Title Page

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Authors names	Yodthong Rodkaew, Prabhas Chongstitvatana, Suchada Siripant, Chidchanok Lursinsap
Affiliation	[1]Advanced Virtual and Intelligent Computing (AVIC) Research Center Deparment of Mathematics, Chulalongkorn University, THAILAND
	[2]Intelligent System Laboratory (ISL) Faculty of Computer Engineering, Chulalongkorn University, THAILAND
Address	5th Floor, Gemmological Research and Testing Building, Phayathai Rd., Patumwan, Bangkok THAILAND, 10330.
phone	(66 2) 218-5469
e-mail	aqualeo.leonics@gmail.com [Rodkaew.Y] prahas@chula.ac.th [Chongstitvatana.P] lchidcha@chula.ac.th [Lursinsap.C] ssuchada@chula.ac.th [Siripant.S]
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A Quick Preview in Particle Systems for Plant Model

Yodthong Rodkaew
AVIC Research Center, Chulalongkorn University, Bangkok, Thailand.
aqualeo.leonics@gmail.com

Prabhas Chongstitvatana
ISL, Department of Computer Engineering, Chulalongkorn University, Bangkok, Thailand.
prabhas@chula.ac.th

Suchada Siripant
AVIC Research Center, Chulalongkorn University, Bangkok, Thailand.
ssuchada@chula.ac.th

Chidchanok Lursinsap
AVIC Research Center, Chulalongkorn University, Bangkok, Thailand.
lchidcha@chula.ac.th

Abstract – *This paper presents a new algorithm for modeling plant structures. The main motivation of this algorithm is based on certain natural phenomena. A property of the plant structure is to transport and exchange energy, water and sustenance between roots, branches and leaves. The plant structures should be suitable for efficient transportation. The algorithm employs Particle Systems. The algorithm is initiated by randomly scattering particles inside a given shape. Each particle contains energy. The transportation rule directs each particle toward a target. When particles are in close proximity, they are combined. The trails of moving particles are used to reconstruct plant structures. In addition, the light effect from an environment is incorporated. The algorithm has been tested with various shapes. It is computationally efficient, and has only a few parameters. The resulting images are realistic.*

Keywords: Computer Graphics, Particle Systems, Leaf Model, Plant Model, Particle Transportation.

1 Introduction

The synthetic modeling for natural shapes is a challenging problem in computer graphics and related fields. The results in the plant modeling are useful for the simulation through virtual reality. However it is difficult to model a natural shape such as a tree or a leaf because of the richness of complex details in plant architecture.

In previous works [1], [2], we introduced leaf model based on L-systems [3]. This method is required specific rules and parameters to create a structure. Finding rules and fitting parameters appropriate for the rules are not a trivial task. The process consumes a lot of computation power and resources. Usually, a tree is constructed with recursive functions. There are other limitations because of its data are hierarchical. For an example, small changes in one part especially trunk's angle near the root will affect the branch's angle and whole tree shape. Since the rules are also very specific. Once the rules have been created for one species of plant, they maybe require more rules and fitting parameters for another type or shape of plant model.

Our new motivation comes from the behavior of nature. The new proposed algorithm is based on efficient construction of veins covering several leaf shapes [4], [5]. It also works well for the structure of trees and root systems including interaction with an environment such as light effect [6]. The modeling method is based on particle systems using rules to define interaction between particles. The algorithm is explained in Section 2. Section 3 presents the result of generating veins of leaf shapes and describes the use of algorithm for modeling trees. Finally, Section 4 gives conclusion.

2 Unified Algorithms for Generating Plant Model

The primary objective of Particle Transportation System is to generate venation pattern of a leaf. The outline of leaf shape and the target point are the main input for the system. The motivation of the algorithm is based on observing natural phenomenon.

2.1 Motivation

In nature, leaves are the essential part of plants that have a role for photosynthesis process. The green substances inside leaves contain chlorophyll for energy absorption from sunlight to help plants grow. During photosynthesis process, the veins are used for transporting energy between leaves and trunks. The arborescence veins that immersed inside leaves are useful for both transporting energy and supporting the leaf structure. The diameter of a vein reflects capacity. The larger diameter of vein transports more energy. A real leaf shape is controlled by its species which depends on genetic.

We assume an energy conservative model. Each part of leaf has equivalent chlorophyll and absorbs equivalent energy. All energy is sent to the plant via veins. Each area can be represented as a particle inside the leaf shape. The particles are scattered inside the whole shape. The particles represent energy which is transported to the petiole. The transportation should be efficient as straight path.

In case that is many paths to the petiole. To improve the efficiency, the path must be shared. While particles move toward the target, they are forced to share their paths. This is accomplished by moving particles toward each others, when two particles come close, they are merged together. The two particles combine energy and other attributes. After the combination, they become a new particle. The process is repeated until all particles reach the target as in Figure 1.

2.2 Particle Transportation

The algorithm creates leaf-veins or tree-trunk from the trail of particles that are randomly scattered within a given boundary. We used 2D boundary for leaf and 3D boundary for tree. In case of 3D, the boundary is represented by a set of polygons. The direction of motion of a particle is controlled by the equation in algorithm below. At each time step all particles move and collapse if it closed together. The process is repeated until no particle remains.

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ALGORITHM PARTICLE TRANSPORTATION

Given an outline boundary:
S is a set of particles. P ∈ S contains: pos (position: a point (x,y)), en (energy), rd (radius).
T is the target point (at the bottom of a leaf). Wp, Wq are weight factors

1.  Place S inside the boundary
2.  For each P do
3.    N is the nearest particle to P
4.    if P.pos - N.pos < P.rd + N.rd then
      // combine two particles
5.      P.pos ← (P.pos + N.pos)/2
6.      P.en ← P.en + N.en
7.      S ← S - {N}
    // check P reaches the target
8.    if | T - P.pos | < P.rd then // delete P
9.      S ← S - {P}
10.   else // move P
11.     V1 ← normalise(T - P.pos)
12.     V2 ← normalise(N.pos - P.pos)
13.     V3 ← normalise((Wp × V1 + Wq × V2)/(Wp + Wq))
14.     P.pos ← P.pos + V3 × stepsize
15.   repeat 2-14 until S = ϕ
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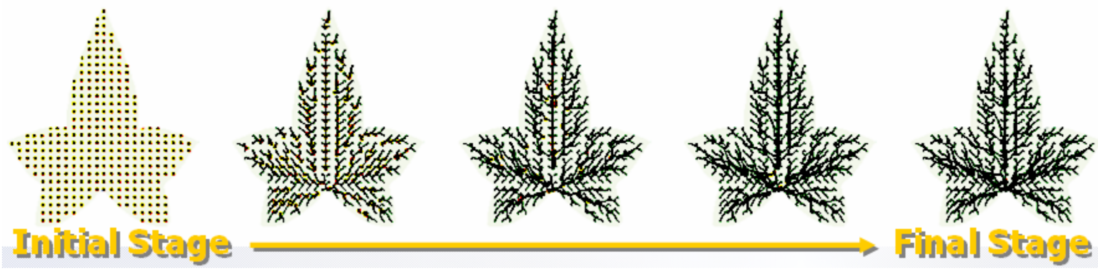

Figure 1: Particle Transportation in leaf shape

3 Use of Particle System for Synthetic Plant Model

With Particle Transportation, It is easy to fill vegetative-like structure from a given shape. All parameters can be leave as default setting and no need to fine-tune parameters that rely on a new shape.

3.1 Leaf Model

Particle Transportation creates venation-liked from a 2D outline leaf. The trails of particles generate the venation structure inside the given leaf shape. The leaf venation structure is extremely complex and can compare to the real leaf as in [4] as in Figure 2.

Figure 2: Synthetic leaves by Particle Transportation

We propose the color shading [5] method based on Particle Transportation System. The venation structures are created from the trails of particle motions. This structure is related to the color of a leaf. The direction of color motion is related to the pattern of the vein structure. The leaf of taro vine (Scindapsus aureus, *Epipremnum pinnatum*) is an example of this case as in Figure 3.

Figure 3: Extended color system for synthetic leaves by Particle Transportation

3.2 Tree Model

With Particle Transportation, The same concept can be applied to model a tree [6]. Particle motions are extended to 3D space and the shape is also in 3D boundary. The outline shape of a tree is given as in Figure 4. The root can also be generated by the same method.

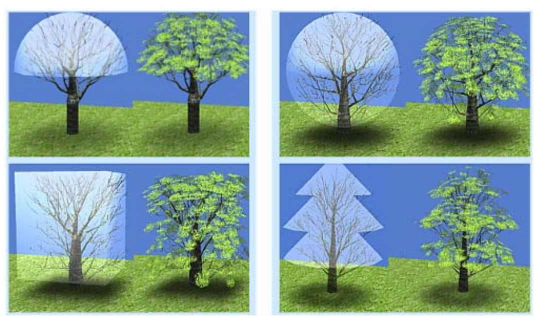

Figure 4: Synthetic trees constructed from given 3D boundary by Particle Transportation

In tree model, the positions of particles are represented as the positions for each leaf. Natural leaves are at appropriate positions for receiving the light. Thus, the density of leaves in an area is based on the amount of received light. This require the effect of light in the model, the light is calculated using ray-tracing. The light intensity is use for calculating the density of particles. The bright area contains more particles than the dark area. Figure 5 shows the light calculation in a 3D array. Because the semi-transparent property of the inside boundary, the shadow cast on the floor in the center is darker compared to the edge. Thus, self-shadow effect is automatically occurred. A twin tree represents with a self-shadow as in Figure 6.

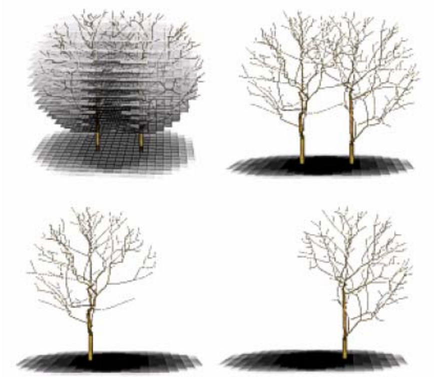

Figure 5: Calculation for light intensity (up-left), the particle density generated and create tree-trunk by Particle Transportation (up-right), the separation of model reveals un-branch region (bottom)

Figure 6: Fine-tune synthetic trees with self-shadow effect by Particle Transportation

4 Conclusions

This work presents an algorithm for modeling natural structures. The algorithm is inspired by nature using the idea based on particle systems. It is easy to synthesize vein images from a given leaf shape and branches from a given boundary. The proposed algorithm uses a few parameters to control the quality of the output. The trails of the motion of interacting particles create very realistic natural structures. The particle system is suitable for plant modeling. However, there are some kinds of leaves and trees that can not be constructed using this algorithm. We are searching for other suitable parameters and extend the algorithm to handle more shapes. The growing factor of plants is worth consideration because there are many well-known theories in botany such as phototropism, gravitropism, photoperiodism and plant hormone. Let's Particle Systems be one of the useful tools for simulating interacting complex system of nature.

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