Graphical Modelling of Higher Plants Using P Systems

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Abstract

L-systems have been widely used to model and graphically represent the growth of higher plants [20]. In this paper we continue developing the framework introduced in [21], which make use of the topology of membrane structures to model the morphology of branching structures.

1 Introduction

The growth of plants, considered as a function of time, have attracted the attention of scientific community for a very long time. Features such as the bilateral symmetry of leaves, the central symmetry of flowers and more recently, the study of self-similarity and fractal structure have been matter of study for computer scientists, mathematicians and life scientists among others.

In 1968, Aristid Lindenmayer presented a theoretical framework for studying the development of simple multicellular organisms. The devices introduced in this framework are known as *parallel rewriting systems* or *L-systems*.

L-systems were introduced for modelling multicellular organisms in terms of division, growth and death of individual cells [10, 11]. These organisms are treated as an assembly of discrete units, which represent the individual cells. These systems must be considered as dynamic models, which means that the form of the organism is the result of development along time. This development is described in terms of *production rules*, which are applied in parallel and are intended to capture the simultaneous progress of time in all parts of the growing organisms.

Several years later, the range of applications of L-systems were extended to higher plants and complex branching structures [3, 4]. In the first approach, the essence of development of lower organisms is the replacement of individual cells by sets of cells, in the terms established by the production rules of the system. On the other hand, in L-systems modelling higher plants the units of information represent complex structures, such as branches or leaves, instead of individual cells. These structures are replaced by other ones using the production rules.

In [5, 6] a first approach for using P systems to simulate the growth and development of living plants is presented. This approach mixes L-systems and P systems, being in fact an L-system "factorised" into several units, which are then computed in the compartments delimited by the membranes of the P system.

L-systems use strings as data structures, which fits in a natural way in sequential structures such as microorganisms or linear structure of fractals such as the Koch curve [8, 9]. Nonetheless, the visual interpretation of strings of symbols as branching structures needs to add memory pointers in order to remember the location and orientation in which the branches were developed. These memory facilities are the key for developing several branches from the same point.

The topology of P systems is inherently a branching structure based on the inclusion relation. This feature allowed us to present a framework for modelling the topology of living plants, without the necessity of considering memory pointers [21]. We think our approach is closer to reality than L-systems, in the sense that we do not make "rewriting" over the membrane structure, but instead we use evolution rules to expand it. This is inspired by the fact that mature structures in higher plants, such as trunks and branches, keep their morphology along time. They change only in length and width, and the growth of new structures (leaves, flowers, new branches, and so on) is started only from specific points, already present.

In this paper we continue developing the framework introduced, providing two means (randomness and non-determinism) for modelling the individual variations among different specimens of a same species that occur in Nature.

The paper is organised as follows: first L-systems and the usual way of visualise them are recalled in sections 2 and 3. In section 4, the variant of P systems used in this paper, a restricted version of P systems with membrane creation, is presented. Section 5 is devoted to the graphical visualisation of the configurations of these P systems, whereas we discuss in section 6 the differences between the representations obtained when stochastic and non-deterministic P systems are considered. Finally, conclusions and lines for future research are presented.

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