Geofísica Internacional (2004), Vol. 43, Num. 2, pp. 281-285

An interactive method for digital tree-ring width measurement

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Received: March 31, 2002; accepted: August 27, 2002

RESUMEN

Presentamos un nuevo método interactivo para la determinación de la anchura de los anillos de los árboles. Se usa un escaner de la alta resolución y un microordenador en los que se trabaja con un programa para estudiar imágenes de anillos de árboles que se desarrolló dentro del ambiente Interactive Data Language (IDL 5.0). La ventaja principal de este método es que lleva a cabo un análisis de imágenes de anillos de árboles de manera interactiva sin necesitar equipo complejo y de alto costo. Se usó una prueba simple para verificar la precisión de las medidas de la anchura de los anillos de una muestra del árbol *Pinus taeda* del sur de Brasil.

PALABRAS CLAVE: Proceso de la imagen digital, imagen de anillos de árboles, análisis de datos de imagen, serie temporal.

ABSTRACT

We present a new interactive method for tree-ring width determination. It uses a high resolution scanner and a PC. A program to process scanned tree-ring images was developed in Interactive Data Language (IDL 5.0) environment. The method successfully performs interactive tree-ring image analysis without high-cost complex equipment. A simple test was used to check the precision of ring width measurements from a sliced tree sample, *Pinus taeda* on Southern Brazil.

KEY WORDS: Digital image processing, tree ring image, image data analysis, time series.

INTRODUCTION

Since the work of Andrew E. Douglass at the beginning of the XX century dendrochronology has gained in importance for paleoclimatic (Kumagai 1995) and climatic (Feng and Epstein 1996) studies. It also has an important and growing role in the study of volcanic phenomena (Brantley *et al.*, 1986; Yamaguchi and Lawrence 1993), earthquakes (Jacoby 1997), ice research (Luckman 1997), cosmonuclides (Stuiver and Quay, 1980; Jirikowic and Damon, 1994), and others.

Wood density measurements from X-ray densitometry are used in dendroclimatologic research (Briffa *et al*., 1990; Briffa *et al*., 1992). However, few laboratories have a X-ray densitometer, and few dendrocronologists can use such systems, due to high costs and complexity (Parker and Meleski, 1970; Schweingruber, 1990). Measuring ring width is usually thought to be (Fritts, 1976; Schweingruber, 1988) and not to require costly and complex equipment. Measurements of ring width time series by digital image analysis present a great potential for tree-ring studies (Thetford *et al*., 1991).

We present a new interactive image analysis method which determines tree-ring widths with precision. Its main advantage is that it uses a simple system, made of a high resolution image scanner, a computer and program software. We developed a program that applies a simple treatment to scanned tree-ring images to enhance the ring contrast and to produce a ring width time series. This program was developed in the Interactive Data Language (IDL 5.0) environment due to its easy operation with images.

Tree ring-width chronologies were also used as records of solar cycle variations in past. In some cases a significant 11 yr cycle is evident, with a slight time delay with the solar cycle (Murphy, 1996; Rigozo, 1998). Rigozo *et al*. (2002a and 2002b) used this methodology to study geophysical phenomena, such as solar activity and El Niño events. They find significant signals around 11 years that were attributed to the effects of solar activity, and periods around 3-7 years that can be attributed to El Niño southern oscillation events.

METHODOLOGY

The method was developed for dendrochronological research on araucarias - *Araucaria angustifolia* and pine trees, *Pinus eliiotti* and *Pinus taeda* - (Veblen *et al*., 1995). This process may be applied to other species of conifers and trees with visible rings. Firstly wood samples are polished, in order to prepare the rings for their optical analysis. The system used to obtain digital images is made of a Hewlett Packard (HP) table high-resolution scanner and a microcomputer Pentium-II.

The sample scanning was performed after selecting regions of the tree trunk slice which are, as much as possible, without defect within the rings, which could difficult their identification. The resolution for scanning was determined according to the distance between rings: samples which presented rings very close to each other were scanned with a high resolution, above 900 dpi, and samples which presented rings more distant were scanned with resolution lower than 900 dpi. The difficulty in using image high resolution is the need of high volumes of computer memory. All the images were obtained with gray scale from 0 to 256. The scanned images were saved in Microsoft bitmap file format (.bmp).

We developed a program named Tree Ring Image Interactive Treatment (TRIIT), within the IDL 5.0 environment, which reads bitmap images (Figure 1) and applies a simple processing in order to obtain an improved image with easier visual ring identification (Dustin *et al*., 1994) (Figure 2). In this work, the tree ring sample that is being used as an example, is from a *Pinus taeda*, collected at Rio Grande do Sul state and with 34 years (1964-1997).

Soon after, the location (in pixel) of each individual ring is determined (Figure 3) through its identification by gray level value differences (Sheppard and Graumlich, 1996). In this operation, the gray scale highest values represent the late wood, while the lowest values represent the early wood (Figure 3B). This is done firstly by clicking the mouse left key after pointing, with the cursor, the sample center (tree core) as initial position (tree first recorded year). After this, one clicks "on" the first ring from the center to record its position. From there, one has only to click "on" successively on every ring to record their positions. To continue the processing ring widths are obtained by the subtraction of two successive ring positions as previously determined, from the first interval starting at the center to the last one when reaching the bark (Figure 3A). In the case of some error by the

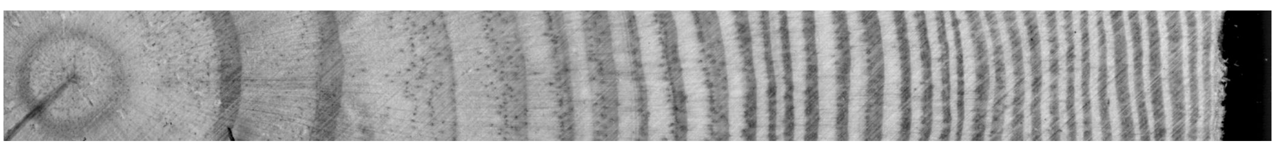

Fig. 1. Example of a bitmap image scanned from a *Pinus taeda* sample, which was collected in southern Brazil. This image was digitized with a 900 dpi resolution.

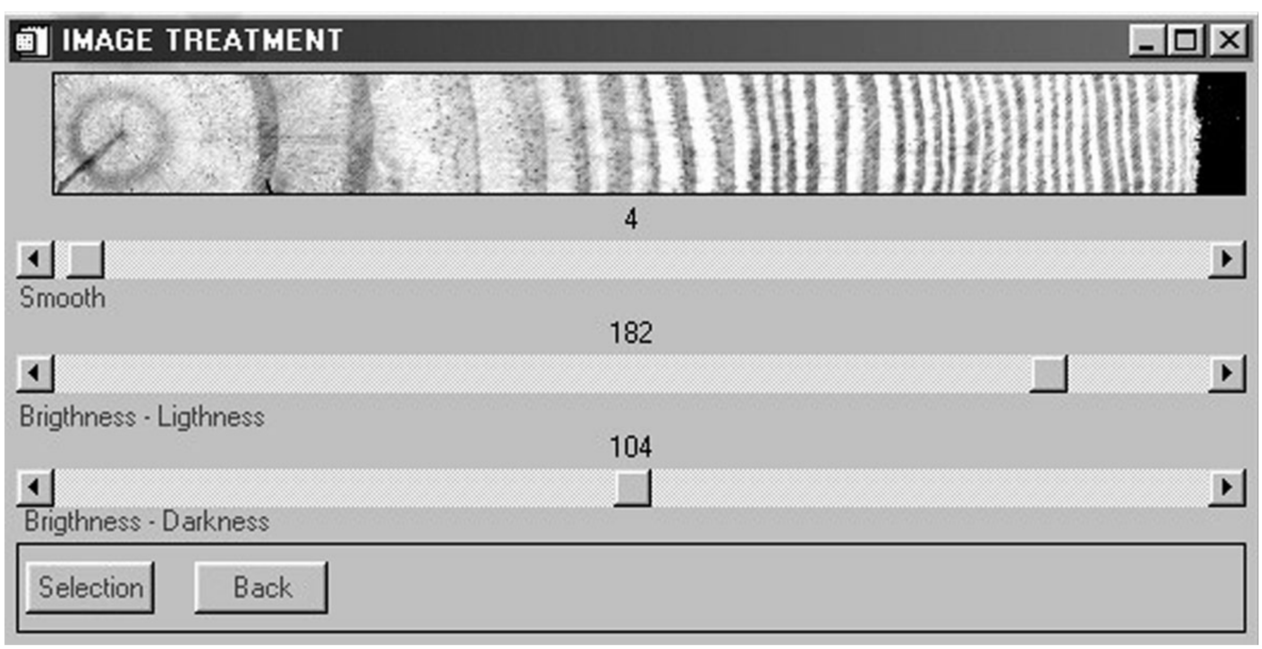

Fig. 2. Initial window of the TRIIT program, which presents the treatment applied to the image to enhance ring contrast.

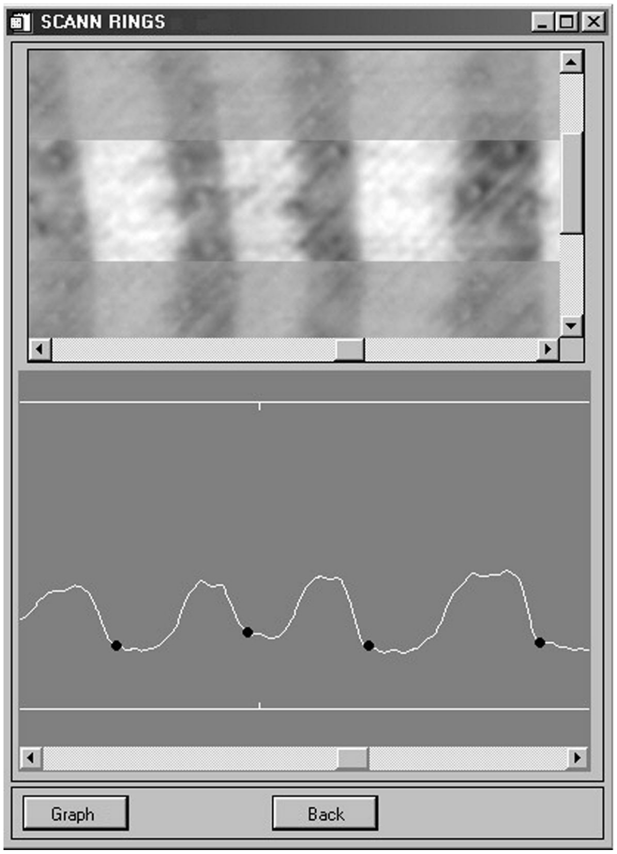

Fig. 3. End window of program TRIIT which shows an image of tree rings (A); to digitize each ring, its position is moved adequately. In (B) the graphic shows gray scale values as a function of its position on the image (in pixel), altogether with the position of each ring (represented by symbol •). As an example rings 11, 12, 13 and 14 (A) are shown with their respective positions (B).

operator at pointing the position of the rings, it is possible to begin again from the first data or just before the mistaken data. Fully automatic conversion of gray level time series read along a tree radius to a sequence of positions and intervals by using maximum detector was tried. But it did not give the expected results because, among other reasons, of the presence in the sample images of undesirable and difficult to eliminate spots. For this reason, the automatic conversion was not adopted and the interactive method described was preferred.

At the end of the process, a graphic is shown with gray scale levels (from 0 to 256) as a function of the position (in pixel) along the chosen radius, altogether with a symbol (•) marking the positions of every ring identified by the operator (Figure 3B). At the same time, a file is created which contains data of the ring width time series. Table 1 shows data output from TRIIT for the Figure 1 image.

Table 1

Data output from TRIIT

Ring number	**Width (pixel)**	**Width (mm)**
01	266	07.507
02	553	15.606
03	503	14.195
04	547	15.437
05	357	10.075
06	221	06.237
07	230	06.491
08	134	03.782
09	184	05.193
10	227	06.406
11	135	03.810
12	099	02.794
13	086	02.427
14	124	03.499
15	160	04.515
16	170	04.798
17	134	03.782
18	101	02.850
19	089	02.512
20	069	01.947
21	130	03.669
22	076	02.145
23	094	02.653
24	085	02.399
25	085	02.399
26	080	02.258
27	073	02.060
28	085	02.399
29	104	02.935
30	071	02.004
31	089	02.512
32	108	03.048
33	072	02.032
34	067	01.891

Note: This sample image is 34 years old. The first (initial) ring was made in 1964 and the last one in 1997.

We performed a test to check the quality of the results obtained by this method. This test consisted in digitilizing a ruler image with different resolutions, and reproducing the measurements of the distance between two points marked on the ruler. The program TRIIT was able to reproduce the distances between points, for different resolutions and with excellent precision.

TIME SERIES DETERMINATION

We obtained time series that represented every tree by digitilizing more than one image per sample and taking the mean of widths corresponding to every ring for the same year. This was done to eliminate the presence of false rings and the absence of some rings which may happen in some parts of the sample; this provided a better confidence in ring dating and width determination (Fritts 1976). As an example, Figure 4 shows ring width time series for every image of a tree sample (*Pinus taeda*) and the mean time series that best represents this sample. Before taking the mean of the time series, the correlation between the rings of every image is calculated in order to determine the temporal position of every ring in the tree slice, to take only the mean of rings which corresponds to the same year. This correlation is calculated with a lag of –5 to 5 years between the rings; in the case of Fig. 4 a mean correlation between the rings of 0.98 was obtained for a lag of 0 year, which means that every ring identified in the images is at the same temporal position, or year of formation, without any false ring or absence of any ring in the sample.

CONCLUSIONS

In this work, we present a new method which makes use of a simple and low cost system to measure tree ring widths. This method could also be used to measure tree ring densities through the conifer wood brilliance (Clauson and Wilson, 1991), but we preferred to work only with ring width, given its simplicity. This method was used on a 200-yr sample of *Araucaria* (with a 700 dpi image resolution for this sample) and on a 419-yr sample of *Fitzroya cupressoides* (Lara *et al.*, 1999). In the last case, a 1200 dpi image resolution was used. In all the samples, the program TRIIT identified and measured ring width with efficiency and precision.

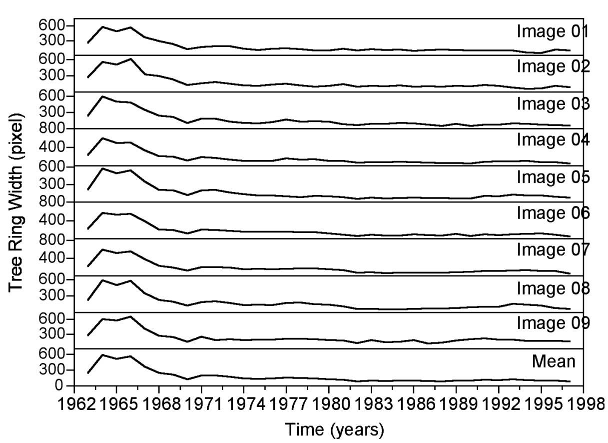

Fig. 4. Ring width time series for every image and the mean time series which is representative of the sample.

The method is more efficient with samples in which rings are not too close to each other, thus not requiring high resolution when digitilizing the images. If the samples present very close rings, a higher resolution scanner must be used. If samples with close rings show tree growth anomalies which may difficult the optical ring identification, the use of a microscope may be required.

This methodology was applied to the measurement of ring width time series (in Brazil and Chile) for the search of periodicities of geophysical phenomenon (such as the cycles of 11 and 22 years of the solar activity, the cycle of 18.6 years of the lunar tides and 3-7 years of El Niño southern oscillation) that influence trees growths.

ACKNOWLEDGEMENT

We thank INPE for general support and use of facilities. We thank also IBAMA, Concórdia Prefecture, Dr. Juan C. Aravena, Laboratorio de Botánica, Faculdad de Ciencias, Universidad de Chile, by samples. Claúdio Cassicia for their assistence in collecting sample in Chile. This research was supported by Conselho Nacional de Ciência e Tecnologia – CNPq (projeto n: 474185/2003-6) e Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (02/12723-2).

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