Design of a Tree Ring Structure Analysis System to Estimate the Accurate Age of Tree Species in Sri Lanka

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Abstract: Determination of an age in a particular tree species can be considered as a vital factor in forest management. In this research we have introduced a novel scheme to determine the accurate age of the tree species in Sri Lanka. This is initially developed for the tree species called'Hora' (*Dipterocarpus zeylanicus*) in wet zone of Sri Lanka. Here the core samples are extracted and further analyzed by means of the different image processing techniques such as Gaussian kernel blurring, use of Sobel filters, double threshold analysis ,Hough line transformation and etc. The operations such as rescaling, slicing and measuring are also used in line with image processing techniques to achieve the desired results. Ultimately a Graphical user interface (GUI) is developed to cater for the user requirements in a user friendly environment. It has been found that the average growth ring identification accuracy of the proposed system is 93% and the overall average accuracy of detecting the age is 81%. Ultimately the proposed system will provide an insight and contributes to the forestry related activities and researches in Sri Lanka.

Key words: Hora (*Dipterocarpus zeylanicus*), Image Processing, Gaussian Kernel Blurring, Sobel Filter, Double Threshold Analysis, Hough Line Transformation, Graphical User Interface

1 Introduction

Tree ring structure analysis is a technique, which has a paramount importance in forestry management, yet it is found to be an ambiguous and time-consuming process. The technique of analyzing ring structures of a tree can be used for defining the age of trees, which is also known as *Dendrochronology*. *Dendrochronology* [1] is the method of estimating tree rings to the exact year, which they were formed. As stated above, the analysis of ring structures of a tree has become a complex and time consuming procedure, thus it requires an improved knowledge in analyzing, if it is done by manually. On the other hand it requires the use of specialized tools and high-end proprietary software, which usually hinders the research works with limited budgets.

Usually, the new growth in trees occurs in a layer of cells near the bark. A typical tree specie's growth rate changes rapidly in a predictable pattern throughout the year in response to seasonal climate changes, resulting invisible growth rings. These rings are also referred to as tree rings or annual rings [3]. Growth rings result from new growth in the vascular cambium, which is a layer of cells near the bark that the Botanists classify as a *lateral meristem* (diameter of growth) is known as the secondary growth. This can be observed by cutting a horizontal cross section through the trunk of a tree or by means of samples taken by drilling a living tree. Visible rings result due to change in growth speed through the seasons of the year. Moreover, the rings are more visible in trees which have grown in temperate zones, due to various climatic differences. During the growing season, the inner portion of a growth ring forms early. If the growth is comparatively rapid (hence the wood is less dense) and it is known as ‘early wood’ (or ‘spring wood’, or ‘late-spring wood’) where the outer portion is referred as ‘late wood’ which is colloquially named as ‘summer wood’.

Sri Lanka is a country which is geographically situated in Tropical zone. In tropical zone, most of the tree rings are far more complex and poorly visible to identified [4] [5]. Therefore, obtaining a direct reading of tree ring chronologies in tropical countries would be a complex process and hence may not be accurate due to various reasons. On the other hand, manual process of counting the ring structures does not ensure the accurate time interval of each and every individual ring.

In Sri Lanka, the age estimation process of a particular tree species is currently done by manually. In order to eliminate the aforesaid issues while estimating the age of a tree on a manual way, we have proposed a novel image processing based methodology for estimating the accurate age of an endemic’ *Hora*’ tree species in Sri Lankan wet zone. The research studies are carried out close to *Rathnapura kalawana* region. Moreover, this pilot project is carried out upon the request of Department of Forestry and Timber cooperation of Sri Lanka.

2 Theoretical Analysis

2.1 Tree Form and its Growth

Usually, woody plants include trees, shrubs and vines, which are separated from each other on the basis of its size and form. Further the species that are taller than 20ft, and have a dominant single stem can be classified under trees where the wood comes from higher-order, vascular (fluid-conducting), perennial plants [4].

Woody plants consist of a secondary thickening layer which is naturally formed by combining with yearly growth cells into the accumulated growth of cell layers. When sliced crosswise through a trunk of a tree limb or a twig and observed at the roughly circular surface, we find the bark. The cambium is found at the inside of the bark, which is consisted of a thin layer of living reproductive tissues. The wood itself is characterized by growth rings which are arranged concentrically around the pith. Fig.1 shows a cross section of a tree stem and its inner formation.

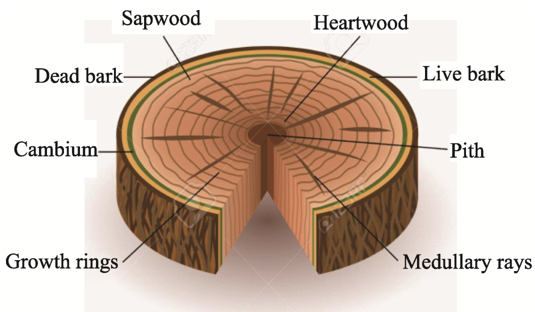

Fig.1 Cross Section of a Tree Stem

2.2 Growth Rings

The growth of a particular tree species can be defined by means of its reproductive activity pattern in the cambium just under the bark. In general, the characteristic life cycle of a particular tree includes its growing and dormant period. Cell formations in most of the trees follow this cycle, resulting growth rings. As mentioned above, these increments are called as annual rings, which are resulted due its annual growth.

Ring width of a typical tree varies from species to species. It also varies within a species from year to year with response to more or less favorable conditions during the growing. Some growth rings are obvious, whereas others are nearly invisible. The distinctive of a growth ring in particular species is determined by the seasonal variation in cell diameter, wall thickness of the cell and by the distribution of different cell structures within the wood. [2]

Variations in the growing environment of a particular species might have a pronounced effect upon the appearance of growth rings, where there is a visible contrast between the primary (first-formed) and secondary (later-formed) portions of a single growth ring. The first-formed portion is classified under early wood and the remainder latewood [6]. In certain species early wood and latewood are visible, where the transition from one to the other is abrupt in some circumstances. [7]

2.3 Wood Cells and Rays

The basic unit structure of a plant is cell. Thus wood can be considered as a collection of different kinds of cells, which are produced due to different divisions in the cambium. The cell structures are typically elongated, consisting of an outer cell wall encompassing a cell cavity.

In most cases, the long axis of wood cells formed parallel to the tree stem, where the cells are originated vertically in the stem. This dominance of longitudinal cells is responsible for grain direction, where it is the direction in which the wood most readily splits or cleaves.

If the cells are significantly non-parallel to the stem, some form of cross grain, such as spiral grain, may result. Whereas most cells are elongated in a direction parallel to the stem, a small number of cells-generally accounting for less than 10% of the volume of the wood are elongated perpendicularly to it. These cell structures form flattened ribbons of tissue called rays. The wide side of the rays are oriented vertically, and the rays radiate outward from the pith and connect with the cambium. Consequently, they cross the growth rings at right angles.

2.4 Viewing Features in a Sample

The principal structural planes in a stem is denoted as X, R and T where X is the cross sectional or transverse plane perpendicular to the stem axis and R is the radial plane passes through the pith and T is the tangential plane which forms a tangent to the cylindrical plane of the growth rings. This research mainly focused on analyzing and developing the samples obtained by the transverse plane, as it is found to be the most convenient way to detect the growth rings. When it is cut horizontally through the stem perpendicular to the grain direction the resultant areas is called as the transverse plane. The magnitude of the gradient (G) and the direction of transverse plane can be computed from the x and y partial derivatives as follows.

$$\|G\| = \infty \sqrt{\frac{\delta^2}{\delta x} + \circ \frac{\delta^2}{\delta y}} \tag{1}$$

$$\angle G = \tan^{-1}\left(\frac{\frac{\delta}{\delta y}}{\frac{\delta}{\delta x}}\right) \tag{2}$$

Here δx and δy are the partial derivatives in the x and y direction. Moreover, the partial derivatives are approximated by the first difference and computed by convolving first difference masks with the image.

Transverse plane allows observing the concentric growth rings and meantime it can also be observed the major growth ring characteristics such as ring width, percentage of early wood and latewood, evenness of grain and abruptness of transition from early wood to latewood etc.

2.5 Obtaining Samples

Basically, samples are obtained using an instrument called ‘Increment borer’. It is an equipment which extracts a small, pencil-sized piece of core sample from the trunk of the tree. A mini-augur is drilled by the hand through the bark to the pith of the tree. The resulting core sample extracted from the hole shows the annual rings at that point in the tree. The tree then pitches the hole over by filling the small cavity with resin. The standard location for taking the increment core samples from a tree is Diameter at Breast Height (DBH) which is in standard of 4 1⁄2 ft. (1.4 m). As the core samples are obtained at DBH, the estimated age is usually donated as the DBH age of that particular tree. Following Fig.2 depicts the way of obtaining a core sample by means of the increment borer.

3 Operations and Functions of the Proposed System

3.1 Identification of Growth Rings[8]

Here the gradient magnitude is used to find the edge features in an image due to the fact that the boundaries between edge features normally contain high contrast edges. In the obtained tree core images, the boundary between two rings are generally at the high contrast level between the dark latewood of one ring and the light early wood of the next. The pixel variation of a particular source image core sample and a source image used for processing is shown in the Fig.3 and Fig.4 respectively.

Fig.2 Taking a Sample Using an Increment Borer

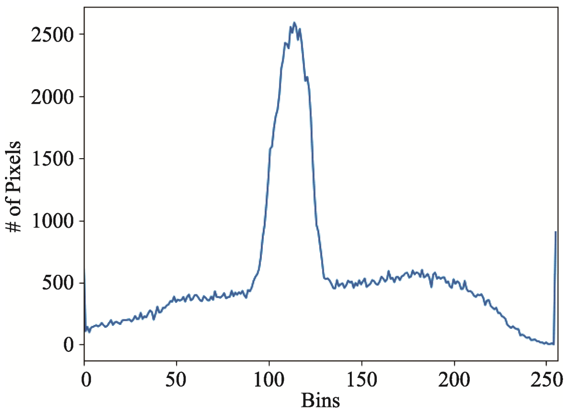

Fig.3 Pixel Variation of a Source Image

Fig.4 The Source Image Used for Processing

In order to extract the high contrast edges from a gradient image, it is required and necessary to apply a threshold level. The threshold value should be high enough to exclude a low contrast noise pixel which usually has a relatively low gradient magnitude, while maintaining the pixels with high gradient magnitude that correspond to high contrast edges in the image.

However, there is no discrimination between the edge pixels at the tree ring boundaries and other high contrast features. Since the tree rings in the images are aligned vertically, a second processing step is applied to filter the additive noise from the threshold edge map. Here the image is loaded and resized to quarter of its size and then converted to gray scale. Moreover, by applying a vertical median filter to the edge map, any edge pixels can be easily discarded.

3.2 Applying Gaussian Kernel Blurring and the Use of a Sobel Filter

Here, the initially processed image is further processed by convolving through a Gaussian kernel blurring and the meantime preprocessing is done in order to further smooth the image through the functions of blurring and by removing excess detail and noise. The Gaussian kernel blur effect is generated by convolving the image with an FIR (Finite Impulse Response) kernel of Gaussian values. Mathematically, applying a Gaussian blur to an image is the same as convolving the image with a Gaussian function. Here The Gaussian smoothing operator is used as the 2D convolution operator. In process is much similar to the mean filtering, however it uses a different kernel that represents the shape of the Gaussian (`bell shaped') hump. The formula of a Gaussian function in two dimensional spaces can be interpreted as,

$$G(x,y)=\frac{1}{2\pi\sigma^2}e^{\left[-\frac{x^2+y^2}{2\sigma^2}\right]} \tag{3}$$

Where x is the distance from the origin in the horizontal axis and y represents the distance from the origin in the vertical axis, and σ is the standard deviation of the Gaussian distribution. When applied in two dimensions, this formula produces a surface whose contours are concentric circles with a Gaussian distribution from the center point. Values of this distribution are used to create a convolution matrix which is then applied to the initially processed image. Here, the new value of each pixel is further set to a weighted average of that particular pixel's neighborhood. The original pixel's value receives the largest weight (having the highest Gaussian value) and neighboring pixels receive smaller weights as their distance to the original pixel increases. This results a blur image that preserves boundaries and edges of the original image and also provides an accurate result for the extraction of growth rings.

The amount of blur needed for the processing is determined by the sigma value, which also corresponds to the size of the kernel to be used in the convolution. As this basically controls the size of the kernel function, higher sigma values result for blur over a wider radius. Based on the sigma value, the corresponding kernel size is chosen and the kernel size is determined by means of the number of pixels in the sample during the convolution process. Here the recommended value of the kernel size obtained as 5. However the values like 3, 5 and 9 can also be used to obtain the desired results.

The blurred image then further processed through a Sobel filter to detect the initially preprocessed growth rings. Fig.6 shows the edges of the preprocessed image in less dark lines. The Sobel operator performs a 2D spatial gradient measurement on the image and also the regions of high spatial frequency that correspond to the edges. Moreover, it is used to detect the absolute gradient magnitude at each point in the initially preprocessed image. Fig.5 shows the gradient mask values used in the Sobel filter.

−1	0	+1
−2	0	+2
−1	0	+1

Gx

+1	+2	+1
0	0	0
−1	−2	−1

Gy

Fig.5 Gradient Masks Used in Sobel Filter

3.3 Obtaining the number of growth rings

The growth rings are detected after extraction and usually these growth rings lie in between the space of the two lines of the processed image. Here the very first line which is been detected is not considered as it directly corresponds to the pith of the tree. Moreover, the numbers of pixels between each pair of lines are calculated as the width, so which can be further used as the length ratio between the rings. Ultimately the detected ring lines are drawn vertically (N.B- the current image is considered to be horizontal where the rings are in vertical direction) so that the user can easily understand how optimum the solution is with reference to the source image.

In order to correctly detect final growth lines, the image is positioned vertically as stated above and a single column is selected by means of the column index process and meantime the white pixel lines are detected through the selected row in that particular column. Here, the column with most of the white pixels is used as column index. By obtaining the number of pixels between each pair of lines, the width of all the rings in the core sample are calculated.

4 Measurements and Discussion

The Sobel filter operates by calculating the gradient of the image intensity at each pixel within the image. Further, it is capable of detecting the direction of the largest increased value from light to dark and also the rate of change of the gradient in that direction. These kernels are designed to respond towards the edges, which are running vertically and horizontally relative to the pixel grid as well as for the one kernel in each of the two perpendicular orientations. The kernels are applied separately to the input image, in order to produce separate measurements of the gradient component in each orientation, which are denoted by G_x and G_y respectively. The kernels are further combined together to obtain the absolute magnitude of the gradient at each point and also the orientation of that gradient. Fig.6 illustrates the preprocessed image after applying the Gaussian kernel blurring and Sobel filter.

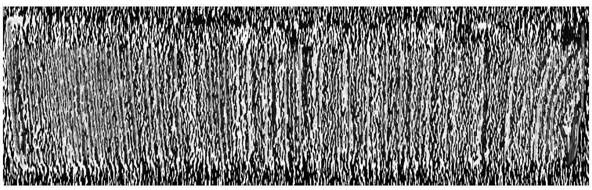

Fig.6 Preprocessed Image after Applying Gaussian Kernel Blurring and Sobel Filtering

4.1 Applying Double Threshold Levels to the Preprocessed Image

Due to the issues related to the degraded tree ring boundaries and also to eliminate the edge noise figures during the preprocessed stage is addressed by further processing, by means of applying double threshold to the image. This is accomplished by selecting a high threshold and it will remove the edge noise while maintaining fragmented, high contrast tree ring edges. Here the high threshold edge map is used to obtain perfect edges. Moreover the edges with low threshold are averaged with the other high threshold values in order to obtain fair results. This has the effect of filling the holes in the high contrast fragmented edges where the gradient magnitude is below the threshold while eliminating extraneous noise edge pixels. Here the conversion of white to black condition is used, i.e. pixels with intensities less than 160 and more than 200 are converted to white (255) and pixels in the range 161-199 are converted to black (0) in order to visualize the rings/lines in black color as shown in the Fig.7. Moreover, the Pixel conversion is done considering each column in every row and the required edges are detected by the rings through the processed image. Fig.7 further illustrates the processed image after the double threshold.

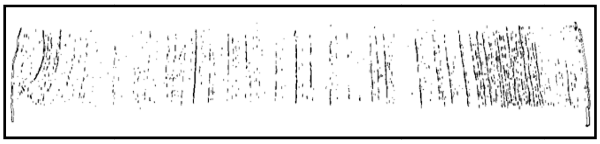

Fig.7 Processed Image after Applying Double Threshold

4.2 Tree Ring Orientation of Tracking and Removing the Ray Cells

As the processed image contains ray cells which are perpendicular to the growth rings, are further needed to be removed in order to obtain an efficient and accurate extraction of the growth rings in width measuring. The ray cells can be identified by the detection of the horizontal lines in the image and can be eliminated by convolving the horizontal kernel and extracting horizontal lines. The processed image with the ray cells is shown in the Fig.8.

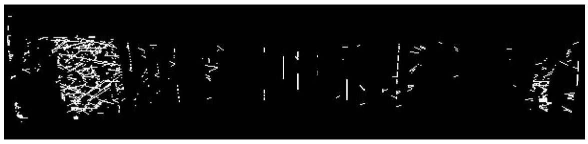

Fig.8 Detection of Ray Cells of a 'Hora' Species

4.3 Obtaining the Final Results of Extraction of Growth Rings

Here, the Hough line transformation is used to detect the final growth rings. The Hough line transform is a feature extraction technique used in image analysis. This Hough line transform algorithm uses a two-dimensional array and a accumulator to detect the existence of the growth rings which can be mathematically interpreted in polar form by

$$r = x\cos\theta + y\sin\theta \tag{4}$$

The dimensional size of the accumulator equals to the number of unknown parameters, i.e. two variables which are the quantized values of r and θ in the pair (r,θ). The Hough transform algorithm determines the straight lines at every pixel in every (x,y) coordinate and its neighborhood. Moreover it calculates the parameters of (r,θ) in that particular line, and then compare with the accumulator output (bin) value and thereafter increment the value of the accumulator. By looking at the bins with the highest values, typically for local maxima in the accumulator space, the final growth ring lines are extracted from the core image as shown in the Fig.9. As mentioned above the lines are detected through Hough line transformation with thickness equals to 1 by connecting end points of detected lines. After detecting the growth rings with the Hough line transformation and eliminating the ray cells in the image, the final step of extraction of the growth rings are obtained.

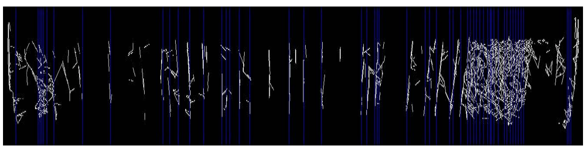

Fig.9 Extracted Growth Rings of the Sample Core Image

Here we have selected the Hora (*Dipterocarpus zeylanicus*) tree species which is an endemic tree in the wet zone, as for the testing purposes and also to generalize a model. The data set is obtained from heavily grown older Hora tree species from wet zone, close to *Rathnapura-Kalawana* region. However due to the unavailability of older species, the data points has been obtained from limited number of species which are tabulated under the annexure 1.By means of the obtained real time data points a generalized random data sets are trained and used in the optimized algorithm. The lab testings are carried out in the plant research lab, the Timber cooperation of Sri Lanka.

4.4 Graphical User Interface (GUI)

Here the Graphical User Interface is made with Bootstrap and by means of the Cascading Style Sheets (CSS) techniques. Bootstrap can be introduced as a web framework which has provided a major contribution in developing the user environment, which caters for choices of color, size, font and layout to the GUI. Moreover, Bootstrap provides basic style definitions for all HTML elements. In addition, this provides the advantage of CSS classes defined in Bootstrap to further customize the appearance of the content of the design such as provisioning of the light and dark colored text boxes, page headings, more prominent pull quotes, and text with a highlight etc.

This separation can improve content accessibility, provide more flexibility and control in the specification of presentation characteristics, and enable multiple web pages to share formatting by specifying the relevant CSS in a separate file which reduces complexity and repetition in the structural content. Moreover, Hypertext Markup Language (HTML) is used as it is the standard markup language for documents designed to be displayed in a web browser. Fig.10 and Fig.11 shows the GUI of the web browser.

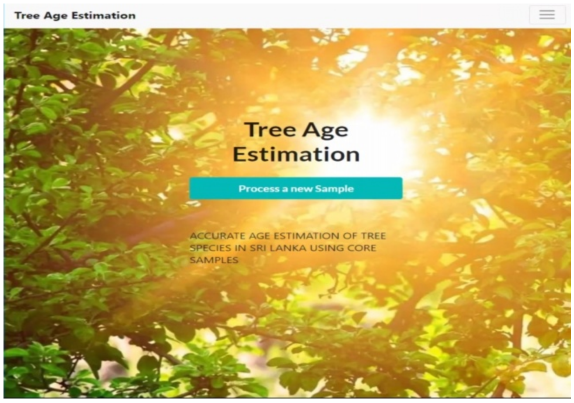

Fig.10 GUI Web Page

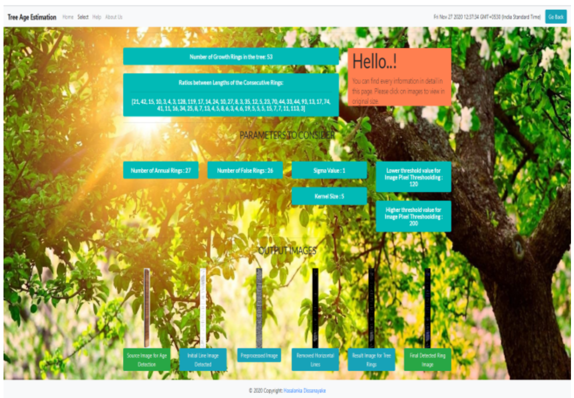

Fig.11 GUI Result Page

Average accuracy in growth ring identification	93%
Average accuracy in false ring identification	69%
Overall average accuracy	81%

5 Conclusion

Through this research, we have introduced a novel accurate tree age estimating system. As a pilot research, it is developed at the first stage for the Hora (*Dipterocarpus zeylanicus)* tree species of the wet zone in Sri Lanka. As stated earlier during this study, samples were obtained from heavily grown older 'Hora' species to generalize the proposed model. However, due to the unavailability of heavily grown older species in the selected study area, we have obtained some limited number of samples for the study and which are tabulated under annexure 1. However by means of the obtained samples, a more general random data set was trained in the optimized algorithm. The accuracy can be further increased by obtaining a large number of real time data points in a particular area and that would be a crucial aspect of this research study. However, this novel system provides a huge insight for the foresters, as well as the researches in the field of forest management. It also contributes to fast detection of the age with high accuracy of the defined species in an efficient way. As stated above the overall accuracy of estimating the age for *Hora* specie was 81% whereas accuracy of detecting the growth rings was 93%. Future developments of this system for other species would give a remarkable an immeasurable support for the forestry related researches and activities in Sri Lanka.

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References

[1] Sutherland E.K. (1999) Dendrochronology. In: Environmental Geology. Encyclopedia of Earth Science. Springer, Dordrecht. https://doi.org/10.1007/1-4020-4494-1_76

[2] Muthumala, C.K., 2014, The Anatomical study of common local and imported timber species in Sri Lanka, Report submitted to the State Timber Corporation, Colombo.

[3] Prabodha J.P.T.H., De Silva Sudhira, De Silva Subashi and Muthumala, C.K., 2017, Application of Non-Class Timber in Construction Industry, Proceedings of the 8th International Conference on Structural Engineering and Construction Management, Kandy Sri Lanka (CD Rom Version), Paper ID: ICSECM/2017/143.

[4] Ruwanpathirana, N., Timber classification, http://www.timco.lk/stc/index.php?module=web&action=timberClassification.

[5] STC (Sri Lanka Timber Corporation). Database: Ministry of Mahaweli Development & Environment, Government of Sri Lanka Network http://www.timco.lk/stc/ (2017). 2. Koch, G., Haag, V., Heinz, I., Richter, H. G

[6] Timber Identifcation Manual. Database: WWF-India. Network,http://envis.nic.in/ifgtb/pdfs/Timber%20Identifcation%20manual. pdf (2017)

[7] Asif, M. J. & Cannon, C. H. DNA extraction from processed wood: A case study for the identification of an endangered timber species (Gonystylus bancanus). Plant. Mol. Biol. Report. 23, 180–187, https://doi.org/10.1163/22941932-20160130 (2005).

[8] Sundari, P. & Kumar, S., 2014. A study of image processing in analyzing tree ring structure. Vol.2(Issue 3).

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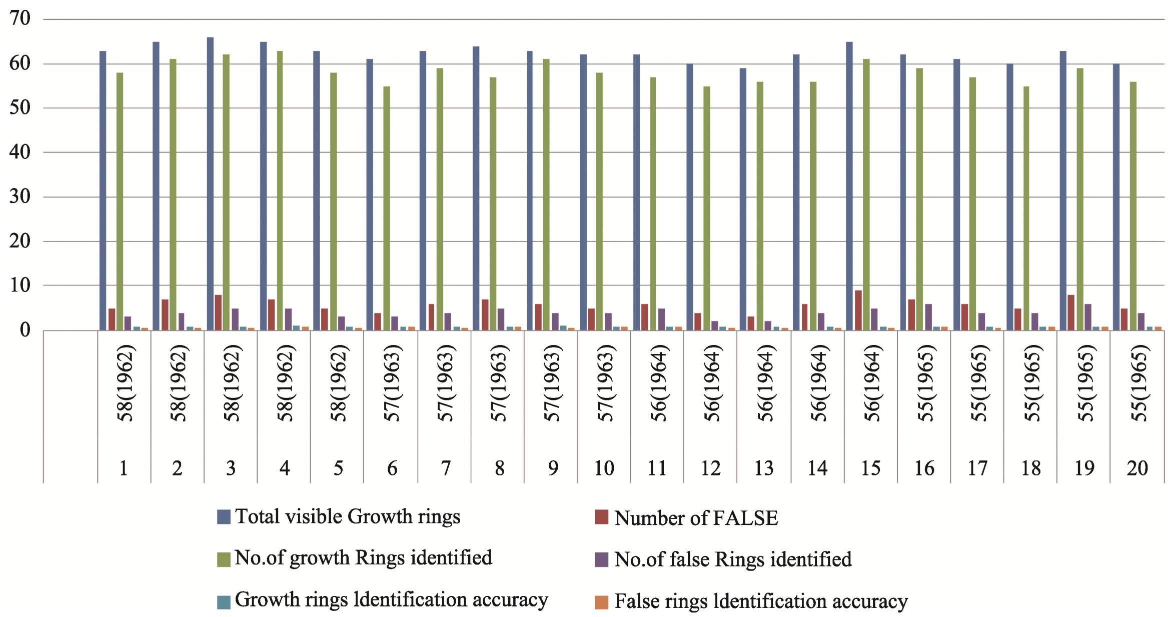
Annexure 1

Sample Number	Age/Year Planted	Total Visible Growth Rings	Number of False Rings	No. of Growth Rings Identified by the System	No. of False Rings Identified by the System	Growth Rings Identification Accuracy	False Rings Identification Accuracy
1	58 (1962)	63	5	58	3	92%	60%
2	58 (1962)	65	7	61	4	94%	57%
3	58 (1962)	66	8	62	5	94%	63%
4	58 (1962)	65	7	63	5	97%	71%
5	58 (1962)	63	5	58	3	92%	60%
6	57 (1963)	61	4	55	3	90%	75%
7	57 (1963)	63	6	59	4	94%	67%
8	57 (1963)	64	7	57	5	89%	71%
9	57 (1963)	63	6	61	4	97%	67%
10	57 (1963)	62	5	58	4	94%	80%
11	56 (1964)	62	6	57	5	92%	83%
12	56 (1964)	60	4	55	2	92%	50%
13	56 (1964)	59	3	56	2	95%	67%
14	56 (1964)	62	6	56	4	90%	67%
15	56 (1964)	65	9	61	5	94%	56%
16	55 (1965)	62	7	59	6	95%	86%
17	55 (1965)	61	6	57	4	93%	67%
18	55 (1965)	60	5	55	4	92%	80%
19	55 (1965)	63	8	59	6	94%	75%
20	55 (1965)	60	5	56	4	93%	80%

Summary of the Results



Graphical User Interface