Proceedings of the Technical Sessions, 27 (2011) 52-59
Institute of Physics – Sri Lanka

Classification of Coir Fibres using Machine Vision

M.W.T. Chamara and D.U.J. Sonnadara
Department of Physics, University of Colombo, Sri Lanka

ABSTRACT

Measuring the length and the width of a sample of coir fibres manually is a time consuming and labour intensive task. With the aim of developing an imaging system based on machine vision, automatic computing of length and width were investigated by processing a set of scanned images of coir fibre samples. Two algorithms were developed using a line searching technique based on the pixel arrangement, in order to measure the length and width of the fibres.

Results showed that the automatically calculated lengths and actual length are linearly correlated with a correlation coefficient of 0.99. The overall error of the length calculation is ±6.4 mm. Over 75% of fibre lengths can be measured within a percentage error of 1.5%. However, the calculation of the width of the fibres did not provide satisfactory results since the estimated error value ±0.05 mm is quite high compared to the width of the fibres (~0.3 mm). Although the percentage error is high for the estimation of the width, the results indicate that the computational technique could be improved and used as an alternative to the manual techniques.

1. INTRODUCTION

Among fibre products, there are three main types known as *Bristle fibre*, *Mattress fibre* and *Twisted fibre*. Out of these three categories, bristle fibre or brush fibre is the stiff, straight and long strands of fibre. The soft fibre strands are called mattress fibre. The fibres that are twisted manually or mechanically are called twisted fibre. Before exporting fibre products, quality of the fibres should be investigated. The quality is determined according to the Sri Lanka Standard. Determination of average length and the determination of average width at the midpoint of the coir fibres are two main parameters in quality determination. In general, from each sample of coir fibres a sample mass of 2.0 g is taken and tested for the moisture, impurities, average length, average width at the midpoint and average breaking load. The determination of average length and the average width at the midpoint are time consuming operations since they are determined manually using a metre ruler and a micrometer screw gauge respectively.

Measuring length of a digital curve is a widely discussed subject in image analysis [1]. Klette et. al. [2] have discussed in their paper multigrid convergence of estimators of the length of digital curves. They report two length estimators; one based on the segmentation of a digital curve into digital straight segments (DSS), and the other based on finding the minimum-length polygon (MLP) to approximate digital region.

The DSS algorithm used by Klette et. al. works as follows. For each maximum length DSS the coordinates of their end points are found and the length of each DSS is calculated as the Euclidean distance between the two end points. The sum of lengths of these DSS's is used as the DSS estimator of the length of the digital curve. The MLP approximation consists of findings the shortest polygon lying completely in the closure of the open boundary of a digital region. The length of MLP is used as the length of the perimeter of the digital region [2, 3].

A comparative evaluation of length estimators of digital curves is presented by Coeurjolly et. al. [4]. They evaluate accuracy of length estimation of previously published algorithms in image analysis for a sample set of 2D digitized curves. Their evaluation uses multi-grid convergence as the characterizing criteria. They have also suggested a new gradient-based method for length estimation which can be considered as an extension to the DSS based approach.

Estimating the length of digitized space curves is presented by Bulow et. al. [5] and Sloboda et. al. [6]. Their solution provides a polygonal approximation and length measurement for curves in 3D space. They define length of digital curve to be the length of the minimum length polygonal curve fully contained and complete in the 3D digital curve.

The work carried out by Harrington et. al. [7], describe a method of incorporating the automatic determination of an arc length of a curve in an imaging system. The arc length is obtained by determining of a sequence of steps of movement along the curve on the pixel grid in one direction. A correction corresponding to the contribution of the termination step is added to the accumulated length to yield an improved estimate.

The intention of this work is to study the possibility of estimating the average length and the average midpoint width of the bristle fibre category using machine vision. The aim is to determine automatically the length values and width values when a set of scanned images of a single or multiple coir fibres per image which are not overlapped with each other is available.

2. METHODOLOGY AND IMPLEMENTATION

The research work was carried out in several steps using Matlab as the development environment. The concepts of the digital curve that are described specially in rubber band algorithm [5] and in principle of digital straight segment (DSS) approximation are used in this work. A thinned image of a coir fibre is considered as a digital curve with *n*-connected vertices. For each two vertices the Euclidean distance is measured and the sum of the distances is taken as the pixel length of the fibre. In order to determine the sequence of steps of movement along the curve, neighbourhood concept is used and the cumulated length of the sequence of steps is determined.

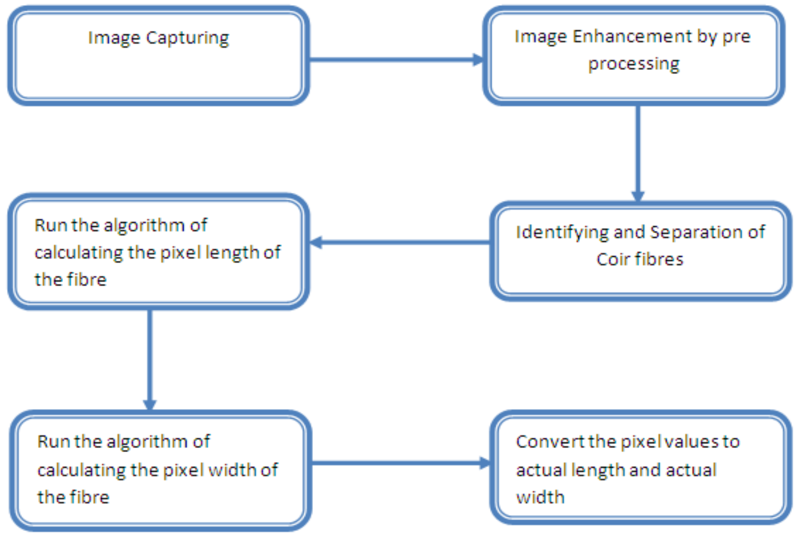

Figure 1: Process of calculating the length and width of coir fibres

Figure 1 shows a graphical representation of the main steps followed in this work to calculate the length and width. A full-page scanner was used to capture the images of coir fibres where up to 4-8 coir fibres could be included in one image. The format of the images was .TIF and each image was a RGB colour space image of 2528×3479 pixels in size.

The captured images from the scanner was not be suitable as a direct input to length or width measurements due to background noises such as lines and dots. Since coir fibres are small compared to the total image size, background noises could make a significant effect on the final calculation. In order to remove background noises the inbuilt function *wiener2* of Matlab was used. After removing the noise, *morphological operations* were applied. *Dilation*, *filling*, *thinning* and *component labeling* are being used in this work as morphological operators.

In some places in the scanned images, the shadow of the coir fibre could be seen. This occurs since during the scanning, some sections of the fibre stays slightly above the glass plane due to their twisted nature. This effect could not be eliminated by noise removal techniques. So the image of the fibre and the shadow of the fibre are merged using the dilation technique. Another problem of the scanned images was that in some places of the fibres, the colours of the pixels were very light compared to other areas (colours along the fibres are not uniform). When converting the images to binary images, threshold values were used. If pixel colour values were under the threshold values, those pixels were eliminated from the final image and the binary image was produced with an image having missing pixels or discontinued parts. In order to rebuilt the image, filling technique was used. The final image was thinned (before the length calculation) by using the thinning technique so a line of one pixel in width which represents the coir fibre in white colour in a black colour background was produced. Figure 2 illustrates the major steps in image enhancement procedure adopted in this work.

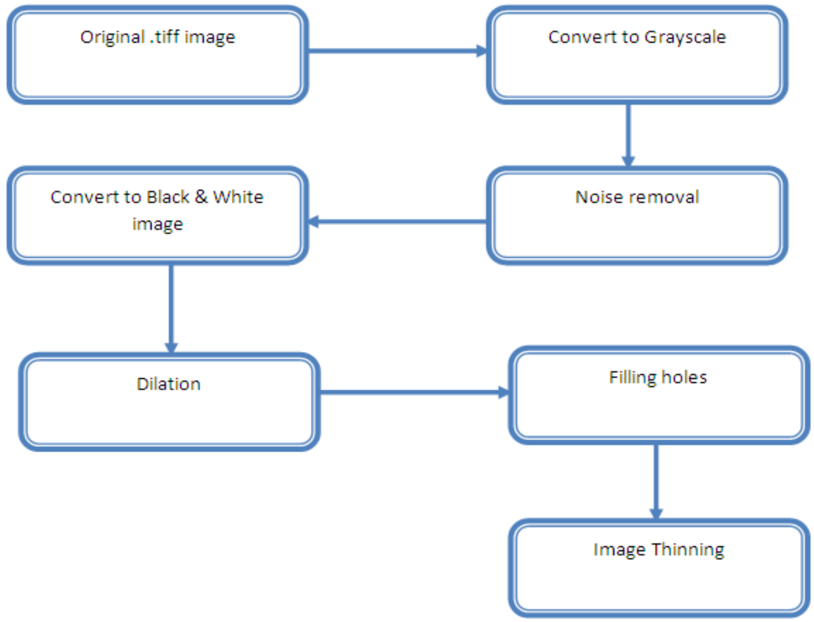

Figure 2: Image enhancement procedure

Each coir fibre had to be identified and separated among a set of 4 to 8 fibres before they were used in the length and width estimating algorithms. Identifying and separation was done according to the concept of connected component labelling [8]. Figure 3 shows the separately identified coir fibres in 4 different colours.

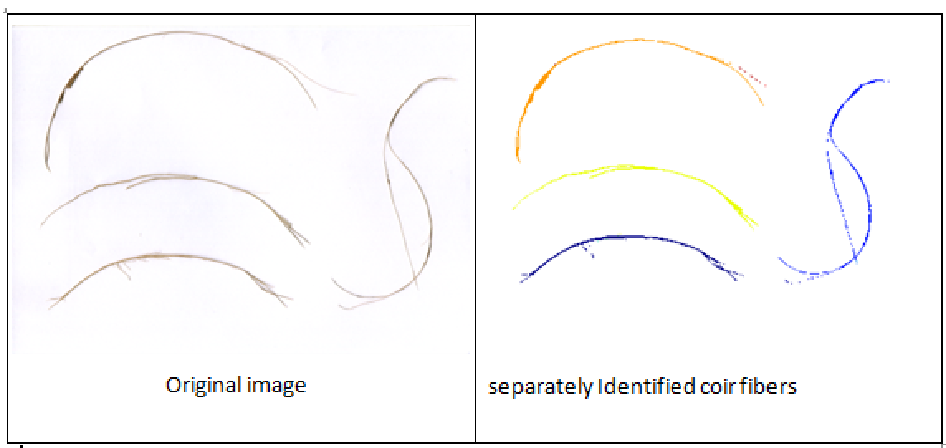

Figure 3: Identification of individual coir fibres from the original image

After identifying individual coir fibres, the original pixel arrangement corresponding to each fibre was used in estimating the length and width of the fibres. When calculating width, average of eight separate locations was used. In order to convert pixel values to length measurement, a sample of coir fibres with known lengths and widths were used.

3. RESULTS AND DISCUSSION

In order to test the automated system, about 200 randomly selected coir fibres were used in several ways. Initially an experiment was carried out by measuring the actual length and the automated length of the fibres in four separate samples. The correlation between these two parameters for each measurement was tested in order to evaluate the accuracy of the developed algorithms by considering only one coir fibre per image. Then another experiment was carried out by increasing the number of coir fibres per image and taking the average length values of a fibre sample and comparing with the actual average fibre length of the same sample in order to test whether the computational technique is applicable when multiple fibres are present in a single image. The same experiments were repeated for the width values of the coir fibres where automated measurements were compared with the actual measurements taken with a micrometer screw gauge.

3.1 Length calculation

The following graph shows the correlation of lengths of all coir fibres without sampling.

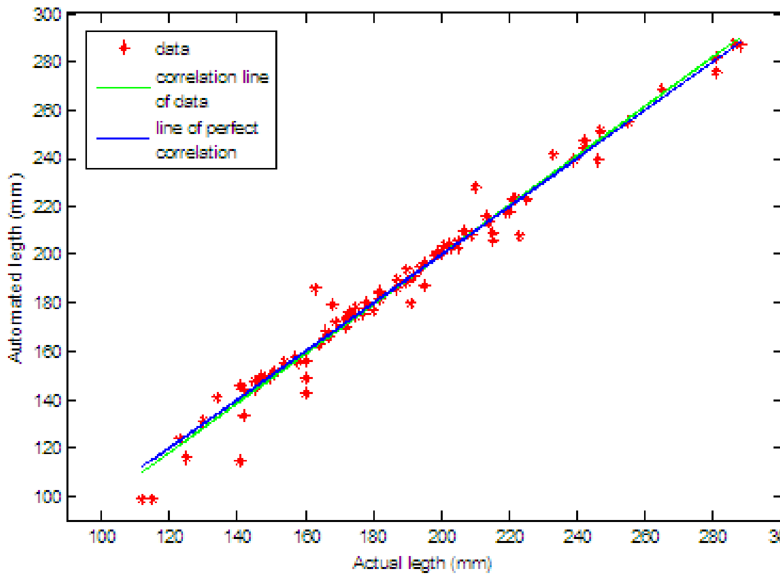

Figure 4: Automated length measurement against manual length measurement

As shown in Figure 4 a linear relationship is seen between the automated length measurements against the manual length measurements. The linear correlation coefficient of the measurements taken together is 0.99 which indicate that the automating length measuring process is suitable to replace manual measurement of coir fibres in bristle fibre category. Although the scatter plot shows that there are data points which are having significant deviations from the linear relationship, large percentage of data tends to stay close to the fitted linear trend. The fitted line almost coincides with the perfect correlation line which indicates that the algorithm works well for different length measurements.

The standard deviation of the differences between the actual fibre lengths and the automatically measured lengths was found to be 6.4 mm. When the outliers were removed, the accuracy improved to 3.0 mm. The accuracy of the length of coir fibres increase when the curvature of the fibre is low and the colour factor is uniform along the length of the fibre.

Table 1 shows the average length of coir fibres measured using manual method and automated system with the estimated errors for four different fibre samples. In the same table, the measurements carried out by the Coconut Development Authority (CDA) for determination of the quality of the same fibres are also shown.

Table 1: Average length values with their errors for four samples

Sample no.	Manual method Average (mm)	CDA manual method Average (mm)	Automated method Average (mm)
1	233 ± 1	230 ± 7	232 ± 5
2	178 ± 1	178 ± 8	178 ± 5
3	176 ± 1	175 ± 7	175 ± 5
4	181 ± 1	178 ± 7	182 ± 10

From the Table 1 it can be clearly seen that for all the coir fibre samples the average fibre length measured manually by the CDA and the average fibre length calculated automatically agree within the estimated errors. Data also show that the automated length calculation works well with the manual measurements for four samples with the difference between manual method and the automated system not exceeding ±1 mm which is better than the estimated error limited.

The automated average length calculation was also tested when there are multiple fibres per image. The average length of a sample of coir fibres was calculated by increasing the number of fibres per image. The number of fibres per image was increased one at a time, as long as a clear image of coir fibres can be obtained with individual fibres not overlapping with each other. The present work was limited to a maximum of four fibres per image.

The results of this test indicate that the length measurements vary within ±2 mm. The average length of the fibres in the sample is 181 mm. Since all the average length values are almost the same and they are very close to the actual average length value, we can conclude that even by increasing the number of fibres per image (without overlapping), an acceptable accuracy can be obtained. The results clearly indicate that the automatic length calculation can be used to estimate the average length of a coir fibre sample effectively.

3.2 Average width calculation

The same experiments were carried out to study the validity of using machine vision techniques to calculate the average width of the same coir fibre samples. Figure 5 shows the relationship between the actual widths of coir fibres and the automatically calculated widths of coir fibres in all considered fibre samples. The linear correlation coefficient for the average width of coir fibres is 0.80 which is a somewhat low value compared to the correlation coefficient obtained with the fibre lengths. The distribution of data also suggests that the linearity of the measured values and the automated values are significantly below the expected accuracy. The standard deviation of the differences between the manually measured width values and the automatically calculated width values is 0.05 mm.

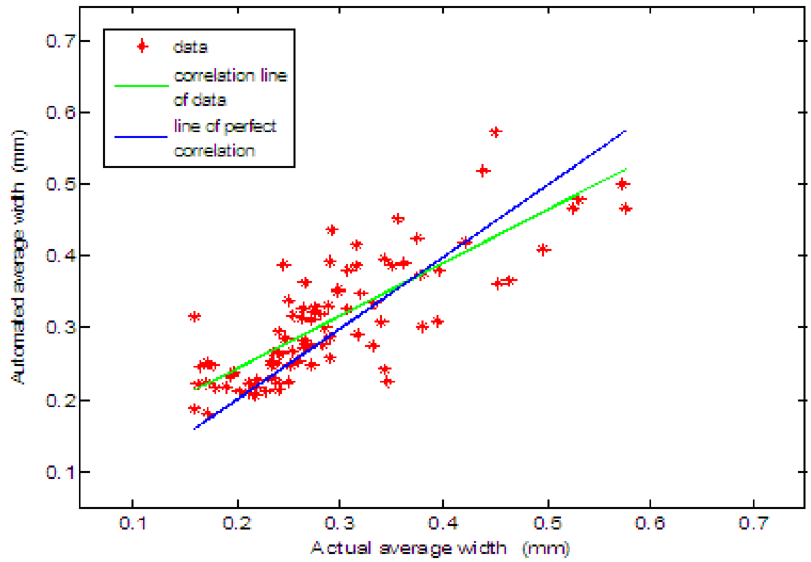

Figure 5: Automated width measurement against manual width measurement

The same four samples that were used to calculate the average lengths were also used to calculate the average widths. The observed results for the four samples are shown in Table 2.

Table 2: Average width values with their errors for four samples

Sample no.	Manual method Average width (mm)	Automated method Average width (mm)
1	0.323 ± 0.006	0.31 ± 0.05
2	0.275 ± 0.006	0.32 ± 0.07
3	0.296 ± 0.006	0.31 ± 0.05
4	0.283 ± 0.006	0.32 ± 0.07

From the results presented in Table 2 it can be seen that the average width values are in the order of ~0.3 mm which is comparatively a low value. Within the estimated uncertainties, the manual and automated measurements tend to agree. Since the average width is relatively small, a difference of 0.05 mm will give a percentage error about 17% which is a significant deviation.

The average width value of the same coir fibre sample is measured by increasing the number of coir fibres per image. Then the differences of the automatically calculated average values and the actual average values were compared. As in the length measurements, maximum of up to 4 fibres per image was considered. The actual average width of the sample was 0.276 mm. When considering the error values for each occasion it was clearly observed that the error values are almost the same for all occasions. i.e., by increasing fibres per image did not degrade the accuracy achieved by the automated system.

4. CONCLUSIONS

Following conclusions can be made from the work discussed above.

- The average length value of a fibre sample measured through the automation process is acceptable and comparable with the manual measurements.
- By increasing the number of coir fibres per image average length value of a sample can be calculated efficiently through the automated system.
- Automated average width calculation is not up to the expected level since the estimated error values are quite high compared to the width of the fibres.
- Increasing the number of coir fibres per image did not show a significant influence to the accuracy of the automated width calculation which can be used to increase the efficiency of the system.

Acknowledgements: Authors wish to thank the Director and the staff of Coconut Development Authority (CDA) for providing fibre samples and supporting this research work.

5. REFERENCES

[1] Klette R., Rosenfeld A. & Sloboda F. (eds): *Advances in Digital and Computational Geometry*. Springer, Singapore (1998).

[2] Klette, R. & Yip, B., *The length of digital curves*, Communication and Information Technology Research Technical Report 54, University of Auckland (1999)

[3] Klette, R. & Kovalevsky, V., *On the length estimation of digital curves*, Communication and Information Technology Research Technical Report 45, University of Auckland (1999)

[4] Coeurjolly, D. & Klette, R., *A comparative evaluation of length estimators of digital curve*, IEEE Transactions on Pattern Analysis and Machine Intelligence, 26(2) (2004) 252-257

[5] Bulow, T. & Klette, R., *Rubber band algorithm for estimating the length of digitized space-curves*, 15th International Conference on Pattern Recognition, 2 (2000) 547-551

[6] Sloboda, F. & Bacik, L., *On one-dimensional grid continua in R^3*. Institute of Control Theory and Robotics, Bratislava (1996)

[7] Harrington, S. J. & Holley, *Determination of the arc length of a curve*, Patent (1993)

[8] Yapa, R. D. & Harada, K., *Connected component labeling algorithms for gray-scale images and evaluation of performance using digital mammograms*, International Journal of Computer Science and Network Security, 8(6) (2008) 33-41