FITTING A PINEAPPLE MODEL FOR AUTOMATIC MATURITY GRADING

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ABSTRACT

In this paper, we present a pineapple skin model and a method to fit the model. Our main application of the model is for automatic maturity grading of pineapples in canned pineapple industry. The model consists of two subparts: Phyllotaxis and pineapple scale models. The Phyllotaxis model represents the spiral arrangement of pineapple-scales, which is a growing pattern of the fruit. It includes a string of scale-model cells. The scale model includes boundary, internal area and petal part of scale. Modified snake algorithm is used to construct the structure model while Active Shape Model (ASM) is applied to each scale. The model can accurately fit to pineapple skins in our experiment and classification features of the fruit can be extracted.

***Index Terms*—** pineapple skin model, Phyllotaxis, Snake, ASM

1. INTRODUCTION

Thailand is the world largest producer of pineapples. Among various forms of pineapple products, canned pineapples take the biggest stake of over 90%. Pattavia variety of pineapples is generally used as raw materials in the production process of canned pineapples. Consistency of their color and texture is a basic requirement for quality control in the transmutation process. Researches in food engineering [1] suggested that their maturity, which is closely related to their color and texture, can be identified by their physical properties and external appearance. This agrees with the way pineapple grading experts employ to classify pineapples for commercial uses. Currently the grading process in most manufacturers is done by human inspectors. They rely on visual appearance of the fruit on transmission belt.

The external appearance used to determine the maturity includes shape, color, texture and relative locations of their scales [2]. Examples are color in internal area of the scale and ratio of scale sizes between lower and higher spiral levels. Some features may be apparent in one fruit while the others are outstanding in others. Moreover, season and growing location also affect the manifest of these external appearances; for example, it is easier to observe the color changes in different spiral levels of summer-crop than winter-crop pineapples. Therefore, in this paper, we propose a method to construct detailed pineapple-skin model to facilitate the extraction of pineapple features.

1.1. Previous Work

Several researchers use visual inspection for grading agricultural produces; however, most of them employ simple cues such as spectral contents and simple shape for the classification. Examples of these are the identification of tomato maturity level by color homogeneity [3] and the detection of damaged soybeans by color and simple shape [4].

In our previous work [5], we created a prototype machine for identifying maturity level of summer-crop Pattavia pineapples. A simple pineapple-skin model is employed and can classify each fruit into one of seven maturity levels by detecting changes in color (from green to yellow) from bottom to top of the fruit. The method works well for winter-crop pineapples but not for pineapples of other seasons or lineages. From this problem, we proposed a detailed pineapple-skin model that can be applied to any pineapple in general.

1.2. Motivation

The pattern arrangement of pineapple scales growth is called Phyllotaxis [6]. Phyllotaxi expands not only the spiral of pineapple but also other natural growing patterns e.g. leaves on branches, seeds of sun flowers and pinecones, and spines on certain cacti. It can generally be modeled by the Fibonacci series [6]. James, S.H., et.al. [7] created a model of the number of spirals on a pineapple from coexistence of three evident paractichies. It was a series of Fibonacci number related to diameter of the fruit. Figure 1. shows the Phyllotaxis of spiral model by 360 degree panorama image called Cylindrical model.

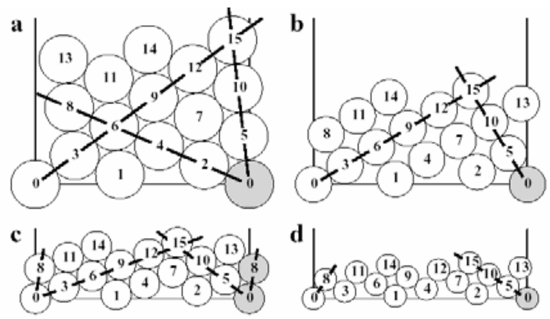


Fig. 1. Patterns of tangent circles drawn on the surface of a cylinder as a function of circle diameter [7].

The pattern is well defined and can be applied in our work to fit the arrangement of the scale. Since repeated pattern can be found in most scales of the fruit, standard contour models may be applied to image of each scale.

2. PINEAPPLE SKIN MODEL

In this section, we introduce our proposed pineapple-skin model. It consists of two subparts: spiral pattern and scale models.

2.1. Spiral Pattern Model

Although Phyllotaxis is established for several natural agricultural produces including pineapples, deviations from such model were evident in real-world fruits. We therefore introduce a spiral pattern model based on the Phyllotaxis with additional constraints of the fruit spirals in this work to deal with the problem. The model is shown in Figure 2.

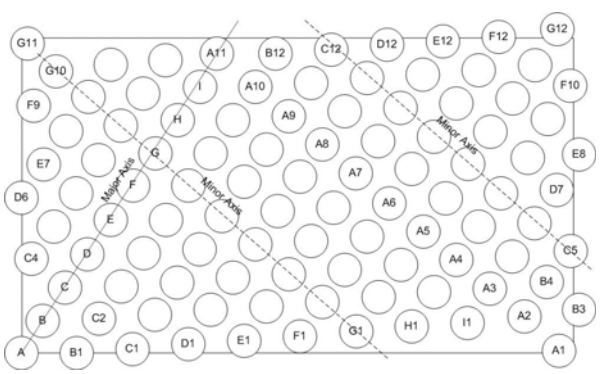


Fig. 2. The new pattern of spirals on a pineapple.

To simplify the model, each scale in the major spiral (major axis) is named by an alphabet in ascending order starting from the lowest spiral of the fruit. The others are labeled with an alphabet followed by a number. The alphabet represents the major spiral whereas the number indicates the corresponding minor axis. The scale 'A' is the lowest scale corresponding to the scale "0" in terms of Phyllotaxis growth pattern [7].

The new constraints of the model include

1) The angle of adjacent scales on the major axis is between 20 and 70 degrees.
2) The angle of adjacent scales on the minor axis is between -20 and -70 degrees.

2.2. Pineapple Scale Model

A pineapple scale comprises of three parts: scale boundary, scale internal area and scale petal.

(a) (b) (c)

Fig. 3. (a) scale boundary, (b) internal scale area, (c) scale petal.

3. MODEL CONSTRUCTION

An overview of our proposed method to construct pineapple-skin surface model is illustrated in Figure 4. The technique can be divided into two modules: Spiral Pattern Modeling and Pineapple Scale Modeling (Figure 4).

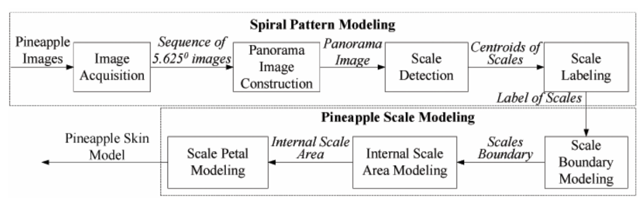


Fig. 4. System Flow Chart.

Spiral Pattern Modeling, operates on the whole pineapple image while Pineapple Scale Modeling is executed on each scale.

3.1. Image Acquisition

In this process, it is a preparation process to obtain pineapple panorama image. It is formed by registering a series of images taken from different views of pineapple on a turntable. To reduce the effect of lens and object distortion, a small image (I_i) covering 5.625 degrees of pineapple angle at the center of the full image (I) is used to build 360 degree panorama image.

3.2. Scale Location Detection

In this section, a process that finds the scale locations in a panorama image is presented. It starts by generating a binary image of candidate areas of scales. Since scale areas are higher in intensity, we identify these areas by thresholding the blue channel of the image (I_{Blue}). Standard morphological closing and distance transformation are then applied to the result, accordingly. From the operations, pixels closed to centers of scales have higher distance and can be detected by a simple thresholding. The result is an image with groups of pixels at the center of each scale. Component labeling algorithm is then applied and centroid of each component is calculated and used to represent the scale location.

3.3. Scale Labeling Process

As described in section 2.1, scales are labeled by an alphabet and number(s) according to its alignment in major and minor axes. Scale labeling process, therefore, starts by searching for the beginning scale of the major axis then identifying and labeling the rest on the axis. The scale "A" can be founded by looking for the lowest scale centroid. The major axis is then identified from the scale 'A' using the first constraint presented in section 2.1. From each scale on the major axis, minor axis is identified according to the second constraint.

3.4. Scale Boundary Modeling

This process is to identify the boundary of each pineapple scale. Techniques to represent several objects simultaneously such as Geodesic Active Contours [9] (GAC) could be applied. They particularly suit to the problem where the number of objects and their locations are not known a priori; however, they require huge computational resources. In our application, the number of objects and their locations are determined by the Scale Location Detection. This allows individual scale boundary modeling which can accelerate the fitting process dramatically. Snake is chosen as the model. Since image of the pineapple is highly textured, weighted gradient image introduced in [10] is applied to adjust the energy surface of the Snake. The weighted gradient map is a pixel-by-pixel multiplication of a gradient image and a weight map. The weight map is an array of weight parameters of the same size as the image. The weighted gradient map is a binary image of candidate boundaries of scales. Since scale boundaries are lower in intensity, we identify these boundaries by thresholding the blue channel of the image. Salt and pepper noise in binary image are removed by median filtering (of size 5x5 pixels) then Gaussian filtering (of size 5x5 pixels and σ^2 of 2 pixels) is applied to the binary image. The external energy of scale boundary is generated by the multiplication of the weight map and gradient image of gray scale

$$E_{ext} = -|\nabla I(x,y)|^2 * W_s \tag{1}$$

where ∇ is the gradient operator, I is the gray scale image and W_s is the weight map.

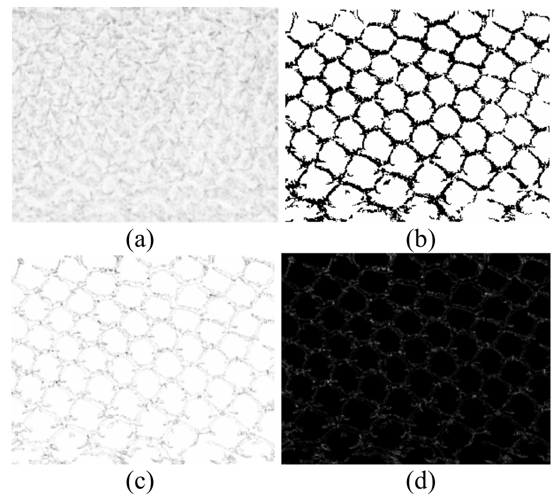


Fig. 5. (a) Gradient image, (b) Inverse of binary image used to initial contour boundary of scale, (c) Weight image (W_s), (d) Weighted-gradient image, E_{ext}.

3.5. Scale Internal Area and Scale Petal Modeling

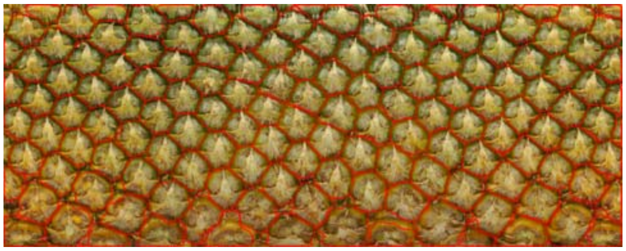
Scale internal area and scale petal models are based on Active Shape Model (ASM) [11]. For scale internal area, training landmark points were initialized by author with 100 training sets and 15 landmark points per set. For scale petal modeling, two ASMs were employed to represent the feature. They were left and right wings of the petal. Training landmark points were 100 training sets and each wing has 13 landmark points per set. The same pinnacle point for both wing models was employed for each set.

4. EXPERIMENTS

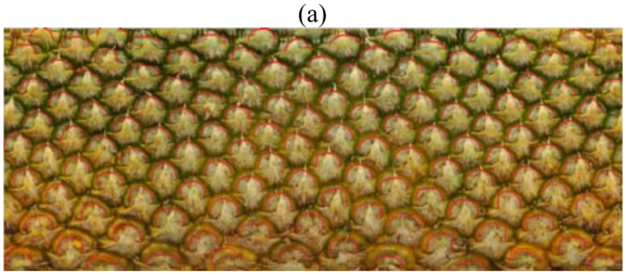
The performance of our proposed method was evaluated by pineapple image testing sets. The testing sets are 24-bit RGB image with width and height ranging from 1300-1600 pixels and 500-700 pixels respectively.

From experimental results, Figure 6 (a) shows a result from the spiral pattern modeling and scale detection. The weight image, E_{ext} was used in this process which improves performance of the Snake algorithm. It gave higher value to potential scale boundary and lower for other areas. This reduced incorrect fitting of scale boundary.

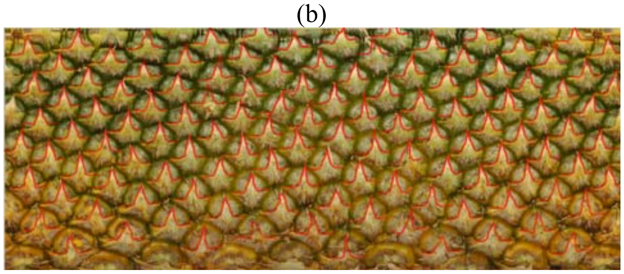
The result of scale internal area and scale petal detection by ASM is shown in Figure 6 (b) and (c). The performance of ASM fitting depended on the shape variance of the training sets. It also relied on the size of the training sets and the coverage of landmark points. From the result, it can be seen that the training sets and landmark points were adequate.



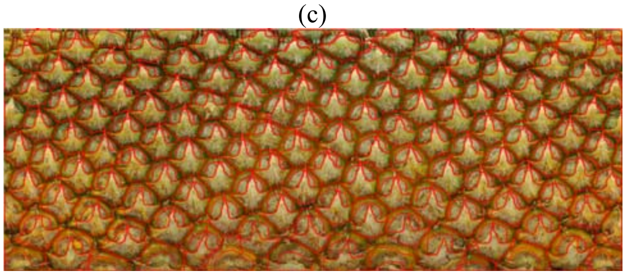
(a)



(b)



(c)



(d)

Fig. 6. (a) The result of Scale Boundary Detection, (b) The result of Internal Area Detection, (c) The result of Petal Detection, (d) Pineapple Skin Model

5. CONCLUSION AND FUTURE WORK

In this paper, we proposed a new pineapple-skin model that could be used to extract classification features for automatic maturity grading. It consisted of pineapple spiral pattern and scale models. The spiral pattern model on pineapple could cope with the problem of deviated pattern of pineapple from ideal Phyllotaxis glowing pattern.

The method can be applied to extract classification features of any pineapple species. Snake algorithm was used in scale boundary and petal detection processes. In stead of using traditional gradient image for external energy calculation, a weighted gradient image was employed. The technique greatly increased fitting accuracy and efficiency. It also reduced fitting convergence of Snake for more than five times. Although, the ASM was an efficient approach to model-based fitting, it could not fit to high shape variance especial peak of petal. Two wing models were therefore introduced. However, internal area shapes were simple enough for ASM to obtain a good solution. The proposed technique can be further applied to other complex object recognition.

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