# Computer Computing and Simulation-In View of the Leaves' Categories, Shapes and Mass

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# Computer computing and simulation—In view of the leaves' categories, shapes and mass

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**Abstract.** Leaf is the important part of a tree. This paper mainly studied its categories, shapes and mass, then established four mathematic models to describe and analyze them. Firstly, this paper analyzed the reasons why leaf shapes are different by the theory of mechanics. The mechanics model explained the structure and forming principles of a leaf. Secondly, in order to classify the leaves accurately, this paper selected digital image processing and built two classified criterion: ratio of leaf area to its perimeter and ratio of maximal length to maximal width. After edge extraction and Fourier fitting. Thirdly, this paper utilized the connection between illumination intensity and leaf area to explain how the distribution of leaves and branches affect leaf area. According to the stem height at each branch tip, this paper got the relation between the branches, then established a model of leaf area to proof that the leaf shape has a relation with the tree profile and the branches structure. Finally, this paper set up leaf mass model to compute the total leaf mass, based on the leaf area index. It was calculated by choosing digital image processing technique. Using the leaves mass, this paper analyzed the relevancy of the mass and the size characteristics of the tree.

**Keywords:** computer, simulation, leaves, mathematic model

## 1 Introduction

Leaves are the important parts of a tree. The classification, shapes and mass of leaves have big relations with a tree. The leaves are the places where plants can absorb the carbon and keep the carbon-water balance; they are also the survival foundation of the plant, so the form and physiology characteristics of the leaves will become important growth indexes of the tree undoubtedly. The leaves have the important denotation to the update of the vegetation, the community and the ecological system [1]. The types, shapes and mass of the leaves contact to the climate and its growth closely. Through the leaves, we can also learn about the relationship between plants and the global carbon cycle, so its significance is far-reaching. Nowadays, someone researched tree structure, obtaining the tree model based on L system and real-time rendering technology conclusion; someone imitated the dynamic model of veins, describing the importance of veins to leaf characteristics; someone applied physical methods to mimic the change process of the leaf shapes. But few has a systematic, integrated and comprehensive research about shape and mass of leaves. In this paper, problems

which we need to solve is the diversity of the shape, the effect of the distribution of leaves and branches to the leaf shape, the relation between the leaf shape and the outline of the tree and the structure of the branches and how to calculate the weight of the leaves, we should establish the corresponding models to describe leaf shape and the mass of the tree.

There are the main steps in this paper,

(1)This paper use some mechanics knowledge which related to the growth of the leaf to describe the leaf shape，then analyze the reasons of shape diversity about the leaves;

(2) This paper simulation the leaf shape according to the Fourier series, then classified the kinds of the leaves according some index in the final figures;

(3)This paper utilized the expression about the light interception ratio $(LIR)$ and the leaf area index $(LAI)$, explaining the blade shape is effected by the distribution of the leaves and tree; By considering the sun light (photosynthesis) affects the leaf shape, we established the model to show the shape has some relations with the outline of tree and the structure of the branches;

(4) To measuring relative parameters easily, this paper selected digital image processing to calculate the leaf area index. So that we can weigh the mass of leaves by leaf area index and projected area. Confirming relations between the leaf mass and the mass, height, volume of the tree, we took correlation analysis and qualitative analysis to accomplish them.

To achieve the goal of simulating the relation between parameters, we did simulating experiment several times.

## 2 Analyses and Modeling

### 2.1 The Leaves Categories

#### 2.1.1 The Leaf Variety

There are no two leaves exactly the same. The same tree's growths of the leaves are not completely the same. This paper mainly studied the leaf shape's diversity of a tree. Through understanding the structures of the leaves and the influence of environment to the leaves, we use the opinion of mechanics [2] that the force can be divided into the internal force and the external force. It is similar to the growth of the leaves which is effected by the external environment and the inherent factors itself. So the leaves stand its weight and external force produced by the environment. Then the petiole will bend and twist, so it can be regarded as a cantilever beam mechanical operation approximately. So we establish the model:

**Nomenclature**

$F = mg$ The gravity expression of a leaf

$$f(x)$$

It is leaf quality

**We can deduced from the following expressions：**

$$M = \int_0^l \frac{m}{x} gx d_x = mgl$$

The moment of force which is received by the leaves

$$\sigma_{11} = \frac{F_1 l^2}{I_Z}$$

(expressed by force)

The bending stress which is received by the leaf roots

$$\sigma_{21} = \frac{Ml}{I_Z}$$

(Expressed by moment of force)

The bending stress which is received by the leaf roots

$$\sigma_{31} = \frac{F_2}{S}$$

It stands for pressure stress

$$I_Z = \frac{\pi d^4}{64}$$

Moment of inertia

$$\tau_{max} = \frac{4FS}{3A}$$

Maximum shear stress

$$\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_x^2}$$

The maximum of normal stress which is received by body of the cell

$$\sigma_{min} = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_x^2}$$

The minimum of normal stress which is received by body of the cell

$g$     Gravity acceleration

$l$     The vertical distance of point to the main branch

$x$     Integral variable

$F_1$   $F_2$     Blade stress

$S$     Stress area
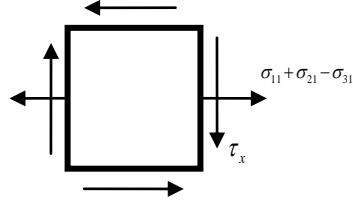
$d$     Related inertia length of the Leaves

$A$     Cross-sectional area

$\sigma_x$   $\sigma_y$     Stress component

$\tau_x$     Shear stress

The expressions above can be shown in the figures:



**Fig.1.** The cell of the leaf body                    **Fig.2.** Simulation tree

$$\sigma_x = \sigma_{11} + \sigma_{21} - \sigma_{31} \qquad \sigma_y = 0 \qquad \tau_x = \tau_{max}$$

then，

$$\sigma_{max} = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_x} \quad \sigma_{min} = \frac{\sigma_x}{2} - \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_x} \quad , \text{ thus}$$

$$\sigma_1 = \sigma_{max}, \ \sigma_2 = 0, \ \sigma_3 = \sigma_{min}$$

According to the third strength theory $\sigma = \sigma_1 - \sigma_3 < [\sigma]$ , in the cell of the body, when the total maximum stress minus minimum stress, the result is less than the allowable stress. Considering the effect of the load from the outside, we should change the third strength theory into the following expression:

$$\sigma = k(\sigma_1 - \sigma_3) < [\sigma] \tag{1}$$

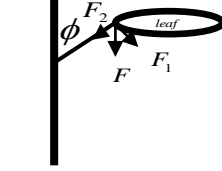Due to the leaf must meets the strength theory to keep standing on the branch, we can get:

$$f(x) = F(\phi, L, k, [\sigma], S) \tag{2}$$

So, the mechanics of the relevant knowledge, analyzes the specific reason for the diversity of leaf shapes. The differences of blade shapes are effected by $\varphi, L, k, [\sigma], S$ and other factors.


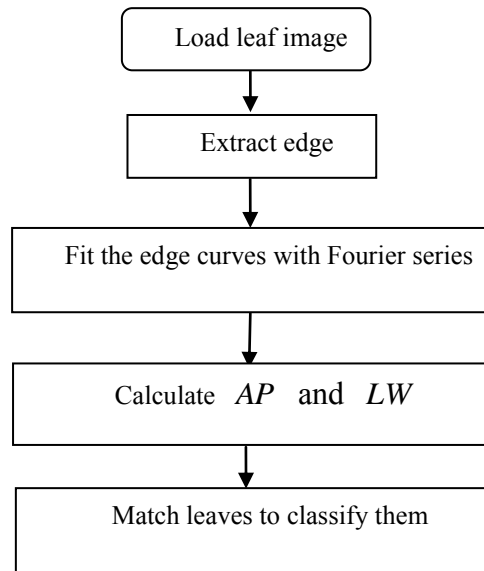### 2.1.2 Image Processing

Boundary extraction
There is a very practical operation called boundary in the image processing. After extracting the boundary of image, we can do the further operation, such as image segmentation, extraction of the location and the skeleton extraction and so on. In this paper, we extracted an image of the leaf, then extract the edge. The process can be described as follow:

```
┌─────────────────────┐
│   Load leaf image   │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│     Extract edge    │
└─────────────────────┘
           │
           ▼
┌──────────────────────────────────┐
│ Fit the edge curves with Fourier series │
└──────────────────────────────────┘
           │
           ▼
┌──────────────────────────────────┐
│     Calculate  AP  and  LW       │
└──────────────────────────────────┘
           │
           ▼
┌──────────────────────────────────┐
│    Match leaves to classify them │
└──────────────────────────────────┘
```

**Fig.3.** The main steps of image processing

   Therein, in the image after introduction, we extracted the edge of the leaf image to meet the requirements of leaf image. Then the graphics morphology processing is based on Mathematical Morphology (Mathematical Morphology) set theory method. IN this model, we applied to "corrosive" and "inflation" which are the morphological processing method [3]. Image processing the rapid expansion of the corrosion, morphology method is characteristic: it USES the rectangular element structure on the additional two sliding window that is vertical and horizontal two directions of the sliding window, with rectangular structural elements through traverse the whole image move corrosion, inflation in the process of operation, through the level and the vertical sliding window a record has been compared with local information, so that in the future can be directly used in calculating the extraction, in order to achieve reduce and eliminate the comparison of the calculation of the repeat redundant, save the computational time, and presents the existing technology results which can compared with experimental. Thus, we will get the leaves of the main context extracted.


**2.1.3 Fourier Series Fitting**

After the boundary extraction, we use the Fourier series [4] image analysis fitting out the boundary of the blade, the coefficients of the normalization of the leaves to final simulation blade shape relevant model. Among them, Fourier series fitting has successfully used by many scholars to achieve closed boundary characteristics, elliptic Fourier descriptor is using the stack to approximate the object boundary curves,

   Because the blade of the image is a continuous border and have closed cycle, so Fourier series can be used to approximate the boundary to a closed boundary, the border in the $x$ $y$ direction of Fourier series could start for as follows:

$$x(t) = A_0 + \sum_{n=1}^{\infty}\left(a_n \cdot \cos\frac{2n\pi t}{T} + b_n \cdot \sin\frac{2n\pi t}{T}\right) \tag{3}$$

$$y(t) = C_0 + \sum_{n=1}^{\infty}\left(c_n \cdot \cos\frac{2n\pi t}{T} + d_n \cdot \sin\frac{2n\pi t}{T}\right) \tag{4}$$

In the mathematical expressions

$$a_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{k}\frac{\Delta x_p}{\Delta t_p}\left(\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right) \tag{5}$$

$$b_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{k}\frac{\Delta x_p}{\Delta t_p}\left(\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right) \tag{6}$$

$$c_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{k}\frac{\Delta y_p}{\Delta t_p}\left(\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right) \tag{7}$$

$$d_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{k}\frac{\Delta y_p}{\Delta t_p}\left(\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right) \tag{8}$$

$$A_0 = \frac{1}{T}\sum_{p=1}^{k}\left[\frac{\Delta x_p}{2\Delta t_p}\left(t_p^2 - t_{p-1}^2\right) + \xi_p\left(t_p - t_{p-1}\right)\right] \tag{9}$$

$$C_0 = \frac{1}{T}\sum_{p=1}^{k}\left[\frac{\Delta y_p}{2\Delta t_p}\left(t_p^2 - t_{p-1}^2\right) + \delta_p\left(t_p - t_{p-1}\right)\right] \tag{10}$$

$$\Delta t_p = \left(\Delta x_p^2 + \Delta y_p^2\right)^{\frac{1}{2}} \tag{11}$$

$$t_p = \sum_{i=1}^{p}\Delta t_i \quad \xi_p = \sum_{j=1}^{p-1}\Delta x_j - \frac{\Delta x_p}{\Delta t_p}\sum_{j=1}^{p-1}\Delta t_j \quad \delta_p = \sum_{j=1}^{p-1}\Delta y_j - \frac{\Delta x_p}{\Delta t_p}\sum_{j=1}^{p-1}\Delta t_j \tag{12}$$

$$\xi_1 = \delta_1 = 0 \tag{13}$$

In the expressions

$n$ ——Elliptic represents the order number, $n > 0$

$k$ ——the number of points on the boundary

$T$ ——period

$P$ ——the boundary point serial number

$a_n$、$b_n$、$c_n$、$d_n$——Elliptic Fourier coefficient

$\Delta t_p$、$\Delta t_j$——Two boundary point between the lines

$\Delta x_p$、$\Delta x_j$——In the direction of $x$ incremental

$\Delta y_p$、$\Delta y_j$——In the direction of $y$ incremental

$A_0$ And $C_0$ the harmonic dc component, from the border, it represents the center point of the border, at the same time it is a harmonic elliptical center.

Every $n$ form of 4 coefficients $a_n$、$b_n$、$c_n$、$d_n$ represents a elliptic, $n$ order elliptic also is $n$ time harmonic Use type above，After the treatment of boundary to get data Fourier transformation calculation, get the elliptic boundary the Fourier descriptor as shown in figure 4：
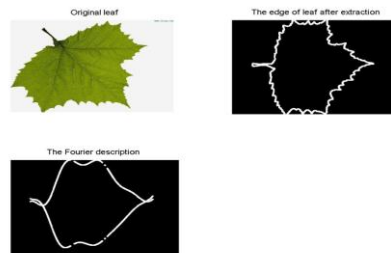


(a) $LW = 1.0489$, $AP = 0.4045$
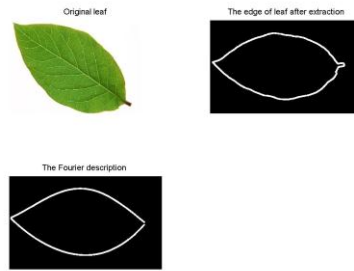


(b) $LW = 4.4091$, $AP = 0.1107$

**Fig.4.** Leaves simulation process

### 2.1.4 Analysis of the Model

For every descriptor, hope it has scale transform rotation transformation and the starting point of the transformation invariance, So gets the elliptic Fourier descriptor for starting point and rotation of the size of the normalized the arbitrary starting point get elliptical Fourier descriptor for the record $a_n$、$b_n$、$c_n$、$d_n$, When starting point along the boundary clockwise movement $\lambda$ units, and when the original $x$、$y$ coordinate counter-clockwise $\psi$ angle to coordinate $u$、$v$, get new elliptic coefficient $a_n^{**}$、$b_n^{**}$、$c_n^{**}$、$d_n^{**}$, there is

$$\begin{bmatrix} a_n^{**} & b_n^{**} \\ c_n^{**} & d_n^{**} \end{bmatrix} =$$

$$\begin{bmatrix} \cos\psi_1 & \sin\psi_1 \\ -\sin\psi_1 & \cos\psi_1 \end{bmatrix} \bullet \qquad (14)$$

$$\begin{bmatrix} a_n & b_n \\ c_n & d_n \end{bmatrix} \begin{bmatrix} \cos(n\theta_1) & -\sin(n\theta_1) \\ \sin(n\theta_1) & \cos(n\theta_1) \end{bmatrix}$$

Where
$$\theta_1 = \frac{1}{2}\arctan\left(\frac{y_1^*(0)}{x_1^*(0)}\right) = \arctan\frac{c_1^*}{a_1^*} \qquad (15)$$

$$(0 \le \psi_1 < 2\pi)$$

$$\begin{bmatrix} a_1^* & b_1^* \\ c_1^* & d_1^* \end{bmatrix} = \qquad (16)$$

$$\begin{bmatrix} \cos\theta_1 & \sin\theta_1 \\ -\sin\theta_1 & \cos\theta_1 \end{bmatrix} \begin{bmatrix} a_1 & b_1 \\ c_1 & d_1 \end{bmatrix}$$

At the same time, half the size of the long axis for

$$E^*(0) = \left(a_1^{*2} + c_1^{*2}\right)^{\frac{1}{2}} \qquad (17)$$

Through the type Calculated about starting point and the rotation Angle of the normalized coefficient; Then to scale to normalization, to get the coefficient of half the size of the divided by long axis can get the result; On to the translation of the normalization, just ignore dc component $A_0$ and $C_0$. The connection between errors of Fourier fitting and series is shown in figure 5：
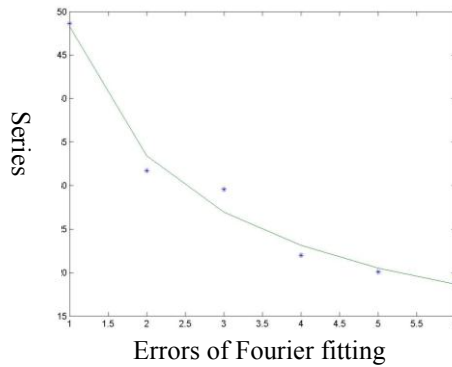


Fig. 5. Error analysis of Fourier fitting

notes：

(1)With elliptic Fourier description method for describing the shape of need only a descriptor can complete complex shape description

(2)When used for reconstruction of the harmonic times are over 10 times, errors can be ignored, and can be accurately rebuild original shape [5]
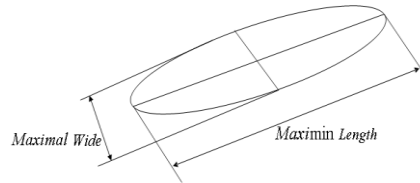
### 2.1.5 Classification Criterion

Many criterions for classifying leaves used digital morphological features, and the main criterions is ratio of leaf area to its perimeter $AP$ and ratio of maximal length to maximal wide $LW$ [6]. Leaf area, its perimeter, maximal length and maximal wide both can't measure leaves shape alone. Since they are affected by leaf size [7]. But their ratio can do. With them, classification leaves became quickly and accurate.

Leaf area ($LA$): the value of leaf area is easy to calculate, if only counting the mount of pixels of binary value 1 on smoothed leaf image.

Leaf perimeter ($LP$): leaf perimeter is calculated by counting the number of pixels consisting leaf edge.

Maximal length ($L_{max}$): maximal length is the maximal distance between arbitrary two point on leaf edge.

Maximal wide ($W_{max}$): it is the longest line which is perpendicular to the main vein. Maximal length and maximal wide is shown in figure 6



**Fig.6.** Maximal length and maximal wide

To avoid leaf size affecting result, we used $AP$ and $LW$ as criterion. They expressed as follows:

$$AP = \frac{LP}{LA} \qquad (18)$$

$$LW = \frac{L_{max}}{W_{max}} \qquad (19)$$

According to the classification criterion, we classified leaves by program. To improve the accuracy, we selected Fourier series to fit the edge of leaves. The advantage of Fourier series is outstanding in nonlinear fitting.

### 2.2 The Leaves Shapes

### 2.2.1 Minimum Overlapping

From the angle of the light energy，we considered the situation that the leaves have the overlapping, then we introduce the light interception ratio (LIR) [8] which is the proportion of incoming of irradiation intercepted by the canopy, is generally

computed by using the turbid medium analogy which supposes a uniform distribution of leaf area in the canopy. This analogy has been proved to be very robust since the Beer-Lambert equation is fairly insensitive to violations of the uniform assumption. See for example [9] the light interception ratio is thus classical given by equation

$$LIR = 1 - \exp(-kLAI)$$
(20)

Where,

$LAI$  The leaf area index whose original definition is the total one-sided area of photosynthetic tissue per unit ground surface area.

$k$  Is a fixed numerical value, standing for the extinction coefficient for the Beer Law, related to the leaves' orientation.

Where,

$PA$  Stands for projection area of leaves and it equals to the leaf area $(la)$ multiplied by leaf sum $(ls)$. So

$$PA = leaf\ area * leaf \qquad sum = la * ls$$
(21)

$FS$    Stands for floor space

$AOE$   Stands for absorbed optical energy

$TOE$   Stands for total optical energy

Then,

$$LAL = \frac{PA}{FS} \quad LIR = \frac{AOE}{TOE}$$
(22)

we can obtain

$$\frac{AOE}{TOE} = 1 - \exp(-k\,\frac{PA}{FS}) = 1 - \exp(-k\,\frac{la * ls}{FS})$$
(23)

In the expression, TOE, $k, ls$ and FS are permanent only $AOE$ and $la$ are variation. So there are some relations between them. When the $la$ is bigger，the shape turns to be large and the AOE also becomes plentiful. So the sentence that "shapes "minimize" overlapping individual shadows that are cast, so as to maximize exposure" was right.

### 2.2.2 Distribution of the Leaves and the Branches

The leaves will get more energy through the exposure in the sun if necessary. The distribution of the leaves and the branches will decide whether the leaves need energy. When the distribution is sparse, the leaves will expose mostly, then the leaves needn't change their shapes to receive the sunshine; when the distribution is dense, the leaves need to change too small to receive the sunlight. So when the leaves change to receive the sunlight, the shapes of the leaves will change as follow. Through the opinion, we can answer to the question 2 that the distribution of leaves within the "volume" of the tree and its branches effect the shape.

### 2.2.3 Outline of the Tree and The Structure of the Branches    Leaf areas

The leaves area distribution for the absorption of light by function have very important influence, so the outline and the branches of the tree structure will affect the growth of the leaves, from cross-sectional area of tree branches and leaves area and branch prediction model is out of the length :

$$h_x = h_0 + \cos\theta \times l_{br}$$

(24)

Where

$h_x$  The stem height at each branch tip

$h_0$  Height of branch emergence

$\theta$   Branch angle from the vertical

$l_{br}$  Branch length

Crown length of each tree was divided into 0.1-m sections and branch leaf area within each section expressed as a proportion of total leaf area. These data were fitted to a two-parameter cumulative Weibull function using the NLIN procedure of the SAS software package (SAS Institute Inc., Cary, NC)[10]. The cumulative foliage distribution function took the form:

Based on (5) the cumulative proportion of leaf area model can be reached

$$l_{ac} = 1 - \exp\left[-\left(\frac{rh}{\beta}\right)^\alpha\right] \div \left[1 - \exp\left[\left(\frac{1}{\beta}\right)^\alpha\right]\right]$$

(25)

Where

$l_{ac}$  Cumulative proportion of leaf area

$rh$   Relative crown height

$\alpha$  $\beta$     Estimated parameters

For $1 < \alpha < 3.6$, the probability distribution is mound shaped and positively skewed; if $\alpha = 3.6$, the distribution is approximately normal and if $\alpha > 3.6$, the distribution becomes negatively skewed. The $\beta$ parameter describes the scale of the distribution and has been interpreted as leaf area density or leaf area per unit height (Gillespie et al. 1994). Which reflects the outline of the outline of tree branches and structure and crown have relationship, the shape of the crown has influence for leaves' shape.

The proportion of leaf area at a given crown location was estimated from the fitted Weibull [11] function:

$$la_x = \frac{la\left\{\exp\left[-\frac{x-w}{\beta}\right]^\alpha - \exp\left[-\frac{x+w}{\beta}\right]^\alpha\right\}}{1 - \exp\left[-\left(\frac{1}{\beta}\right)^\alpha\right]}$$

(26)

Where

$la_x$   The predicted leaf area

$la$   Total tree leaf area

Crown volume was estimated by calculating the horizontal projection length of each branch at its maximum stem height, which is related to the branches of the tree. The branches of the different Angle will influence the leaves accept photosynthesis. Photosynthesis decided to the leaf to sunshine absorption and their own manufacturing organic matter, for the leaves the veins which influence the shape of leaves are the influence of photosynthesis determined to the movement of nutrients and carbon dioxide absorption.

So the outline of the tree branches and the distribution of the shape have influence for the leaves.

## 2.3 Section 3 the Leaves Mass

### 2.3.1 Calculating the Mass

Improving the production of orchard, protecting trees and the ecological environment require us to monitoring trees growth condition. One of monitoring indexes of trees is the mass of leaves [12]. The mass usually calculates by the total leaves area ($PA$) and its surface density ($SLM$), just is

$$LM = PA * SLM$$

Since $SLM$ relates to the tree species and its environment of its location. So $SLM$ needs to measure when counting $LM$. Calculating $PA$ needs leaf area index ($LAI$) and projection area of crown ($PA$) [13]. Projection zone is usually treated as ellipse. So $PA$ is easy to gain.

### 2.3.2 Based on the Digital Cover Photography

There are many ways to measure $LAI$. Among those ways, graphic processing has many advantages, such as no damage to trees and high precision. Using graphic processing to measure $LAI$, we should define crown porosity $\eta$.

$$\eta = 1 - \frac{IM_{PA}}{IM_C}$$

（27）

Where,

$IM_{PA}$  Is foliage cover in image. It counts by the fraction of pixels not in any gaps;

$IM_C$ is defined as the ground fractional of the vertical projection of solid crown which include the porosities.

$LAI$ can be expressed as follow:

$$LAI = -IM_C \frac{\ln(\eta)}{k}$$

（28）

Where, $k$ leaf inclination angle distribution.

### 2.3.3 Analysis of the model

After $LM$ calculated, we confirm the connection between $LM$ and the size characteristics of the tree by Correlation analysis. The result is showed in table1. According it, we can know the mean crown radius correlation obvious. And then we inferred the qualitative relationship by fitting (fig.7.).

**Table 1** The connection between leaf mass and some characteristics of tree

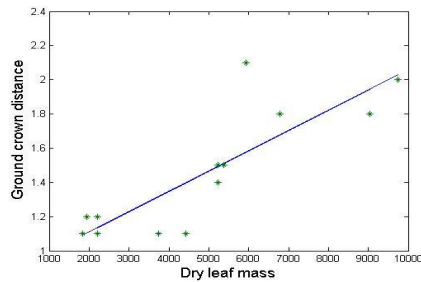|  | Tree height | Ground-crown distance | Mean crown radius | Trunk circum. breast | Sapwood rings |
|---|---|---|---|---|---|
| $LM$ | 0.447 | 0.0582 | 0.8394 | 0.2168 | 0.5816 |



Fig.7. The relationships between dry leaf mass and ground crown distance

### 2.3.4 Result of the Model

Through the calculation expression，we can get the mass of the leaves. Next, we based on the Digital Cover Photography and the Analysis of the model, we can draw the leaves quality and the radius of the crown, and the tree height, the volume of the tree have some relationship.

## 3 Conclusion

(1)There are many reasons that lead to the difference between leaves. Some of them are primary causes, another are not. In order to search for the primary causes, we selected the mechanics structure of leaf. In the mechanical angle, we established the mechanism model based on leaf forming and analyzed reasons which affects leaf shape, then we found out the influence factors. To classify leaves exactly, we defined the classification criterions which are chosen from image processing technology to accomplish the goal.

(2)Leaf incidence and internodes can affect the rate of leaf coverage, enlarging the exposure. At the same time, the rate of leaves coverage should make production of photosynthesis equal or large to the production of transpiration. So leaf area and distribution of leaves and structures are affected each other.

(3)The mass of leaves was calculated. With the mass, we analyzed and confirmed the relativity between mass and some of the size characteristics of the tree.

(4)The cover rate of the leaves will content the photosynthesis and the transpiration for the final purpose. The use of light and carbon for leaves influence the leaf shape. The distribution of leaves and branches influence the light absorbed by the leaves, so the shapes of the leaves are affected by the distribution of leaves and branches.

(5)The mass of the leaves is determined by the canopy height, volume and radius, so they have the certain relations.

## Acknowledgment

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