# Chapter 2

# Literature Review

This chapter describes the survey of paper that used the L-systems to applied for plant model and plant development. There are a lot of researches that use L-systems to simulate and visualize the plant model and development. This chapter consists of two sections, a first one reviews about the research that related to L-systems, and the last one describes the research about plant model.

## 2.1 Review of Literature Related to L-systems

In 1968, Aristid Lindenmayer introduced L-systems, which provided a mathematical formalism for parallel grammars well adapted to the modeling of growth phenomena [27]. In 1984, Alvy Ray Smith, a computer graphics researcher showed how L-systems could be used to synthesize realistic images. He also pointed out the relationship between the concept of Fractals and L-systems [35]. L-systems used to generate plants with or without inflorescence, cell growth and geometric patterns such as Indian kolams or mathematical 'monsters' such as the Von Koch or Hilbert curves. Many geometric patterns and tilings can be generated using L-systems. The problem of describing patterns and tilings using L-systems is largely unexplored in [27].

In 1988, Friedell and Schulmann developed a prototype for the automatic generation of architectural scenes. Which would allow the infinite range of forms that can be generated using L-systems formalism to be explored.

- One set of rules (in the simplest example, only one rule) describes the pattern to be repeated.
- Another rule describes the expansion of the pattern through translations

- And a third rule describes the rotational symmetries. Using the basic structure, all symmetry groups can be described easily using the same grammar skeleton.

The rule-based language of “stochastic sensitive growth grammars” as an extension of parametric L-systems [27] was developed to describe algorithmically the changement of the morphology of forest trees in time, taking endogenous and exogenous factors into account, and to create systematically three-dimensional simulations of tree crowns. At different tree species, mainly at spruce, morphological measurements were carried out to get a basis for the design and parameterization of such rule systems.

The software GROGRA (Growth Grammar Interpreter) creates time series of three-dimensional crown structures [14,15] from the rules; the basic elements of these structures (annual shoots) can additionally bean non-geometrical attributes. Furthermore, GROGRA contains several analysis tools and data interfaces.

The generated architectures serve as an “ecomorphological basis model” for different process-oriented simulation models. There is already realized a model of tree-internal water flow (HYDRA) [15], based on the artificial tree structures.

Lin implemented the animation of L-systems based on three-dimensional plant growing in Java [17]. His animation used a number of iteration to animate the plant development. His animation was not smooth.

Prusinkiewicz, James, and Mech extended Lindenmayer systems [29] in manner suitable for simulation the interaction between a developing plant and its environment. The formalism was illustrated by modeling the response of trees to pruning, which yields synthetic images of sculptured plants found in topiary gardens.

Hammel and Prusinkeiwicz extended the notation of L-systems with turtle interpretation [8] to facilitate the construction of such objects. The extension was based on the interpretation of the entire derivation graph generated by an L-systems, as opposed to the interpretation of individual words. The illustrated the proposed method by applying it to visualize the development of compound leaves, a sea shell win a pigmentation pattern, and a filamentous bacteria.

Prusinkiewicz extended it further to language-restricted iterated function systems (LRIFS’s) [24]. They generalized the original definition of IFS’s by providing mean for restricting the sequences of applicable transformations. The resulting attractors include sets that cannot be generated using ordinary IFS’s. Their research was expressed using the terminology of formal languages and finite automata.

Prusinkiewicz, Hammel, and Mjolsness introduced a combined discrete/ continuous model of plant development that integrates L-system-style productions and differential equations [28]. The model was suitable for animating simulated developmental processes in a manner resembling time-lapse photography. The proposed techniques were illustrated using several developmental models, including the flowering plants.

Prusinkiewicz and Kari expressed the development of modular branching structures [26] that satisfy three assumptions: (a) subapical branching, meaning that new branches can be created only near the apices of the existing branches, (b) finite number of module types and states, and (c) absence of the interactions between coexisting components of the growing structure. These assumption were captured in the notion of subapical bracketed deterministic L-systems without interactions (sBOL-systems). They presented the biological rationale for sBOL-systems and proved that it is decidable whether a given BOL-system was subapical or not.

Hemmel, Prusinkiewicz, Remphrey, and Davidson presented a methodology for creating models that capture the development of plant using the formalism of L-systems and incorporating biological data using *Fraxinus pennsylvanical* shoots based on L-systems [30].

Hammel, Prusinkiewicz, and Wyvill proposed a method for modelling compound leaves in plants [9]. The layout of leaf lobes is captured by a branching skeleton generated using an L-systems. The leaf margin is then traced around the skeleton. Their work focused on the specification and tracing of the margin, and including references to the techniques described in the literature for performing the other tasks. The margin is defined as an implicit contour.

## 2.2 Review of Literature Related to Plant Model

Lintermann and Deussen presented a modelling method and graphical user interface for the creation of natural branching structures such as plants [19,20]. Structural and geometric information is encapsulated in objects that are combined to form a description of the model. The model was represented graphically as a structure graph and could be edited interactively. Global and partial constraint techniques were integrated on the basis of tropism, free-form deformations and pruning operations to allow the modelling of specific shapes.

Deussen, O. developed a system built around a pipeline of tools [3]. The terrain was designed using an interactive graphical editor. Plant distributing was determined by hand, by ecosystem, or by a combination of both techniques.

These two topics of literature review have stimulated the idea for the researcher to improve the previous works. The improvement of the previous works will be discussed later.