 40) that calls derivation of the other L-system within the same L-script.

3 L2JS LIBRARY

The L2 language is accessible within our L2JS library which is the core of L2 Designer. The library includes compiler, interpreter and module for genetic programming.

The compiler of the L2JS library translates L2 to JavaScript (Figure 1). The scripting language was chosen due to its flexibility, dynamic scoping, closures and both functional and object-oriented programming support.

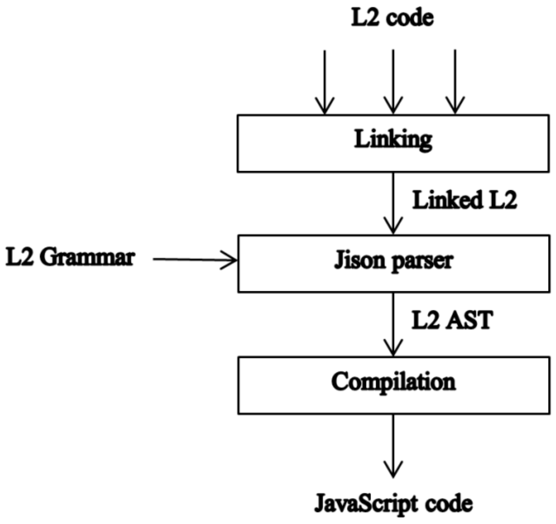


Figure 1: Scheme of the L2JS library.

The usage of JavaScript allows us to distribute the computing within the web browser and Node.js web server. The compilation starts with the linking of the input source files. The whole code is parsed by Jison parser into the abstract syntax tree (AST). The AST consists of the nodes representing statements, arguments, entities, names, variables and expressions. Jison is a JavaScript implementation of the combination of (Flex, 2015) and (Bison, 2015). The parser requires the L2 grammar description file. After the L2 AST is created by Jison, the translation to the JavaScript code can be performed.

Our compiler is able to decompile L2 AST back to the L2 code. This feature is essential for further application of genetic programming.

The output of the compilation process is a JavaScript program representing the derivation of the L-script.

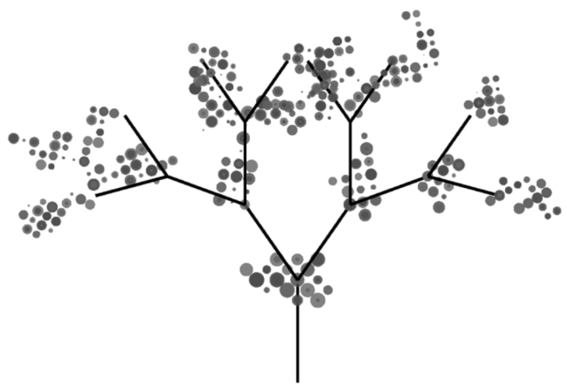


Figure 2: Turtle graphics for the sample code.

The Interpreter operates with an alphabet of the L-system to resolve the type of interpretation. In our sample code, an alphabet *Turtle2D* is used. Symbols of the alphabet are understood as the instructions for the turtle graphics (Figure 2).

The Interpreter works with rules that specify how symbols are related to the set of statements from the alphabet. E.g. the module *F(a)* is replaced with `F($a, 0.003, __rgb(0,0,0,0))` according to the corresponding interpretation rule (lines 15–16). The interpretation in this particular case results in *a*-long line with 0.003 size filled with transparent colour.

The Evolver implements the L-system genetic programming over the hierarchy of L-systems in L2 language. Details are provided in the next section.

4 GENETIC PROGRAMMING

Genetic programming is involved in the process of iterative modifications of L-scripts.

After the initial L-script is provided to the Evolver module, it becomes the base for the initial generation. Each individual is represented by the L-script which is converted to L2 AST (see Figure 3 for illustration). The user has to specify which of sub-L-systems should be modified by the Evolver.

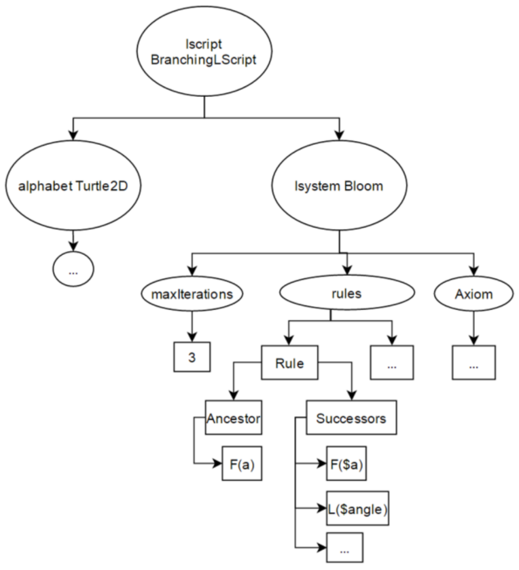


Figure 3: Example of simple AST of L2 script.

The genotype for the Evolver is represented by a tree data structure, as it was originally introduced by (Koza, 2000). Genetic operators modify the abstract syntax trees using crossover or mutation. The genetic operators designed for the parametric L-systems were originally proposed by (McCormack, 2008).

In our case each part of AST has to its special operators. The operators are applied either on the L-systems (axiom, production rules) or on the expressions used within the program (variable assignments, expressions within modules). The Evolver module supports:

- mutation of production rules,
- crossover of production rules,
- mutation of expressions – variation, creation and colour mutation.

The main task was to identify the right terminals. We found the way of an automatic detection of terminals without the need of its explicit specification by the user.

In case of production rule mutation, the set of terminals consists of distinct symbols occurring in all production rules of parent L-system. In case of expression mutation the set of terminals depends on the context of expression. On the other hand the terminals within the rule are enriched with parameters from the ancestor of the rule.

The Evolver implements two types of mutations. The first of them modifies the numbers only (variation mutation), the second one generates new expressions (creative mutation).

Special mutation operator was developed for the colours: user can specify maximum percentage of modification for each of the channel of the colour model. For hue channel it is possible to specify an exact angle that can be added or reduced.

We represent production rules using target tree structures similarly to (Jacob, 1994). Every leaf is a module of the rule and every new level of the tree is determined by stack symbols (*[*, *]*).

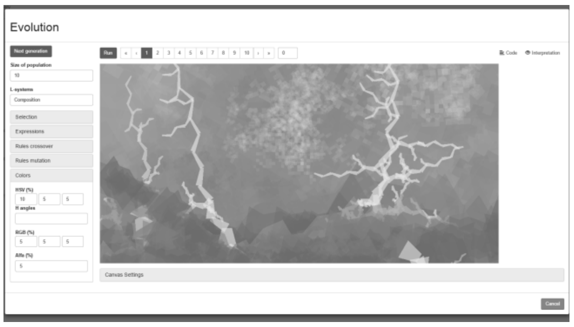
The crossover is represented by an exchange of the branches from the tree representation of L-systems. The newly created production rule either replaces the rule which was selected for the crossover (parent rule) or is added to the definition of the L-system. Probability of the newly created rule is determined by product of the probability of parent rule and a predefined constant.

In the process of the fitness evaluation, the user selects the best solutions generated by the program and assigns the integer fitness values to these solutions. This approach is known as interactive evolutionary computation (IEC). In comparison with other methods, IEC is more time consuming, only small populations and low number of generations can be processed effectively. On the other hand, with IEC the user can apply his aesthetic preferences.

The rank selection mechanism is combined with elitism. For details of this method see (Sivaraj and Ravichandran, 2011).

5 IMPLEMENTATION

The L2 Designer is a web-based JavaScript application enabling the interactive designing of L-systems. The core of the application is L2JS library. The server is running on Node.js. Other main technologies we are using are MongoDB and Angular.js.


Evolution

Size of population: 10
L-systems: Composition
HSV (%): 10 5 5
H angles:
RGB (%): 5 5 5
Alfa (%): 5

Figure 4: Interface of L2 Designer with a visualization of L-system.

Within the L2 Designer the user can manage projects and directories of scripts. The main focus is on the process of designing new L-systems (Figure 4). The source codes are available together with their interpretations.

6 CASE STUDY

Let us demonstrate the L2 Designer workflow. The decorative floral pattern *Michaelmas Daisy 1929* (The Warner Textile Archive, 2015) was our inspiration.

The process starts with creation of L-script which contains several sub-L-systems. The first part of L-systems represents basic shapes (flower petal, leaf, disc floret); the second part represents a layout of basic shapes (flower head, layout of flowers, layout of leaves).

The aim of interactive evolutionary computation (IEC) is to increase the similarity of the output graphic interpretation of L-system with the original pattern. The original pattern background is covered with leaves. The interpretation of the L-system before and after the process of IEC is shown on Figures 5 and 6.

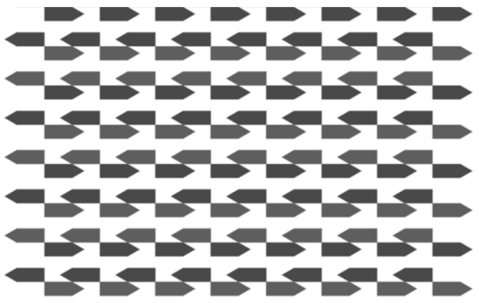


Figure 5: Layout of leaves before the interactive evolution computation: completely regular distribution of leaves of one size, with limited number of colour shades.

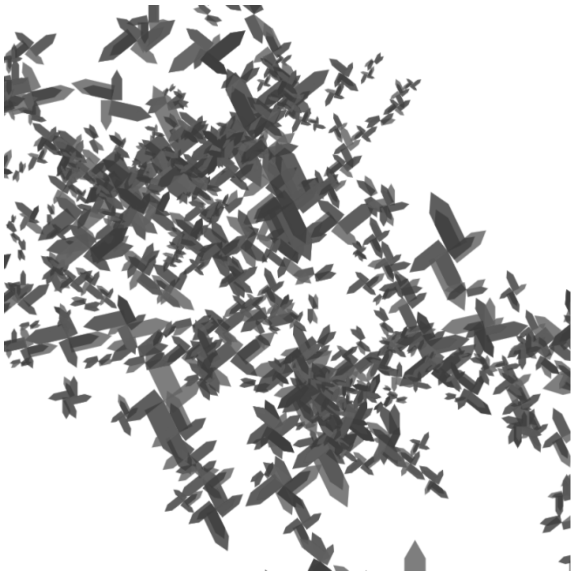


Figure 6: Layout of leaves after the interactive evolution computation: irregular distribution of leaves on the canvas, higher number of colour shades and variable sizes.

The next step is the creation of the main L-system which generates the layout of flowers. Firstly it is necessary to define L-system for random distribution of flower heads over the canvas. This initial result still does not correspond to the original artefact (Figure 7): there is a lack of the grouping of flowers of the same type. Again, this issue can be solved by evolution of the L-system.
See Figure 8 for the final pattern. Notice that our L-script does not cope in any way with external image files or predefined patterns. Every shape is produced solely by the turtle graphics interpretation of our L2 script. The source code of the L-script is available online (L-script Examples, 2015).

For more graphical outputs produced by L2 Designer see (Konrády, 2014).

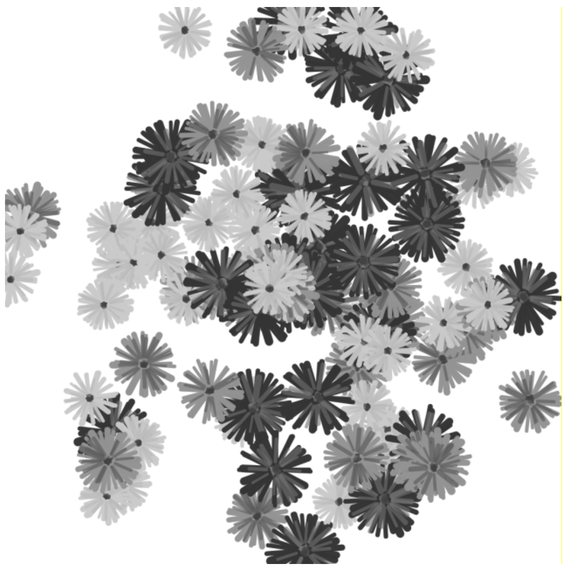


Figure 7: Random distribution of flowers.

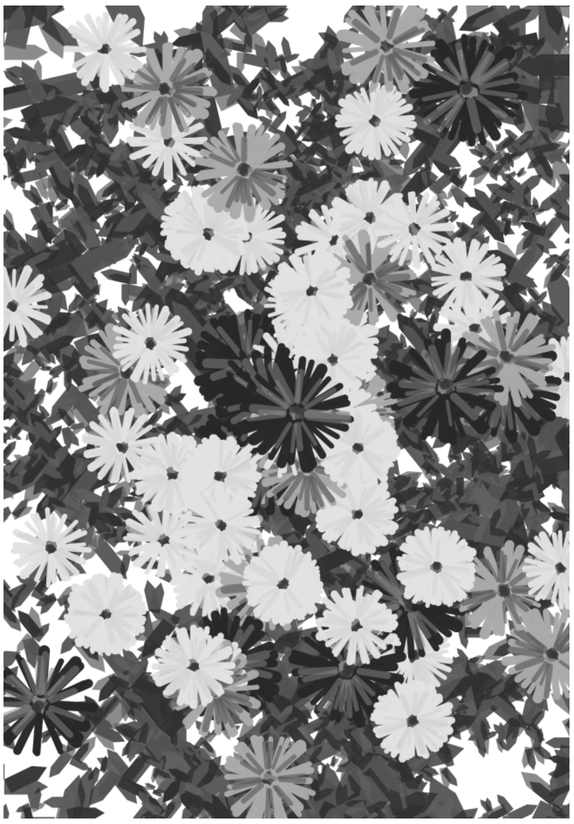


Figure 8: Final pattern resulting from the evolution of L-system.

7 CONCLUSIONS

The current version of L2 Designer is capable of evolving stochastic parametric L-systems which are described by L2 language and generate complex graphical patterns.

Our next intention is to improve the effectiveness of genetic operators to speed up the fitness evaluation. For that we are going to implement a module for the processing of user's input using graphic tablet or vector image file.

The development of L2 language continues. New features will be added such as decomposition rules or rule conditions.

Finally, with respect to the generative art applications, we want to explore the possibility of integration of L2 Designer with graphical editors to support creativity in users.

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