LSound: An L-System Framework for Score Generation

Chen Kim Lim, Kian Lam Tan, Hazwanni Yusran, Vicknesh Suppramaniam
Faculty of Art, Computing & Creative Industry, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia.
kim@fskik.upsi.edu.my

***Abstract*—Visual language or visual representation has been used in the past few years in order to express the knowledge in graphics. One of the important graphical elements is fractal and L-Systems is a mathematics-based grammatical model for modelling cell development and plant topology. From the plant model, L-Systems can be interpreted as music sound and score. In this paper, LSound which is a Visual Language Programming (VLP) framework has been developed as a tool that can model plant to music sound and generate music score and vice versa. The objectives of this research have three folds: (i) To expand the grammar dictionary of L-Systems music based on visual programming, (ii) To design and produce a user-friendly and icon-based visual language framework typically for L-Systems musical score generation which helps the basic learners in musical field and (iii) To generate music score from plant models and vice versa using L-Systems method. This research undergoes four phases methodology where the plant is first modeled, then the music is interpreted, followed by the output of music sound through MIDI and a score is generated. Technically, LSound was compared to other existing applications in the aspects of the capability of modelling the plant, rendering the music and generating the sound. LSound is a flexible framework in which the plant can be easily altered through arrow-based programming and the music score can be altered through the music symbols and notes which encourages non-experts to work with L-Systems and music.**

***Index Terms*—L-Systems;, Plant Modeling; Music Rendering; Score Generation; Visual Language Programming.**

I. INTRODUCTION

Visual languages have become popular in the computing world with the presence of visual programming and the visual user interface. The development of visual languages is to help in problem-solving. It is a problem-oriented tool. This is to ease the users to understand more on the new knowledge. As the time passed by, the VLP has been used in various aspects such as in games, education and also in music. According to a research, VLPs can be used to make computer science more approachable to a wider range of students [1]. Normally, visual language is used in a learning process that is to ease the students who want to learn a particular subject without having any basic [2]. In educational purpose, visual languages are used to make a better understanding as compared to traditional programming languages [1]. Using graphical presentation data, many problems can be easily solved. It can also be a tool for better communication because of the usage of visual instead of text. Most of the times, using graphics can help people to understand more about the new knowledge that they learn.

Astrid Lindenmayer (1968 – 1989) is a theoretical biologist that introduced l-system model to describe the growth pattern of fractals including the branch for structuring the plants. In L-system, there is a set of symbols (sequence of strings) that has its own application of certain rules. It consists of the axiom (the starting point), alphabets and a set of production (rules). More other symbols or strings can be produced when the rules are mutated [3]. By using the L-system, it can produce infinite numbers of strings that with its own rules. Grammar can be generated by the L-system without variance between the terminal and nonterminal symbols [4]. Grammars can be a music analysis tool and as a composition, tool to find the right grammar with modelling a piece and generated by following the grammar [5].

Music is one of the languages to connect people. Music can be used to communicate on things that cannot be conveyed by using a normal language. Art of ordering tones or sounds in succession and in combination which to produce a composition with unity and continuity music is defined as a part of the science [6]. Music has been important nowadays which encourage all the music industries to produce more music by using the technologies. There are many technologies that have been used by the music industries such as recording, sound production, audio quality and much more. The music score is a prior knowledge for the basic learner who learns music. It is a part of music theory that is learnt by the learners. A music score consists of music notation, pitch, beat (octaves) and much more.

A musical score or a musical composition is a written form with scores as major importance in compositional processes in computer-aided frameworks and parts of variance instruments appear on separate staves on large pages [3]. Nevertheless, the score is also important in music. Thus, a combination of technology with the music helps in developing better music in the future. L-System is an effective language but could not be fully utilized by the non-experts. The latest technology is mainly for advanced development of fractals and is not based on Visual Language Programming (VPL).

A reproduction of L-System based application to convert plants to music sound and generate the music scores would be an interesting research. So, the main objective here is to investigate on the L-System model, identify which grammar is more viable for non-experts to utilize it to be able to perform plant modelling, music rendering and score generating.

II. LITERATURE REVIEW

L-Systems have been used intensively in modelling of fractals, plants, trees, rendering music, chord spaces and generating music score. There are many types of L-Systems namely DOL, turtle interpretation of strings [7], branching structures, bracketed OL, stochastic, context-free, context-

sensitive and parametric [8]. Through the evolutionary algorithms, genetic operators are incorporated into L-Systems to increase the variability in the musical interpretation [9]. Besides, a rule-based L-Systems model could reach the optimal value when the algorithms are all applied concurrently [10]. In terms of plant modelling, the developmental of the tree models have been combined with dynamic and evolving conditions such as turbulent [11]. The simulated tree is then able to interact with the environment and biologically transformed to create visually convincing ecosystems [12]. Besides, Derzaph and Hamilton [13] also proposed to let the branches of the virtual plants to be responsive to wind, growth and motion where the leaves could bend, twist and vibrates themselves through nested L-Systems. In terms of music rendering, one of the greatest challenges faced is in producing words of fixed length. By using Finite L-Systems, it is found to be a promising technique in creating word of infinite length with controllable complexity [14]. However, unsupervised algorithms may be considered as undesired. Kaliakatsos-Papakostas et al. [15] proposed to produce rhythmic sequences with fitness characteristics to diversity the output. Lim and Talib [16] have also proposed to hybrid the context-sensitive and stochastic L-Systems to produce harmonious musical sound. Through the laws of probability, a series of automated music could be generated in a more unpredictable manner [17].

In terms of score generation, there are many types of research where L-Systems are interpreted through the plant model. To generate both melody and rhythm in melodic sequences, Holder et al. [18] proposed to add coefficient weights to notes, intervals, articulations, key signatures, dynamics and note durations. Kathiresan also proposed to hybrid the Hidden Markov Model (HMM) with Categorical Distributions (CD) [19]. Furthermore, Rubin and Agrawala [20] proposed to add emotion to music score relevantly to improve its expressiveness. However, there is not a single attempt to interpret the plant through the music score. In a case study of performing pattern formation using Neyname's words to produce a Persian poem from Rumi, L-Systems gave a realistic orthography result [21]. Other than these, L-Systems are also used as a precise parametric tool to model the forest with various weather conditions [22]. As the structure of L-Systems language is in a complicated form, it is hard to deal when the user has no prior knowledge in this domain. Therefore, VPL is introduced to L-Systems in many types of research with regards to plant modelling, music rendering and score generation.

III. Methodology

Figure 1 shows the workflow of the LSound application that intends to facilitate the processes to execute the application in more easily and systematically manner for the user.

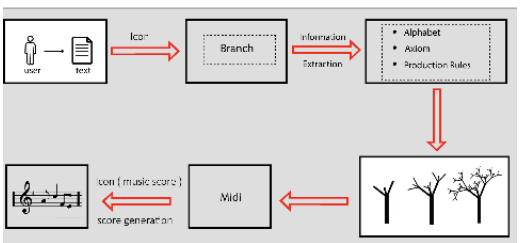


Figure 1: Workflow of LSound application

In the first phase, the information is extracted from the user input for describing the properties of the plant such as branch sizes and angle. The information is the data sources in which the text is generated from the user's drag and drop's actions. In the second phase, the data is extracted into text annotation before applying it for the interpretation of the plant model. The text annotated is classified into axiom and alphabet which then undergone the context-sensitive and stochastic processes. Through the random mutation of the alphabets, production rules are generated. In the third phase, as the appropriate action that has been assigned to each terminal in the alphabet based on the properties of the plant, a plant is modelled using the information interpreted by the production rules. From the plant model, the music sound is rendered through MIDI and finally, the music score is generated. If there are changes to the music icons themselves, the graphical interpretation of a string is extracted from musical score to re-modal the plant. The extraction uses the mathematical model of L-Systems in processing the new structures of the virtual plant.

IV. Development of Sound

In this research, the visual language framework is used in music symbols or notes and the arrows are to improve the user-friendliness. The user can use the application easily by selecting the different icons or symbols and they are able to generate the music score with different instrument choices. The user could reconstruct the icons that have been put together to experiment the sounds that have been generated from the music score or from the plant model and make more style or pattern of the plant with more choices of audio. With that, the user is able to learn that easily because they can see and hear the music generate with that particular symbols. More options are provided for users such as the tempo could change as needed and also different musical instruments such as piano, violin and guitar can be selected. The development modules of LSound are depicted in Figure 3. The modules consist of virtual plant modeling, music rendering and score generation respectively.

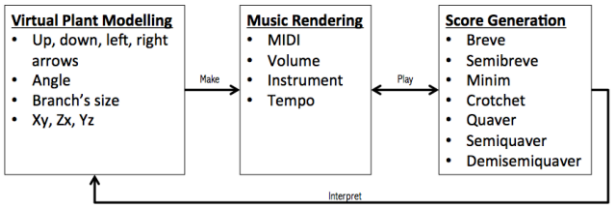


Figure 3: LSound development framework

The usage of the visual language framework is to meet the needs of the user who does not have prior knowledge in music and L-system. For the user who does not have prior knowledge in programming is also able to use this application because it uses visual language framework. This framework encourages and eases the non-researcher to generate a musical score, sound and model the plant based on the L-system concepts as shown in Figure 4.

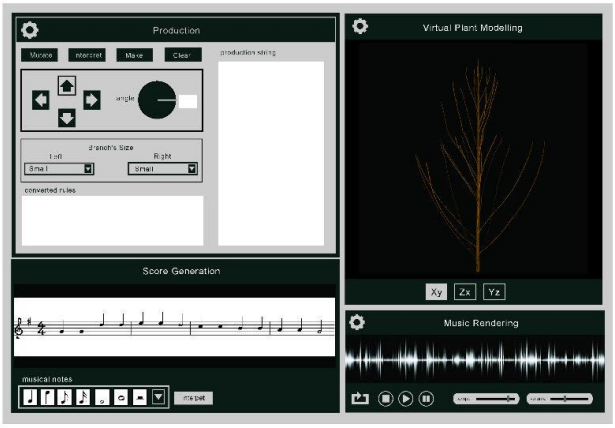


Figure 4: Interface of LSound

The plant model would be visualized by the set of grammar models that are represented by the up, down, left and right arrows. Starting from the axiom which is at the root of the plant begins, the user can easily use the arrow to make the pattern (branching) of the plant and the visualization of the plant is visible to the user at the left of the production part. The converted rules are produced through the icons where mutations can be applied in an uncountable time. Once the 'Interpret' button in the main interface is clicked on, a new set of grammars is produced at the production string. The angle and the sizes of the right and left branches (small, medium, large) can be determined. Figure 5 shows the simplified VLP based on icons in LSound.

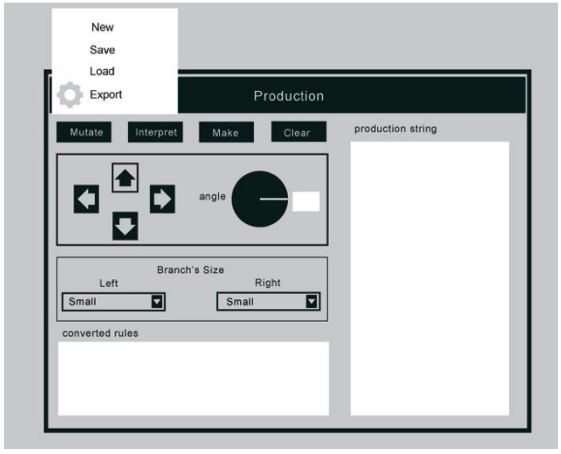


Figure 5: Icon-based simplified VLP of LSound

The plant model could be viewed in the Xy, Zx and Yz perspectives when the button 'Make' is clicked on. The virtual plant model appeared as shown in Figure 6.

From the plant model, the music is rendered through MIDI. The audio part for rendering is visible to make the user do changes easily as how they want it. Figure 7 shows that the audio could be rendered as a different instrument which allows the user to use various types of music to generate the music scores. LSound has three major types of instruments that are piano, guitar and violin. The user can also change the tempo for the audio and adjusts the volume easily with the 'stop', 'play' and 'pause' buttons.

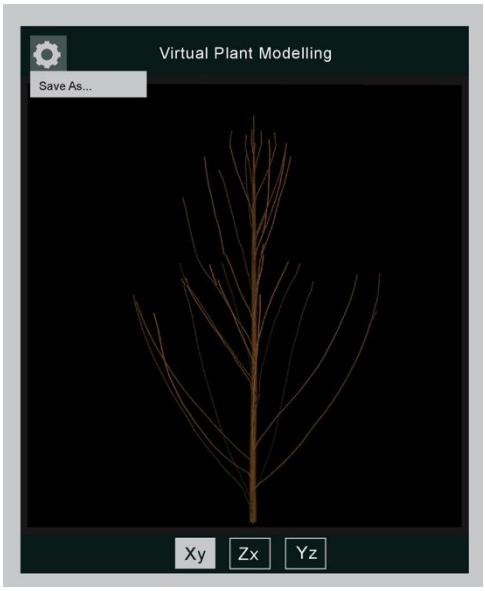


Figure 6: Virtual plant for LSound

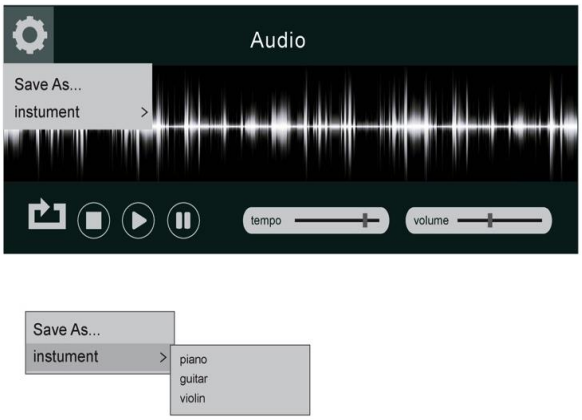


Figure 7: Audio for LSound

Figure 8 shows the score generation module that has universal music notes and symbols where the user can just drag and drop the symbol to the music sheet and can re-model the plant by clicking 'interpret' button. The plant model would change according to the music score and user can play the audio and edit the audio before rendering it as the final output.

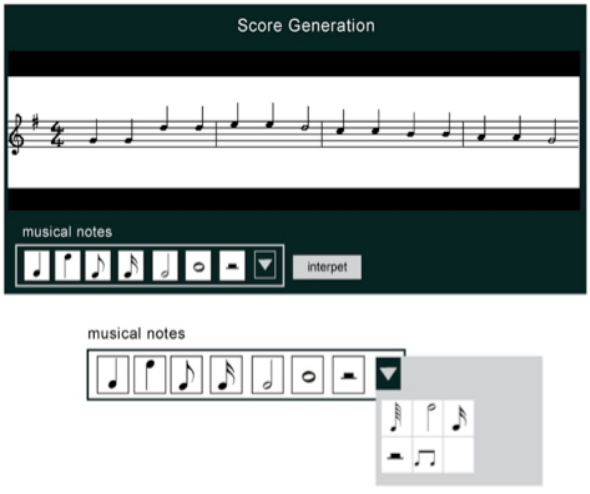
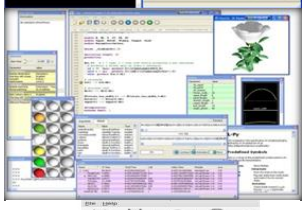
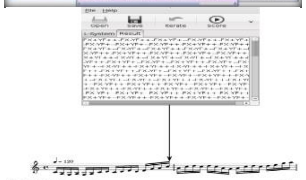
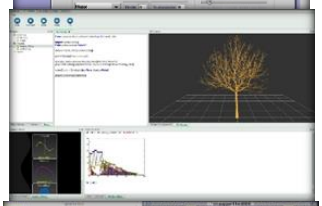
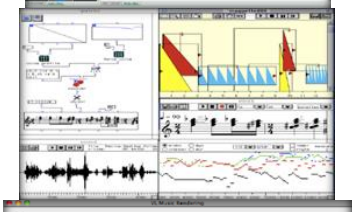
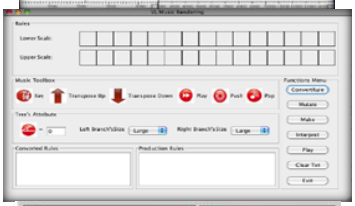


Figure 8. Score generation for LSound

Table 1
L-System Based Application

Application	Visual
TreeSketch	
L-Studio	
L-Py	
L-Score	
LMuse	
OpenAlea	
OpenMusic	
VLMR	
LSound	

The result consists of various grammatical dictionaries with a user-friendly and icon-based visual language framework typically for L-Systems musical score generation which helps the basic learners in the musical field. The mutation of the virtual plant is done through the stochastic L-Systems.

V. Technical Evaluation

For the preliminary evaluation, there was no involvement on the user comments. From the technical perspective, the comparison is done between various applications as shown in Table 1.

L-System based applications namely TreeSketch, L-Studio, L-Py, LScore, LMUSe, OpenAlea, OpenMusic, VLMR and the proposed LSound are technically analysed and compared (See Table 1). On one hand, the tree is modelled at real-time while the motion of the brush is determining its forms by using TreeSketch. Besides, L-Py's architecture is solely for plant modelling with various optimization tools to alter its parameters. Furthermore, L-Studio allows the generated plant model to undergo changes of surfaces, contours, animations and others. However, TreeSketch, L-Py and L-Studio neither render music nor generate a musical score by utilizing VLP.

On the other hand, LScore could only render music sound through MIDI files from L-Systems' descriptions. Furthermore, LScore concentrates only on Deterministic Context-Sensitive and Stochastic Parametric. With LMUSe, 2D and 3D plants could be drawn with x-, y- and z-axes. Besides, music is only rendered, provided a set of complete L-System grammar is inputted. However, LMUSe is rather a complicated program where it is not based on VLP and no music score could be generated. With OpenAlea, the plant could be viewed in 3D and is generated through iPython Shell. OpenAlea also provides a GUI named VisuAlea. VisuAlea is a visual and an interactive modeling environment typically for advance Functional-Structural Plant Model (FSPM). OpenMusic is a VLP-based program that could render musical sound and generate a score. However, OpenMusic does not have an interface to portray the plant model even though it is based on L-System tree generation to render music using Lisp. VLMR could generate plant models and music sound but not the music score when icons are connected and assembled to represent its L-System grammars. Therefore, in the context of L-Systems, there is a clear necessity to propose an application where it can model plant, rendering music, generate a musical score and it is based on VLP. On top of these, none of the applications mentioned could model plant and generate score vice versa when the L-Systems grammar is altered through VLP.

Table 2
Comparison Between Different Existing Applications with Regards to L-System

Application	Virtual Plant Modelling	Music Sound Rendering	Visual Language Programming (VLP)	Music Score Generation
TreeSketch	Yes	No	No	No
L-Py	Yes	No	No	No
L-Studio	Yes	No	No	No
LScore	No	Yes	No	No
LMUSe	Yes	Yes	No	No
OpenAlea	Yes	No	Yes	No
OpenMusic	No	Yes	Yes	Yes
VLMR	Yes	Yes	Yes	No
LSound	Yes	Yes	Yes	Yes

VI. CONCLUSION

The main purpose of this research is to design and produce a user-friendly and icon-based visual language framework typically for L-Systems musical score generation which helps the basic learners in the musical field. This framework can be fully utilized by the non-experts, non-programmers and also non-researchers of this L-system music score generator for the producing of music sounds. It is very convenient and has an understandable graphics and visual aid that can help in generating a musical score. This research is about expanding the dictionary to as wide as possible compared through mutation of rules to writing the textual programs in order to ease the users to use this framework. Based on the technical evaluation of the other existing applications, this framework has been successfully deployed using VLP that can model plant, render music and generate a score. Besides, the user can conveniently change the score or plants vice versa to generate a new piece of music. This framework is able to encourage individuals who do not have prior knowledge in music and L-system but would like to learn about the musical notes, to apply the visual language tools in generating musical score and understanding L-Systems.

ACKNOWLEDGMENT

This work presented is supported by KPT FRGS Grant (No. 2015-0163-109-02). The authors would like to acknowledge the many helpful suggestions of the anonymous reviewers.

REFERENCES

[1] K. H. Koh, A. Basawapatna, V. Bennett, and A. Repenning, Towards the automatic recognition of computational thinking for adaptive visual language learning. In *Visual Languages and Human-Centric Computing (VL/HCC)*, 2010, pp. 59-66

[2] C. K. Lim, and A. Z. Talib, L-System Controlled Music Expression through Visual Language Framework. *Applied Mechanics and Materials*, 2013, vol. 284, pp. 3549-3553.

[3] J. Bresson, and C. Agon, Visual programming and music score generation with openmusic. In *Visual Languages and Human-Centric Computing (VL/HCC)*, 2011, pp. 247-248.

[4] T. Tanaka, and K. Furukawa, Automatic Melodic Grammar Generation for Polyphonic Music Using a Classifier System. *Proc. SMC*, 2012, pp.150-156.

[5] M. Giraud, and S. Staworko, Modeling Musical Structure with Parametric Grammars. In *International Conference on Mathematics and Computation in Music*, 2015, pp. 85-96.

[6] *Merriam-Webster: Definition of MUSIC.* (2015). Retrieved August 8, 2016, from http://www.merriam-webster.com/dictionary/music

[7] A. Suyantohadi, M. Hariadi, and M. H. Purnomo, Plant Growth Modeling Using L-System Approach and Its Visualization. *MAKARA of Technology Series*, 2011, pp. *14*(2).

[8] X. R. Fan, M. Z. Kang, E. Heuvelink, P. Reffye, and B. G. Hu, A knowledge-and-data-driven modeling approach for simulating plant growth: A case study on tomato growth. *Ecological Modelling*, 2015, pp. 363-373.

[9] Y. Fu, D. Ren, G. Xu, and J. Wang, Morphogenetic models of virtual plant: A survey. *IEEE International Conference on Automation and Logistics*, 2010, pp. 25-30.

[10] W. Ding, L. Xu, C. Hu, and Y. Zhang, Parameter acquirement methods for rule-based model of virtual plant based on optimal algorithms. *10th World Congress In Intelligent Control and Automation (WCICA)*, 2012 pp. 748-752.

[11] S. Pirk, T. Niese, T. Hädrich, B. Benes, and O. Deussen, Windy trees: computing stress response for developmental tree models. *ACM Transactions on Graphics (TOG)*, 2014, vol. *33*(6), pp.204.

[12] S. Pirk, O. Stava, J. Kratt, M. A. Massih, B. Neubert, R. Mech, B. Benes, and O. Deussen, Plastic trees: interactive self-adapting botanical tree models. *ACM Transactions on Graphics*, 2012, vol. *31*(4), pp.1-10.

[13] T. L. Derzaph, and H. J. Hamilton, Effects of wind on virtual plants in animation. *International Journal of Computer Games Technology*, 2013, pp.3.

[14] M. A. Kaliakatsos-Papakostas, A. Floros, and M. N. Vrahatis, Intelligent generation of rhythmic sequences using Finite L-systems. *Conference In Intelligent Information Hiding and Multimedia Signal Processing*, 2012, pp. 424-427.

[15] M. A. Kaliakatsos-Papakostas, A. Floros, N. Kanellopoulos, and M. N. Vrahatis, Genetic evolution of L and FL-systems for the production of rhythmic sequences. In *Proceedings of the 14th annual conference companion on Genetic and evolutionary computation*, 2012, pp. 461-468.

[16] L. C. Kim, and A. Z. Talib, Improving L-System Music Rendering Using a Hybrid of Stochastic and Context-Sensitive Grammars in a Visual Language Framework. In *International Conference on Arts and Technology*, 2011, pp. 46-53.

[17] M. H. Yamaguchi, *An extensible tool for automated music generation* (Doctoral dissertation, Lafayette College), 2011.

[18] E. Holder, E. Tilevich, and A. Gillick, Musiplectics: computational assessment of the complexity of music scores. *International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Softwarexi*, 2015, pp. 107-120.

[19] T. Kathiresan, Automatic Melody Generation, 2015.

[20] S. Rubin, and M. Agrawala, Generating emotionally relevant musical scores for audio stories. In *Proceedings of the 27th annual ACM symposium on User interface software and technology*, 2014, pp. 439-448.

[21] M. M. Dehshibi, A. Shirmohammadi, and A. Adamatzky, March. Pattern formation using L-systems: A case study in forming Neyname's words. In T.E. Simos and C. Tsitouras eds. *AIP Conference Proceedings*, 2015, vol. 1648, pp. 580015.

[22] R. Tobergte, R. David, R. Curtis, and R. Shirley. The Structure of L-System. *Journal of Chemical Information and Modeling*, 2013, vol. 53(9), pp. 1689–1699.