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Research on Motion Simulation of Trees Model in Wind Filed

Xumin Liu[1], Yongxiu Xu[1], Xu Zhai[1] and Weixiang Xu[2]

[1]College of Information Engineering
Capital Normal University, Beijing 100048, P. R. China
[2] School of Traffic and Transportation
Beijing Jiaotong University, Beijing 100044, P.R. China
liuxumin@126.com

Abstract

With the development of computer animation and demands for gaming, the motion simulation of trees in wind filed has become one of the research hotspots. In order to better simulate the 3D motion of trees to wind filed in the natural environment, this paper proposes a method to establish real-time animation visualization of trees in the wind. The research focus is making the process of performance of ranches swaying motion become more real, layered modeling was carried out on the branches and combining the theory of fractal iteration for simulation, making the effect of wind field on the branches can carry on the hierarchical structure to analysis and calculation in detailed, so as to achieve good swing results. This paper implements a dynamic simulation demonstration system of trees in the wind based on fractal iteration system to be consistent with branches in the wind with the nature of the scene. Therefore it can generate both satisfied visual effects and dynamic images that meet the real-time requirements.

Keywords*: tree modeling; animation simulation; wind field; trees sawing*

1. Introduction

Trees are a kind of common natural scenery, belongs to complex real entity object. With the continuous development of computer graphics technology, the researchers are more focus on finding a mathematical model that accurately describe of the trees in the objective world. And the model not only should meet the static sense of reality, also can be able to realistically depict the dynamic display effects. It is difficult to simulate the dynamic nature trees by some simple methods, and it can be completed rely on objective laws in the real world. Therefore, we can use computer graphics and virtual reality technology to visually depict the movement characteristics of trees, and reveal the relations between trees and its external environment influence by the visual experience and three-dimensional human-computer interaction interface. Computer graphics and virtual reality technology in computer animation, games, film and television, landscape simulation, battlefield simulation, virtual reality, and other fields have a wide range of applications.

With the deepening of the simulation study about trees in recent years, many trees simulation methods are proposed. Process modeling method of Trees that are widely used has fractal methods [1], particle system [2], L-system [3, 4], A-system [5], *etc.* Those methods generate more complex geometry based on simple rules. And the researchers usually can create growth model of trees by combining with the knowledge of tree's physiology to simulate the growth, development, dormancy and death that the whole process of trees. Lintermann B [6] *et al.*, Boudon F [7] *et al.* and Bilsborough GD [8] proposed a parameterized modeling method for the whole structure of the tree, it fine control the geometry of the trees through the given parameters, generating geometric structure of trees and getting a good tree model. J. Lluch [9] *et al.* put forward a method

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that express the bifurcate structure of trees by polygon mesh based on L system, and draw out the model of the trees. Meng Yang [10] *et al.* put forward dynamic tree branch model based on physical model. Chin-Hung Teng [11] *et al.* proposed a reconstruction method of 3D tree model with a very narrow range in several images. Daniel Wesslen and Stefan Seipel [12] put forward a method that can generate real-time virtual dynamic trees. Rui Wang [13] *et al.* proposed a natural tree statistical model with double stochastic characteristics. In the next layer it defines planton, which is a set of similar plant organs used to describe the detail characteristic information of the plant organs. However, in upper layer, is a set of transformations for describing the random position of plant organs. And a novel modeling method was designed based on this, extracting sample plantons from real tree to generate tree model. Alexandre Peyrat [14] *et al.* put forward a initial method of generating a lot of details of the leaves atlas from a single formal grammar. Leaves are described as a kind of parameterized 2 Gmap L-System that describe the growth process of their Shape texture from the whole life cycle. With the change of leaf age, this method can automatically generate the change of color and texture and can automatically generate such as hole cracks caused by insect attacks and some accidents, *etc.* Johan Knutzen [15] *et al.* proposed a new method of generating climbing plants using L-system sequencing. The method takes generating geometry and texture by 3D modeling and generating stylized context as the basis of the final design. The algorithm efficiently simulates external tropism, such as, geotropism, phototaxis and some other pseudo tropism. The structure of climbing plants is described by using the discrete string expression of L-system. Although above algorithms for tree swinging in the wind field have a better simulation, but all of them have a problem: take a tree as a whole to study, affecting the authenticity and the vitality of simulation results. However, this paper takes the branch as a model unit to analyze and study.

Fractal algorithm is an early model used to simulate the natural scenery, it can generate some complex natural scenery images with strong realistic from a small amount of data. This method is often used to solve simulation modeling problem about irregular shape of trees, flowers and plants, mountain, water, cloud and terrain. In this paper, the tree model is described based on the fractal algorithm. On this basis, this paper studies the dynamic tree model and presents a method that use hierarchical modeling on branches and simulate by combining the theory of fractal iteration. We use OpenGL graphics library and VC + + 6.0 programming realized the algorithm proposed in this paper, and build a simulation demo system of dynamic tree swaying effects. This demo system can generate not less than 25 frames per second or more on common desktop computer, can meet the requirements of real time, and the generated trees with strong sense of reality.

2. The Simulation of Trees Sway in Wind Field

The basic form of trees is an representation of trees in the objective world , is the aggregated results with influence of the growth rule in the process of its own grow and external environmental factors. So, for more realistically simulate the trees on the computer, we not only draw and build model for appearance characteristics of the trees but also we need to do some in-depth study about the behavior characteristics of the trees. Only set up the motion model that obeys the law of trees growth rule, we can more accurately simulate the process of motion and morphological specificity of trees in the virtual world. On the other hand, due to the motion behavior characteristic of trees under the influence of external factors is the fundamental way of people cognition, evaluation and analysis trees.

Based on structure characteristics of trees, the amount of tree leaves is large, and the texture of trees is extremely complex. Therefore, if these factors are response to the program code when set up 3D modeling for a tree, it will cause the data expansion and consume large amounts of time. But human eyes receiving information is very limited, so, modeling take the tree as a whole, and there is no need to simulate some of its details feature, especially in the animation. On the contrary, the truth degree of the tree's motion process becomes even more important. In view of this, the focus of this article is more vividly simulating the motion process of swings sway in the wind field.

2.1. The Structure of Trees

Trees discussed in this paper are the tree model that computer simulated, it only includes trunk, branches and leaves of a natural tree those visible parts on the ground. Generally, visible parts of a natural tree on the ground are mainly including trunk, branches and leaves. Note that， if there is no specified, both tree trunk and branches can be referring to branches. The tree trunk system consisting of branches supports the whole tree and determines the shape of the tree; Leaves grow on the branches, cover the tree trunk system, forming the overall appearance of the tree. Locally, each leaf and its veins patterns, bark's concave and convex texture *etc.* constitute the detailed features of the tree.

2.1.1. The Overall Structure

Due to the tree branches system has a natural hierarchical structure, therefore, this paper generates the branches in the form of hierarchical, and those branches in the same level is controlled by the same set of parameters. The trunk system in this paper is based on the fractal theory, generated by relatively simple iterative process. First, the trunk began to grow up from the ground as the whole tree's trunk lied in the highest level of the branch system (zero level), then, a main branch and a side branch grow up form this trunk, this is the first level of the branch system (shown as Figure 1), including a main branch and a side branch. The second level of branch system makes the main branch and side branches of the first layer system separately as its backbone, then generating main branches and side branches on the second level of branch system. By analogy, until generated n layer (the last layer) branch system, and only in this layer, leaves are generated from its main branches and side branches. Main branches and side branches offset some Angle respectively, so that it can achieve a satisfactory effect.

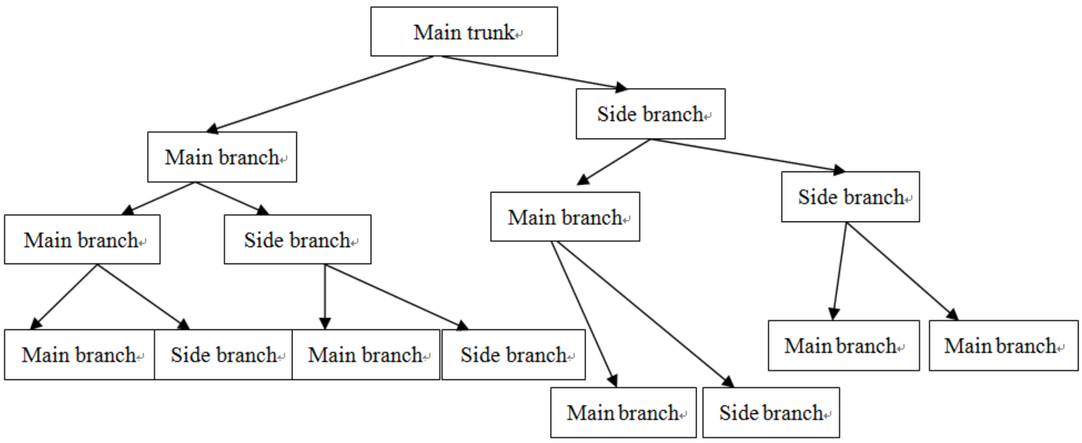


Figure 1. Trunk System

The trunk system is based on fractal theory, using the simple iterative thought to complete. IFS (Iterated Function System) method is a kind of method based on fractal, adopts the method of point model, its basic principle is not complicated, it concludes general and local view of the geometric objects and has self-similar structure in the sense of affine transformation. It can transform the whole morphology into a local morphology by constructing several suitable affine transformations, and this process can proceed iteratively, until satisfactory results are obtained. In three-dimensional space, iteration function system begins from a specified initial point in space, after an iteration of three dimensional compression affine transformations, eventually, forming the desired 3D fractal tree model.

Let $W=R^3->R^3$ be a affine transformation of three dimensional space and $X=(X,Y,Z)^T$ be a point in this three dimensional space that mapped to the point $X'=(X',Y',Z')^T$ after the affine transformations, which expressed by matrix form is as follows:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = W \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & k \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} m_1 \\ m_2 \\ m_3 \end{bmatrix}$$

This matrix form can be abbreviated as X'=A (X) + M. Note that, A is a composite transformation matrix, which includes basic affine transformation, such as rotation, scaling, *etc.*, M is a translational transformation matrix.

2.1.2. The Overall Structure

For each branch of the tree, it can make up an independent system relative to the whole tree. And those systems have many similar characteristics, for example, all of them have a root node, branches, leaves, and so on. For each branch of the tree, there are some attributes or features as followings:

● Root node ,which branches grow out from.

● The total leaf, which including leaves that grow out from the main branch and leaves that grow out from branches that derived by the main branch.

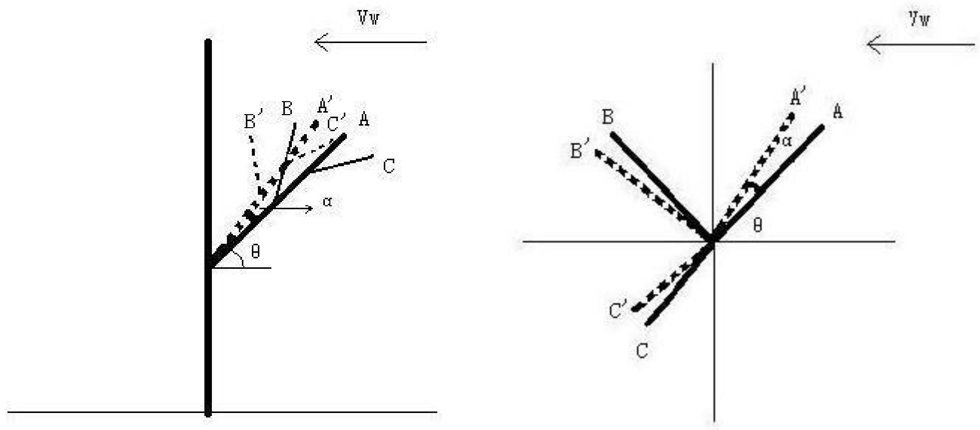
● Sub-branches that a new branch grow out from the main branch, which including direction vector, diameter, *etc.*

2.2. Mode of Motion

From the past materials and research works, for simulating the branches in the wind field, we can see that we usually consider the tree as a whole, approximately take a tree as a pendulum, simulating the movement of the tree very roughly. This paper is taking each branch of trees as a research object, considering the condition of each branches sway in the wind. This seemingly has increased a lot of computation, but the number of branches is very limited. The method in this paper can better reflect the force of trees, so as to achieve a better realistic simulation results.

2.2.1. Direction of trees and direction of branches

Due to the direction of the branches is arbitrary, the direction of wind also is arbitrary (assuming the direction of wind parallel to the horizontal plane), so, generally there presents a certain Angle θ between direction of branches and wind's direction. Through a lot of experimental analysis, it is concluded that branches affected by wind field and branches will have the same movement trend with the direction of wind. If the wind size is different, the maximum offset and Angle α also are different, as shown in Figure 2. Among them, the solid line represents the position of branches before branches were impacted by wind force, and dotted line represents the position of branches after they were impacted by wind force.



a. Vertical Plane b. Horizontal Plane

Figure 2. Branches Movement

Figure 2-b is a top-down view of looking down from the top of the tree. And, V_w is the wind direction, A, B, C are initial position of branches, and A ', B ', C 'are the biggest displacement branches can move. Branches' movement can be represented by that branches rotate a certain Angle in one direction, and its direction is decomposed into horizontal and vertical these two direction vectors, Figure 2-a is a representation of the vertical movement of the branches, Figure 2-b is a representation of branches' horizontal motion. According to the force branches got in vertical and horizontal directions, we can respectively determine branches' move direction in vertical and horizontal. However, the displacement or Angle branches moved would take a determine value that a lot of experiments have tested, and in order to achieve best visual effects, we also consider the influence of other factors described in followings.

2.2.2. The Diameter of Branches and the Total Number of Leaves

Trees are affected by the wind, in addition, all kinds of factors of itself should be considered, especially the amount of leaves and the diameter of the branches. When branches were impacted by the same size wind force, coarser branches would swing with a smaller Angle and thinner branches would swing with a bigger Angle. In addition, when branches were impacted by the same size wind force, branches that have larger leaves would swing with a smaller Angle and branches that have less leaves would swing with a bigger Angle. That is to say, branches close to the tree roots get smaller wind effects and branches close to the leaves get larger wind effects. Therefore, we should comprehensively consider these two aspects of influence to simulate the movement process of the trees.

2.2.3. The Duration of Wind

Because the wind force is changing with time and intermittent, so the size of the wind force is not constant. Assume that the wind force is constant in a very short period of time, and the wind force goes to zero at the end of time. The branch is affected by the wind force, it will move to the furthest position away from the original location, then the branch do a swing of the pendulum, which forms branches swing process. However, the time of branches continued impacted by wind force and the time branches need for restoring calm are random, so there will appear the following two special cases:

(1) When the time branch impacted by wind force of is very short, the branch has not reached its farthest location, but the wind has stopped, the branch will come into the quiet time and will swing back.

(2) When the time that branches need for restoring quiet is very short, branches haven't back to its farthest position, even have not reached its initial position, branches immediately enter the loading time and branches move to the direction of wind again.

In the process of branches swing in wind field, the speed of branches motion and the speed of branches' rotation are not uniform, assume that branches would get an initial speed v when branches were exposed to wind field in an instant, and branches will turn to the maximal displacement (Angle) position its can achieve. Note that the speed gradually decreases in the process of rotation, and it would reduce to zero when branches reached the maximum displacement (Angle). At this point, the branch turn to the initial position, and the speed increases from 0 to maximum speed v when branches reach the initial position; After passed the initial position, branch continues turning, but its speed is decreasing, and the speed reduced to zero when branch reached biggest reverse placement position; Then, the branch continues to turn to the initial position with opposite direction, its speed would gradually changes to the initial velocity v from zero, the following process repeats above steps. Of course, described above is an ideal situation. Actually, if there is no other outside force impacting branches, the oscillation amplitude of branches and the time when branches reached the initial position all will gradually become smaller, until they become zero, finally branches still.

3. Design and Implementation of Simulation Demo System of Dynamic Trees

In order to verify the effect of the algorithm proposed in this paper, this paper designs and realizes a simulation system that trees in the wind field and provides an experimental platform.

3.1. Overall Framework of System

Its overall framework is shown as Figure 3.

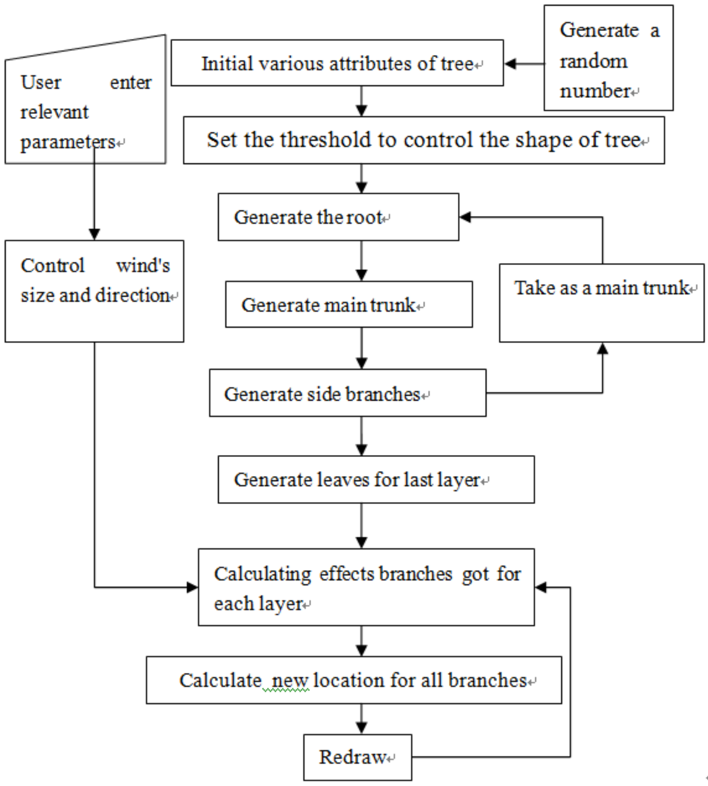


Figure 3. Overall Framework

This demo system is mainly composed of several modules, such as, branches system module, calculating module for new position, texture mapping module and so on. Branches system module is mainly responsible for initializing the shape of tree modeling. We can determine the shape of the trees according to predetermined parameters and updated parameters those input into the interface, such as the luxuriant degree of trees, the inclined angle of branches, the height and the thickness of trees, *etc.* Note，Once building the tree model, the basic form of the tree is no more changes. The main function of calculating module for new position is calculating branches' new position under the influence of wind filed according to the branches system step by step. The main function of texture mapping module is loading texture images with format of 24 bits bmp, generating texture objects, then doing texture mapping when draw the tree model.

3.1.1. Branches System Modules

The basic shape of tree model can be determined through setting some attributes of the tree by branches system module. Such as, branches' diameter size, the number of branches' layer, the amount of leaves, branches' deflection Angle, the length of branch, the shadow of branches and so on. We can obtain different branches model, by changing the basic attributes of branches and changing the rotation matrix to get a real 3D skeleton tree model.

Branch system is based on fractal theory and uses the simple iteration function system to complete. According to the natural hierarchical structure that branches system has, this paper generates branches in the form of hierarchical. The branch in the same level is controlled by setting a same set of parameters. Details were shown in the content of 2.1.1.

3.1.2. Calculating Module for New Position

There is not a separate class to be responsible for works of calculating module for new position. Because this algorithm calculates the wind force influence on branches according to the hierarchy of branches that based on branches system, so the calculation module is embedded in branches system module, and it was executed by TwistInWind() function. Of course, there is a nested relations between this function and branches system, and if this function is defined in the branch system it will be more convenient for data operation and calculation.

3.1.3. Texture Mapping Module

In dynamic tree simulation demonstration system, texture mapping module's main function is reading branches and leaves pictures user provide, resulting in generating a more real tree image. Add a texture mapping class CLoadMap() in the system. The texture picture Class CLoadMap() process is in the form of 24 bits bmp .The Class is defined as follows:

```
Class CLoadMap
{
Public:
CLoadMap();
Virtual ~CLoadMap();
Bool loadMap(TCHAR * fileName);
glLoadTexture(GLuint * pList);
}
```

The picture used in this experiment is 24 bits bmp image, and CLoadMap() function is used to read image file. BMP image file generally include file header, bitmap information header, palette and data area, therefore, read BMP file image information, we should firstly know the data size and the offset that data area is relative to the data file. The main function of glLoadTexture() is loading the texture image, and it will generate texture objects before loading. Because the texture images is usually rectangular, and the surface of the object can be any shape, so after mapping and transforming the texture image is difficult to be one-to-one correspondence with the screen image texture. Firstly, we can call glBindTexture() that in the core function library of OpenGL to bind texture, and then through setting corresponding parameters by the texture filtering function glTexParameterf() in OpenGL to change the size of the texture image, therefore, texture images and screen images will be one-to-one correspondence.

3.2. The Experimental Results and Analysis

We design and develop this system based on VC++ platform and SGI OpenGL graphics library. Hardware condition is: Intel Core P7370 dual-core 2.0 GHz processor, memory is 2GB DDR2 667, graphics card for ATi3470 with 256MB memories. From the generated image we can see that not only the tree is vivid, has a good visual effect, and matches physical movement rules in the real world, but also the proposed system can generate at least 25 frames images per second, achieving the result of real-time requirements. Figure 4 and Figure 5 are effect pictures that system generated. Figure 4 depicts the shape of the tree under a static condition, and Figure 5 is the shape of the tree which was impacted by the wind blowing in a direction that perpendicular to the display.

Figure 4. Trees' Still Rendering

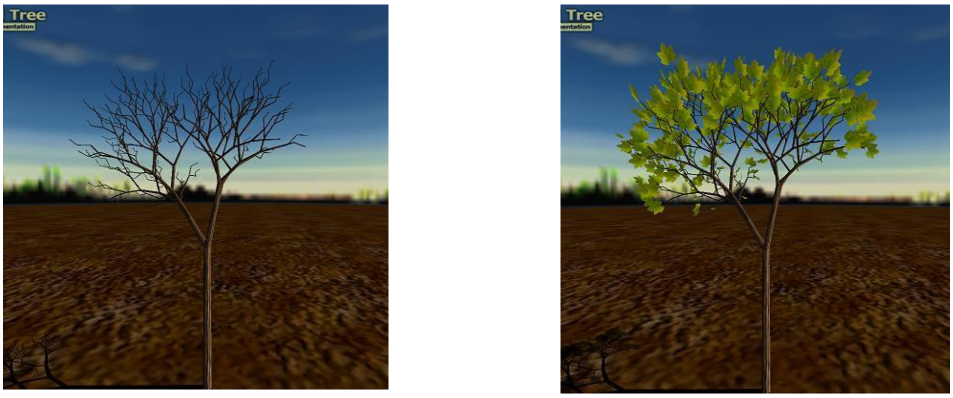


Figure 5. The Trees in the Wind Rendering

The proposed model has the following advantages:

(1) This system is belong to the universal model and has nothing to do with tree's type, so it is advantageous to have a deeper study and extension for other systems.

(2) This model takes the branch as a model unit to analyze the force applied on it, veritable and vividly shows the process of tree branches' movement.

(3) This model adopts the recursive method rather than the traditional L system, which consume less time and better solve the problem of time complexity.

In this paper, we mainly considered the real-time of algorithm and improved the running speed from the following several aspects.

(1) On the basis of guaranteeing the realistic graphics rendering, we use recursive algorithm to reduce the amount of calculation and memory footprint.

(2) The system adopts the chain table structure to manage memory allocation and recovery and improves the operation efficiency.

(3) The system simplified the motion model of tree branches, not only simulated the real phenomenon of the branch in wind field, but also ensured the running speed of the system.

4. Conclusion

This paper proposed a dynamic tree simulation algorithm based on fractal theory, focused on the depiction of the tree motion process to make tree motion simulation be more vivid, make simulation speed be faster and make real-time performance be better under the dynamic condition. We can use the demo system for validating the dynamic tree simulation algorithm that is put forward in this paper. This system provides a good interface and provides a good platform for analyzing various factors those that influenced branches swing in wind field.

However, in the dynamic tree simulation, the simulation for details of tree is not enough. We can introduce a method that special for details of tree to strengthen the reality of dynamic tree simulation. In the next work, we can do some improvement about the balanced problem between increasing the number of branches and reducing the calculation on branches' detail.

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Authors

Liu Xumin, she was born in Liaoning, China in 1956. She took the B.S degree in computer application and M.E. degree in computer application from the Dalian University of Technology, in 1982 and 1993, respectively. She received the Ph.D. degree in School of Computer and Information Technology from the Beijing Jiaotong University in 2008. Currently, she is a professor at College of information Engineering, Capital Normal University. Her research interests include graphics and image processing and data mining.

Xu Yongxiu, she was born in Weifang, Shandong, in 1991. She received the B.S degree in Information and Computing Science from Qufu Normal University, Shandong, in 2009 and she is currently accepting M.S degree in Computer Application Technology from Capital Normal University, in Beijing. Her research interests include digital image processing, data mining, and computer graphics.

Zhai Xu, was born in Beijing, in 1985. She received the B.S degree in computer Science and Technology from Capital Normal University, Beijing, in 2007 and M.S degree in Computer Application Technology from Capital Normal University, Beijing, in 2012. Her research interests include digital image processing, data mining, image processing and computer graphics.

Xu Weixiang, is presently a Professor of School of Traffic and Transportation at Beijing Jiaotong University of China. He obtained his M.S degree in computer science from Dalian University of Technology of China in 1993 and PhD degree in System Engineering from Northern Jiaotong University of China in 2000. His current research interests focus on data mining, intelligent information processing and management, the analysis and integration for Transport systems, and their joint applications in engineering design, Rail and urban rail transit for knowledge discovery and management purpose.