PLANT GROWTH MODELING USING L-SYSTEM APPROACH AND ITS VISUALIZATION

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Abstract

The visualization of plant growth modeling using computer simulation has rarely been conducted with Lindenmayer System (L-System) approach. L-System generally has been used as framework for improving and designing realistic modeling on plant growth. It is one kind of tools for representing plant growth based on grammar sintax and mathematic formulation. This research aimed to design modeling and visualizing plant growth structure generated using L-System. The environment on modeling design used three dimension graphic on standart OpenGL format. The visualization on system design has been developed by some of L-System grammar, and the output graphic on three dimension reflected on plant growth as a virtual plant growth system. Using some of samples on grammar L-System rules for describing of the charaterictics of plant growth, the visualization of structure on plant growth has been resulted and demonstrated.

Keywords: L-System, modeling, openGL, virtual plant growth, visualization

1. Introduction

The developing study on morphology and synthesis using artificial life on many kind of plant growth has been solved on modeling technology at agriculturure technology application. For knowing natural procesess would be happen, studying on morphology and charateristic of plant has been developed by many scientist. Modeling in computer graphic for plant growth and biology cel have rarely been developed in plant growth analysed [1]. Aristid Lindenmayer who introduced theory of growth celluler by using string writing has been identified by Lindenmayer System (L-System) method [2].

Biologies processed for developing of plant growth by grammar roles are a fundamental of L-System method. L-System method [3], Prusinkiewicz et al. has been good properties tools for improving and designing realistic modeling on growth [4]. Proces growth on the nature including self similarity and rewriting has been designed grammatical rules by using L-System. L-System methods has been improved for modeling tools at many kinds of plant [5,6]. Soybean growth and development visualized, Pachepsky et al. have been investigated by L-System simulation [7]. The sowthistle model using L-System formalism and parameterized according to measurements of structure was developed in modeling the morphogenesis of annual plant [8]. L-System syntaxis usually are used for describing of rules on plant growth using grammar [9,10]. On the nature, the plants growth has been processed in Axiom by using L-system. Its have a production for developing conduted with DNA (*Desoxyribonucleid acid*) for all off plant.

At the beginning of plant growth, the bud of plant initially denoted as axiom. This characteristic rules are illustrated in the reproduction of L-System also occur in nature of plant growth conditions. On the growth of leaves and branches of plants growing above the main stems. The probability of growth of leaves more higher with the branches plants. Axiom compilation of basic concepts and rules are the basis of how the growth of L-System that works [11]. Development of L-System method for describing growth based on environmental characteristics affected in the design of realistic modeling [12].

This study of research aimed to generate plant growth with L-System method using grammar of the plant growth roles. Design of plant growth used Visual C++ programming on Windows Operating System, generated with graphically standart OpenGL for visualizing of plant growth grammar [13]. The output graphic on 3D reflected on plant growth as a virtual plant growth system.

2. Methods

Research has been done at Multimedia and Networking Laboratory, Institut Teknologi Sepuluh November (ITS) with several data references on plant growth graphically in syntax and grammar L-System that its would be designed and developed. Hardware of equipments used Personal Computer with specifications standart Processor Intel Pentium Dual CPU 2.8 GHZ, RAM 768 Mbyte, 30GB Hard drive, Graphic Card NVIDIA GeForce 8400GS. Softwares were used by Operating System Windows, Visual C++ and OpenGL. Figure 1 showed the methodology of research for designed virtual plant growth.

Rules of plant growth generating by L-System have been initially used from developing old branch and young branch of plant growth to diference of abjad notations (young branch has been initiated with F and G for old branch). Using turtle graphics, sign of new branch of plant to left using '+', sign of new branch of plant to right using '-' in noted L-System have been written in the front of abdjad symbol that it has been used as a grammer rules. Adding new branchs in plant growth in noted of L-system have been represented with '['symbol for firsting and']' symbol for finisihing. Using L-System, plant growth illustrations with syntax and grammer could be written as mentioned below:

Derivation length: 8
Axiom: F
F --> G[+F][-F]GF
G --> GG
Syntaxes in L-System have been developed and analyzed for designing on this research.

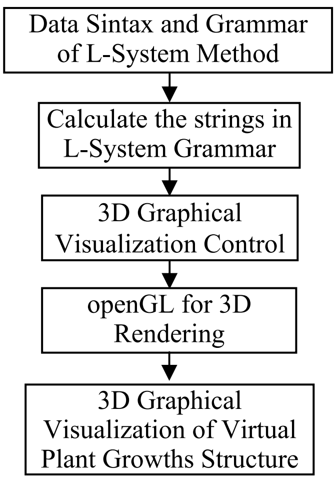

Figure 1. Methodology of Research for Virtual Plant Growth Design

Table 1. Data Processing Input for Programming L-System

Parameters	Descriptions
N_repetitions	Iteration of production rule (Integer Values)
Angle	Value of angle changes δ mentioned by production rule (in degree)
Axiom	String First axiom from production rule L-System
Rules 1	String production rules for first characters
Rules 2	String production rules for two characters

Table 2. Input Parameter Processing in L-System Programming

Name of File	Descriptions of File
Axiom.txt	Load first axiom data and grammer L-System
Ulang.txt	Load of repetitions number value and level of angles degrees

Input grammar of L-system including rewriting of input parameter of plant growth, deeply of rotations, string axioms and string rule for describing reproduction rules is fundamentals L-System methods to developing on visualizations on graphics environments. Table 1 showed input grammar parameters has been used in research areas.

In this cases, system has been developed generally with L-system grammar for desrcibing general rule of plant growth. In principles, L-System grammar have the same of rules with diferences parameters depends on user written on grammar of L-System such as iterations number, deeply of angles, axioms and productions rules for diferences of every plant growth.

Parameters of L-System grammer would be read by input data files (*.txt). Input data files indicate a descriptions of file, axiom, L-sytem grammer, repetitions and level of angles. Table 2 showed Input processing parameter in l-system programming Production process that its suitable with L-System grammer for growing plant characteristics have been initiated with axiom string in the first process on first iterations. If in string has been found character, it would be changed with string and rules equivalences. Process would be continued in first axiom to change with string characteristics up to finish. String change on first iteration, will be processed in second iteration with the same procedures iteration previously up to finishing iterations. Listing below showed calculation processing algorithm on L-System grammar;

Calculations String Grammer L-System
Require: n-repetitions
Require: axiom
Require: Angles

Require: Production rules

```
  pan j rule:length()
    alamat[::]
        for i = 0 to nrepetitions do
          Length axiom:length()
          kar 0
          hit  0
          for b = 0 to length do
              For every Character rule
              if find character rules then
                 change with character rules with new rules
                 char = char +1
                 hit   = hit +1
              end if
           end for
        end for
return String L-System calculation result
```

Visualization of plant growth has been processed by turtle geometry rules, also implemented bracket concepts. DOL-System could be applied for data structure abstract in graphics environments. Turtle rules for interpreting 3D graphical during this research have been showed at Table 3.

Visualization graphics for virtual plant growth with applying geometry of turtle graphics for 3D has been done using rendering to display for user relate to control rules and grammar of L-System. Figure 2. showed illustration of graphic turtle on 3D. Visualization of plant growth displayed stems of plant that it represents by bold line, growth to more length and more branch with smaller line like as growing plant at fields.

Table 3. Turtle Rules for Interpreting 3D

Symbols of Strings	Description
+	Rotations with angles δ in the opposite with clockwise
-	Rotations with angles δ in line with clockwise
&	Moving down with angles δ
^	Moving up with angles δ
)	Moving beside to left with angles δ
(	Moving beside to right with angles δ
!	Moving right with angles δ
[	Saving data from stack positions
]	Send data from stack positions

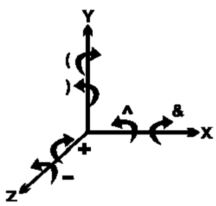

Figure 2. Ilustration of Turtle Graphic on 3D

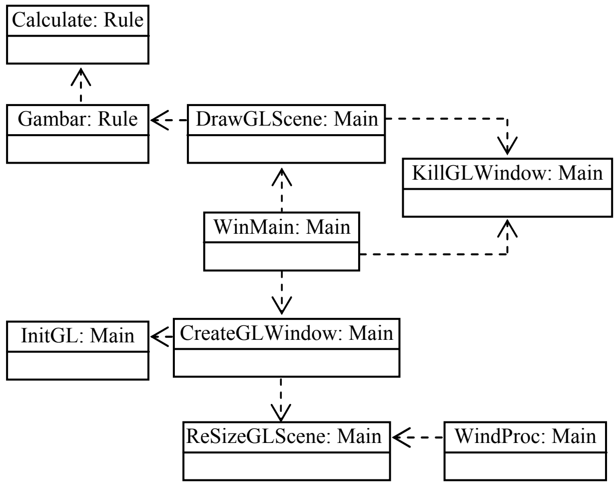

Figure 3. Main Menu Program Design to Control and Monitored

Table 4. The Names of Functions used for Controlling and Handling of Main Program

Name Functions	Usefull
WinMain	Handling of Window OpenGL
CreateGLWindows	Create Window OpenGL
InitGL	Initially OpenGL
DrawGLScene	Handling all of process rendering OpenGL
Gambar:Rule	Handling Implementations rules L-System
Calculate:Rule	Handling Calculate process string L-System

3. Results and Discussion

Visualization design of plant growth which as result of this research has been analyzed and implemented using samples of L-System Grammar.

L-System grammar has been processed by system including input parameter such as iterations, change of angles, axiom of the first, and string of production rules. These parameters have been got from input file after reading by program. For changing of rules, user could change the parameter in this files. Files is txt exstentions using name ”axiom.txt” and ”ulang.txt”. File ulang.txt has showed like as below;

4
22,500000
Number 4 is the iterations data and number Angka 22,500000 is the changes of angles d.
And file axiom.txt has showed as below:
F
F[-&)G][)++&G]||F[--&(G][+&G]
F[+G][-G]F[+G][-G]FG

The first of line paragraphs is string of first axioma and second and third paragraps are rule of F and G characters.

Algorithms for searching L-System string have been done by calculating process L-System grammer like as below:
Axiom First:
F
Axiom awal:
Production Rule:
F : F[-&) G] → length of string 5
G : F[+G] → length of string 7

1) First Iteration to process Axioma of F Characters
F[-&)G] → axioma First of 'F' changed with rules of F characters
2) Second Iteration to process of string on result iterations first.
   a) F[-&)G][-&)G]
      (1) F Character in adress string 0 would be change with rule of F characters
      (2) G character in adress previos in adress string 5 would be change with ``
      (3) 11 = 5 – 1 + 7 → (address first – indexs + length of F rules)
      (4) Indexs is sum of character rules that it has been found at the moments
   b) F[-&)G][-&)F[+G]]
      1) Character in adress string 0 would be change with rule of characters
3) Third iterations to process result of second string iterations
   a) F[-&)G[-&)G][-&)F[+G]]
      (1) F Character in adress string 0 would be change with rule of characters
      (2) G character in adress previos in adress string 5 would be change with 11
      (3) 11 = 5 - 1 + 7 (adress first index length of F rules)
   b) F[-&)G[-&)F[+G]][-&)F[+G]]
      (1) G Character in adress string 11 would be change with rule of G characters
      (2) F character in adress previos in adress string 11 would be change with 21
      (3) 21 = 11 - 2 + (5 + 7) → (adress first indexs (length of F rules + length of G rules))
   c) F[-&)G][-&)F[+G]][-&)F[-&)G][+G]]
      (1) F Character in adress string 21 would be change with rule of F characters
      (2) G character in adress previos in adress string 14 would be change with 30
      (3) 30 = 14 - 3 + (5 + 7 + 5) → (adress first – indexs + (length of F rules + length of G rules + length of F rules))
   d) ....[+G]][-&)F[-&)G][+F[+G]]]
      (1) G character on adress string 30 would be change with new rules of characters

Positions formulations of character on string from resulting of calculations that its would be changed with the new rules have been replaced in formulation of string = adress character n indexs + Σ length of string characters 0 up to n characters. Indexs is sum of character rules that it founded up to n characters.

Application of visualization L-System Control with turtle rules has been implemented by OpenGL instructions. Program code [alg:control-for character] from listing below showed controlling impelementation of string symbol and ^
Code of Program – Control for Character of +;-;& and ^

```
//Rotation of the oposite of clockwise
case "+":
        glRotatef(degree, 0,0,1);
        break;
//Rotasi in line with clockwise
case "-":
        glRotatef(-degree, 0,0,1);
        break;
//Moving up
case "&":
        glRotatef(degree, 1,0,0);
        break;
//Menukik down
case "+":
        glRotatef(-degree, 1,0,0);
    break;
    .....
```

Implementation of visualization control by OpenGL also covered rendering to display on Graphic 3 Dimensions. Result of implementation for sampling plant growth grammar generated by L-System has been showed in listing below:

1. Using Grammar L-System
Axiom: F
F[+F]F[-F][F]
N repetitions from 1 to 4, with angles =25.7 and the visualization has been showed in Figure 4.

2. Using Grammar L-System
Axiom: F
F → F[-\&)G][)++\&G]||F[--\&(G][+\&G]
G → F[+G][-G]F[+G][-G]FG
N repetitions from 1 to 4, with angles =22.5 and the visualization has been showed in Figure 5.

Visualization system on plant growth generated by L-System in this design complicated to understand it due to labor-intensive writing rules and grammar. L-System methods provides a visual and geometric representations for symbols and rulses which the result in production rules of a grammer. These production rule operate in parallel to replace that symbols related to a rule in a given grammer. This has been demonstrated by implementing of this result program. With this result, also could be developed and improved for studying

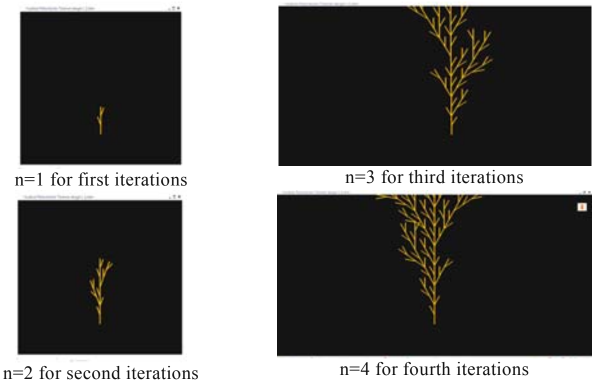

Figure 4. Visualization on First Sampling of Virtual Plant Growth

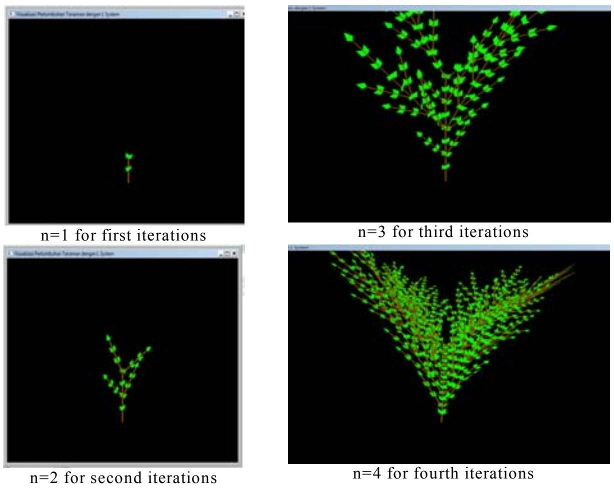

Figure 5. Visualization on Second Sampling of Virtual Plant Growth

plant growth by using visualization modeling and graphically used. By the result of this research, system could be visualized some of effects from manipulating the change of grammar and rules conducted to study of plant growth.

4. Conclusion

Using some of grammar L-System rules that it describes charaterictic of plant growth, design system and implementations have been resulted on visualization of plant growth structure. With manipulate some of grammar and rules in L-System methods that it represents plant growth component such as branch, steam, leaf, finally could be visialized in graphical display. Using some stages of plant componens at first initiate axiom, then generated L-String with rules grammer, do repetition of calculate string grammer, describes and interpreted in graphic turtle using geometric graphics, finally could be displayed plant growth modeling on realistic 3D.

Visualization of plant growth could be improved with intelligence system approaches to generate for developing in prediction plant growth, varieties and also the effects of environments to plant. Developing on Graphical User Interface also need to complete of resulting in this developing research.

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