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EDIBLE BIRD NEST SHAPE INSPECTION USING FOURIER DESCRIPTOR (FD) AND FARTHEST FOURIER POINT SIGNATURE (FFPS) METHOD

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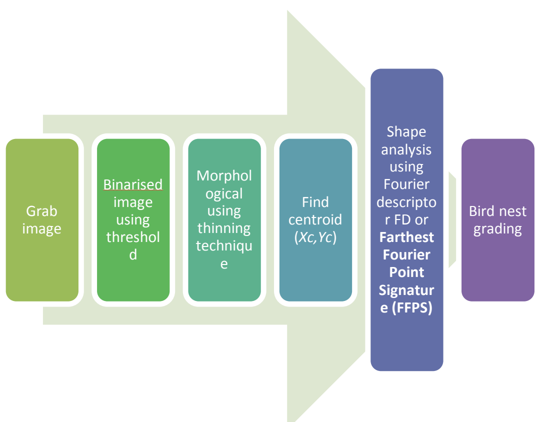
Graphical abstract



Abstract

Swiftlets are birds contained within the four genera Aerodramus, Hydrochous, Schoutedenapus and Collocalia. To date, the bird nest grading is based on weight, shape and size. Current inspection and grading for raw, edible bird nest were performed visually by expert panels. This conventional method is relying more on human judgments and often biased. A novel hybrid method from Fourier Descriptor (FD) method and Farthest Fourier Point Signature (FFPS) was developed using Charge Coupled Device (CCD) image data to grade bird nest by its shape and size. From the result, the hybrid method was able to differentiate different shape such as super AAA, super and corner grade depending on the Swiftlet species and geographical origin. The Wilks' lambda analysis was invoked to transform and compress the data set comprising of a large number of interconnected variables to a reduced set of varieties. Overall, the vision system was able to correctly classify 92.6 % of the super AAA, super and Corner shaped grades using the combined FD and FFPS features.

Keywords: Edible bird nest, shape analysis, vision system, Fourier descriptor

Abstrak

Burung layang-layang adalah burung yang terkandung dalam empat genus Aerodramus, Hydrochous, Schoutedenapus dan Collocalia. Sehingga kini, penggredan sarang burung adalah berdasarkan kepada berat badan, bentuk dan saiz. Pemeriksaan semasa dan penggredan untuk mentah, sarang burung yang boleh dimakan telah dijalankan secara visual oleh panel pakar. Kaedah konvensional bergantung lebih kepada pertimbangan manusia. Satu kaedah hibrid novel dari Fourier Descriptor (FD) kaedah dan Farthest Fourier Points Signature (FFPS) telah dibangunkan dengan menggunakan Peranti Caj Bersama (CCD) data gambar untuk sarang burung gred dengan bentuk dan saiznya. Dari keputusan, kaedah hibrid dapat membezakan bentuk yang berbeza seperti AAA super, super dan sudut gred bergantung kepada spesies Burung Walit dan asal geografi. Analisis lambda yang Wilks 'telah memampatkan set data yang terdiri daripada sejumlah besar pembolehubah saling untuk set yang dikurangkan daripada jenis. Secara keseluruhan, sistem penglihatan, yang dapat mengelaskan dengan betul 92.6% daripada super AAA, super dan Corner gred berbentuk menggunakan gabungan FD dan FFPS ciri-ciri.

Kata kunci: Sarang burung layang layang, analisis bentuk, sistem camera, *Fourier descriptor*

1.0 INTRODUCTION

Edible bird's nest refers to the nest produced by several different Swiftlet species. Human consumption of these nests has been a symbol of wealth, power, and prestige, as well as being used medicinally in traditional Chinese medicine dating as far back as the Tang (618–907 AD) and Sung (960–1279 AD) dynasties (Koon, L. C., & Cranbrook 2002.). Swiftlet belong to the four genera Aerodramus, Hydrochous, Schoutedenapus and Collocalia. They form the Collocaliini tribe within the swift family Apodidae. The nests are built almost exclusively by the 7–20 g male Swiftlet over a period of approximately 35 days. The building material is composed almost entirely of a glutinous material found in saliva secreted from the Swiftlet (Marcone 2005). By the 18th century, the volume of trade was enormous, and early this century, about 9 million nests weighing some 76 tonnes were imported into China each year at US$2000–4000 a kilogram, the wholly white edible nests of Swiftlet, now rank amongst the world's most expensive animal products (Koon, L. C., & Cranbrook 2002.). Harvesting of the edible bird's nest for human consumption is a painstaking and often times dangerous operation for local collectors. After collection, the tedious process of cleaning approximately 10 nests takes a person approximately 8 hours (Koon, L. C., & Cranbrook 2002.). The nests are cleaned by soaking them in water until the nest strands-is softened and the tightly bound weave partially loosens. Bird's feathers, branches, twigs, sand, bird's dropping are then manually removed with tweezers. The cleaned strands are subsequently being re-arranged and molded into biscuits of various shapes, air-dried, and packaged for sale around the world (Marcone 2005). Many establishments are currently engaged in bird nest farming and trying to improve the quality and quantity of nest production. The inspection and grading of raw edible bird nest are performed visually by expert panels.

To date, the bird nest grading is based on weight, size and shape. This conventional method relies more on human judgments and often biased. Unfortunately, it is a tedious process and often inconsistence from one person to another.

Automated inspection would help standardize the quality evaluation of Bird nest, Since inspection requires assessment criteria that would traditionally performed by human inspectors, artificial intelligence methods may be used to simulate the human thought process that occurs when bird nest are graded. This paper describes the methods and procedures developed to inspect and provide quality of bird nest, through image analysis and machine vision technology.

1.1 Machine Vision Technology

Machine vision provides innovative solutions in the direction of industrial automation (Malamasa, Petrakisa *et al*. 2003) since few years ago the revolution of the computer technologies covered different methods and techniques by several researchers around the world in order to build new machines for agricultural product's Quality as an automatic grading system (Leemans and Destain 2004;). The use of the automatic grading system as inspection quite increased during recent years. Basically, two inspection stage of the automatic grading system can be identified as external inspection and internal inspection stage. The external grading system is a combination of programming language, operating system and image processing techniques as software while computer, Charge Couple Device (CCD) camera, data accusation and convey system as hardware to process the surface features of products as color, texture, shape and size (Abdullah *et al*.).

1.2 Bird Nest Grading Standard

The Bird's nest has natural shape that looks like human eyelid shape, currently, our supplier SSCM Northern Sdn. Bhd decides their standard, for export there are 3 grades super AAA, super and corner. Figure 1 shows the grade of the bird nest.

Corner grade

Super grade

Super AAA grade

Figure 1 The grade of the bird nest

1.3 Methodology

1.3.1 Elements of Machine Vision System

The procedures and methods are implemented on machine vision workstation show in Figure 2, which included a Personal Computer (PC), a frame grabber board, an illumination system, a charge coupled device (CCD) camera, a BNC cable and a test station. The particular image analysis and processing developed in this study consisted of three levels: low-level processing, intermediate processing and high-level processing. In summary the first level includes image acquisition and pre-processing such as image enhancement, extraction and restoration. Meanwhile the second level concerned with the image transformation such as RGB to HSI transformation, segmentation and filtering. Finally, the third level involved recognition and interpretation. All programming was implemented directly using NI-IMAQ Vision module running on Labview 9.0 environment.

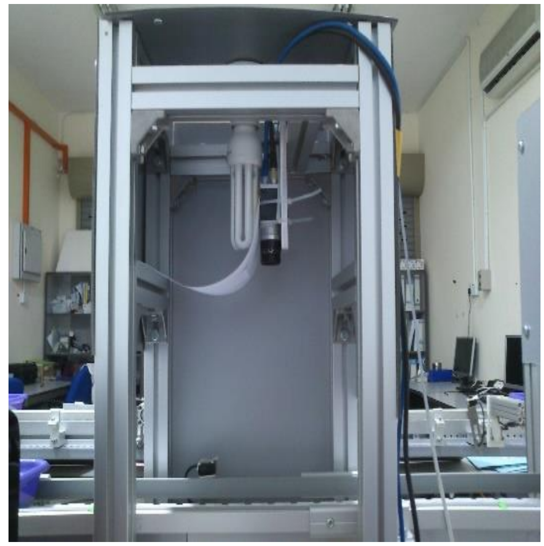


Figure 2 Elements of the machine vision

1.4 Shape Analysis

Bird nest can be viewed adequately by 2D perspective; therefore they are most suitable for real-time machine processing. Presently, there are many methods available for analyzing the shape of an object, ranging from a simple multiple point features method to a complicated geometric features approach (Zahn and Rookies 1972). Before this method could be extracted, several image pre-processing operations were performed on real bird nest image. The basic operations are erosion and dilation. Based on these operations, opening and closing operations are defined. The morphological operations have been successfully used in many applications including object recognition, image enhancement, texture analysis, and industrial inspection. Mathematical Morphology can be used in various areas of image processing, such as image compression, pattern recognition, object recognition, image enhancing, etc. For binary images, Mathematical Morphology provides a well-founded theory for analysis and processing (D.N. Vizireanu 2003).The image was firstly binarised with an adaptive threshold, and secondly, processed via a sequence of morphological image processing such as thinning. The Image shows in Figure 4 and Figure 3 shows the detail process for shape analysis.

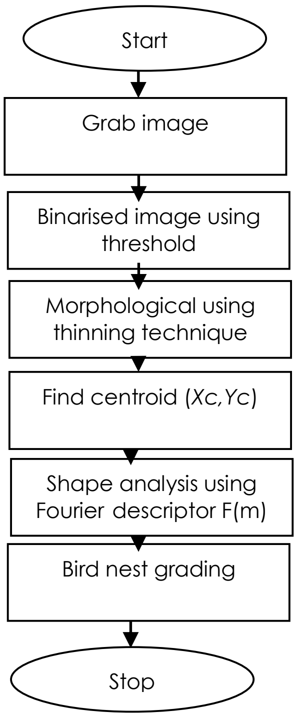


Figure 3 The flow chart for shape analysis

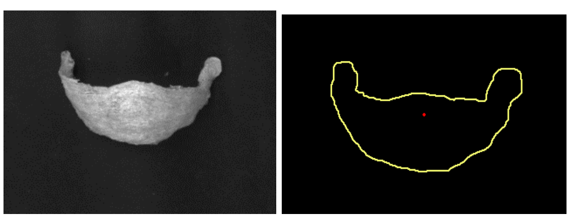


Figure 4 Image greyscale and image after Morphological using thinning technique

1.5 Fourier Descriptor (FD)

The Fourier Descriptors (FD) were used in this project conceptionalised by (Zahn and Rookies 1972). They gave details mathematical explanation of FD for use in object recognition, matching and registration. One unique feature of this method is that it uses global image descriptors instead on the local ones, making it more applicable to real-world images in which simple multiple point features may be difficult to extract, and eliminating the need for feature matching between the reference and observed images. Figure 5 shows the centroid and the boundary of the object. The object centroid was extracted using first-order geometric moments and derived using Green's theorem. Mathematically, the two-dimensional centroid (x_c, y_c) is given by (Abdullah *et al.*)

$$x_c = \frac{\sum_{k=0}^{N} y_k\left(x_k^2 - x_{k-1}^2\right) - x_k^2\left(y_k - y_{k-1}\right)}{2\sum_{k=0}^{N} y_k\left(x_k - x_{k-1}\right) - x_k\left(y_k - y_{k-1}\right)} \quad (1)$$

and

$$y_c = \frac{\sum_{k=0}^{N} y_k^2\left(x_k - x_{k-1}\right) - x_k\left(y_k^2 - y_{k-1}^2\right)}{2\sum_{k=0}^{N} y_k\left(x_k - x_{k-1}\right) - x_k\left(y_k - y_{k-1}\right)} \quad (2)$$

where N is the total number of boundary pixel defined in a clockwise direction from any starting point; (x_k, y_k) are the coordinates of the boundary pixel, k. The distance of each boundary point to the centroid was calculated as follows:

$$R(k) = \sqrt{\left(x_k - x_c\right)^2 + \left(y_k - y_c\right)^2} \quad (3)$$

The $R(k)$ was then subjected to the discrete Fourier transform (DFT), yielding a one-dimensional feature vector of bird nest. In Fourier space, such transformation was mathematically implemented as follows:

$$|F(m)| = \frac{1}{N}\sqrt{\left[\sum_{k=0}^{N} R(k)\cos\left(\frac{2\pi mk}{N}\right)\right]^2 + \left[\sum_{k=0}^{N} R(k)\sin\left(\frac{2\pi mk}{N}\right)\right]^2} \quad (4)$$

Since the descriptors are influenced by the curve shape and by the initial point of the curve, therefore, calculating and examining each harmonic component in $|F(m)|$ providing some clues of the shape. For a given shape, the plot of Fourier descriptors produces a pattern or fingerprint which uniquely describes this shape. In theory, the order of Fourier descriptors ranges from zero to infinity. However, one favorable property common to Fourier descriptors is that the high-quality boundary shape representation can be obtained using only a few lower-order coefficients. Therefore, only the first few components of $|F(m)|$ are generally required to distinguish between shapes that are reasonably distinct.

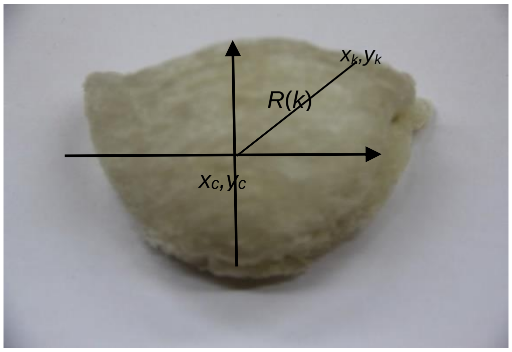


Figure 5 The centroid and the boundary of the object

1.6 Farthest Fourier Point Signature (FFPS)

The Farthest Fourier Point Signature is developed to overcome some of the shortcomings of existing techniques, such as ignoring the distances between corners (Akrem *et al.*). The signature is calculated by adding the Euclidean distance between point k and the centroid c to that between the centroid c and the farthest point. Figure 6 shows the centroid and the boundary of the object. FFPS at the boundary point $x(k), y(k)$ is calculated as follows:

$$FFD(u) = \sqrt{([x(u) - xc]2 + [y(u) - yc]2)} + \sqrt{([xfp(u)]2 + [yfp(u) - yc]2)} \quad (5)$$

where $xfp(u), yfp(u)$ is the farthest point from $(x(u), y(u))$, and (xc, yc) is the centroid of the shape.

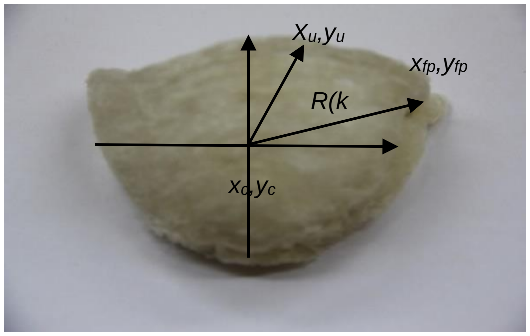


Figure 6 The centroid, the boundary and the farthest point of the object

1.7 FD, FFPS and FD and FFPS Combined Features Using Discriminant Analysis Technique

Discriminant analysis technique are applied to the same real data set for Fourier descriptors and Farthest Fourier Point Signature method. The advantage of decision-level fusion is that all knowledge about the sensors can be applied separately. Each sensor expert knows the most about the capabilities and limitations of their own sensor and they can use this information to optimize the detection performance. The availability of this expert knowledge was the reason for choosing decision-level fusion for our application.

Assuming that the distributions shape of *g* group population are characterized by multivariate normal distributions having shape vector $\overline{h_i}$ and the within-group covariance matrix Σ_i and for $i = 1,2,3,\cdots,g$, then, the probability density function for the *i*th group is given by (Takeuchi, Yanai and Mukherjee, 1983):

$$f_i(h) = \frac{1}{|\Sigma_i|\sqrt{(2\pi)^p}} \exp\left[-\frac{1}{2}D_i^2\right] \quad (6)$$

where D_i^2 is the popular Mahalanobis' distance defined as (Takeuchi, Yanai and Mukherjee, 1983):

$$D_i^2 = \left(h - \overline{h_i}\right)^{\mathrm{T}} \Sigma_i \left(h - \overline{h_i}\right) \quad (7)$$

In Equation (7), variable *h* is the *p*-dimensional principal hue vector produced by Wilks' lambda analysis, and, "T" indicates the matrix transpose. Defining the likelihood of each group as:

$$U_i = \log f_i(h) \quad (8)$$

Then, the logarithm of $f_i(h)$ can be expressed using Equation 8, yielding

$$U_i = -\frac{1}{2}\left\{\left(\log|\Sigma_i| + p\log(2\pi)\right) + D_i^2\right\} \quad (9)$$

Similarly for group *j*

$$U_j = -\frac{1}{2}\left\{\left(\log|\Sigma_j| + p\log(2\pi)\right) + D_j^2\right\} \quad (10)$$

We discovered that both Eqs. (9) And (10) were difficult to manipulate because the problem was hateroscedastic, or the within-group covariance matrices were not equal, i.e. $\sum i \neq \sum j$ .This was mainly due to noise or disturbances caused by environmental drift, particularly the changing of surrounding temperature and instrument instability. We solved this problem by firstly replacing the within-group covariance matrices with the approximated pooled-covariance matrix defined as follows:

$$\hat{\Sigma} = \frac{1}{g}\sum_{i=1}^{g}\Sigma_i \quad (11)$$

Secondly substituting Equation (11) into Equation (9) And after linearizing yields

$$\widehat{U}_i = -\frac{1}{2}\left\{\log\left|\widehat{\Sigma}\right| - \log K_i - D_i^2\right\} \qquad (12)$$

where $\widehat{U}_i$ is a linear discriminant function and K_i is a classification coefficient. Using Equation (12) we discriminated the subject into group having the highest $\widehat{U}_i$ (Morrison, 1967).

2.0 EXPERIMENTAL

2.1 Data Collection

Over 240 samples were evaluated by the inspectors and categorized as an independent test set, comprising of 40 samples for each grade. This set was used to independently assess the accuracy of machine vision system. The quality grades of each Bird nest were categorized into super AAA, super and corner grade.

2.1.1 Machine Vision Training

For shape inspection, the machine vision system was trained using Fourier descriptor input variables. All images were captured on a black background since it was heuristically discovered that this color produced shade that reflects light in a range which falls outside those reflected by bird nest. Once the optimum or potent FD and FFPS subset has been located, the system established criteria from the image of multiple samples by calculating and memorizing classification coefficients and constants. After the training was completed, the machine vision system was switched from training to test mode. In this mode, the system was used to re-classify the training samples in order to assess its accuracy, consistency, repeatability and reproducibility. After this was done, the system was used to classify all samples belonging to the independent test set. In this way, the variability in grading between inspectors could be compared and the accuracy between machine vision system and inspectors could also be investigated.

3.0 RESULTS AND DISCUSSION

3.1 Fourier Descriptor

A total of 120 Bird nests comprising of 40 samples each of Super AAA, Super and corner. These samples were then used to investigate the machine vision algorithm on shape recognition. The shape factors for each shape category were computed using Equation (4). The distribution of these samples by shape factors are shown in Figure 7. It can be seen from this figure that the shape factors formed two distinct bands corresponding to two shape grade categories of bird nest. Hence it was possible to determine the suitable cut-off thresholds for the shape factors. Referring to this figure, the shape factors for most of Super AAA and Super were consistently lie between 1 and 3 and the corner shape were consistently lie between 1 and 4. For super AAA and super, it shows that no single threshold exists that can effectively separate one class of bird nest from another. However for a corner, an optimum classification can still be guaranteed provided that the threshold value is correctly chosen. From this figure; we can see the different size for each grade.

The Wilks' lambda analysis yielded 82.3% correct classification.

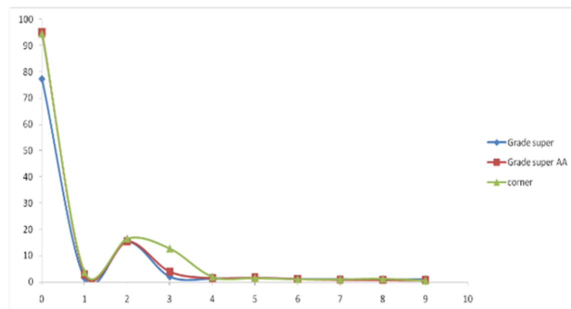


Figure 7 The distribution of three grade of the bird nest using FD

3.2 Farthest Fourier Point Signature (FFPS)

A total of 120 Bird nests comprising of 40 samples each of Super AAA, Super and corner. These samples were then used to investigate the machine vision algorithm on shape recognition. The shape factors for each shape category were computed using Equation (5). The distribution of these samples by shape factors are shown in Figure 8. It can be seen from this figure that the shape factors formed into two patterns corresponding to two shape grade categories of bird nest. Referring to this figure, the shape factors for most of Super AAA and Super were consistently same pattern and and the corner shape has their own pattern. For super AAA and super, it shows that no single threshold exists that can effectively separate one class of bird nest from another. However for a corner, an optimum classification can still be guaranteed provided that the threshold value is correctly chosen. From this figure; we also can see the different size for each grade. It can be seen the Wilks' lambda analysis yielded 81.5% correct classification.

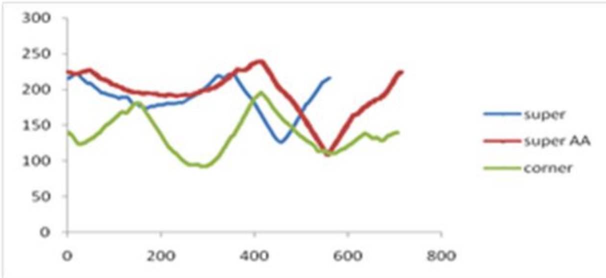


Figure 8 The distribution of three grade of the bird nest using FFPS

3.3 Combined FD and FFPS Features

All 240 samples from FD and FFPS features were put together using Discriminant analysis. Table 1 shows the analysis yielded 92.6% when using combined FD and FFPS.

Table 1 Combined Fourier descriptor and Farthest Fourier Point Signature

	VAR 00001		Predicted Group Membership			
			1.00	2.00	3.00	Total
Original	Count	1.00	75	3	2	80
		2.00	2	78	0	80
		3.00	0	1	79	80
	%	1.00	87.5	7.5	5.0	100.0
		2.00	7.3	92.7	.0	100.0
		3.00	.0	2.5	97.5	100.0

a. 92.6% of original grouped cases correctly classified.
b. 90.8% of unselected original grouped cases correctly classified.
c. 91.7% of selected cross-validated grouped cases correctly classified.

Table 2 Comparison FD, FFPS and combined FD and FFPS

Method	FD	FFPS	Hybrid FD and FFPS
Results	82.3%	81.5%	92.6%

Table 2 shows the comparison results for FD, FFPS and hybrid FD and FFPS. From this table the hybrid FD and FFPS method give the better results when compare with FD and FFPS method.

4.0 CONCLUSION

The inspection using machine vision technology has shown a good potential to estimate the quality of the bird nest. Results from this study have shown that combined method from Fourier descriptor and Farthest Fourier Point Signature are capable of making correct inspection decisions. Overall, the vision system was able to correctly classify 92.6% using hybrid FD and FFPS. Therefore system could be used for regular and on-line monitoring for better control of bird nest packaging operations

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