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Possible use of Euclid`s second theorem to determine the growth ring characteristics

Moguća primjena Euklidova drugog poučka pri određivanju obilježja godova

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ABSTRACT • *Transverse section of Sitka spruce was analysed according to the Euclid`s second theorem (EST) in order to determine whether EST could be used for establishing wood growth ring characteristics. The results were adjusted so as to provide comparability between radial width of earlywood (E) and latewood (L) throughout the whole annual ring of the experimental sample. It was observed that, although the EST gives only the approximate mean for E and L, the calculation of the mean radial width of E and L was reliable and confirmed by video scanning method. When considering its integrity, this method could only be used effectively, if the growth rings have the same pattern and show the rarefied variations.*

Key words: *Euclid's second theorem, growth ring characteristics, Sytka spruce, earlywood, latewood*

SAŽETAK • *Zamisao ovog rada bila je uz pomoć Euklidovog drugog poučka (EDP) pokušati odrediti i predvidjeti obilježja godova sitkanske smreke, i to na bazi poprečnih presjeka. Rezultati su bili prilagođeni za usporedbu radijalne širine ranog (E) i kasnog drva (L) cijeloga goda uzorka. Iako EDP daje samo približne srednje vrijednosti za E i L, izračunavanje srednje vrijednosti bilo je pouzdano i potvrđeno primjenom metode digitalne analize. U promišljanju mogućnosti uvođenja EDP metode razvidno je da bi ona mogla biti korisna samo ako su godovi podjednako široki ili s malim odstupanjima u širini.*

Ključne riječi: *Euklidov drugi poučak, obilježja godova, sitkanska smreka, rano drvo, kasno drvo*

1 INTRODUCTION
1 UVOD

It is useful to know the growth ring structure when studying the quality of wood, grading it, or determining how its structure affects other parameters (Thompson, 1992). The proportion of early-wood to latewood on the cross-section plays a dominant role in influencing the quality of wood (Megraw, 1985). Therefore, it has been repeatedly demon-

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strated that there is a correlation between the growth ring structure of wood and its mechanical properties (Pearson and Gilmore, 1980), and also density (Fries, 1986).
Although, the growth ring structure of wood is determined by either x-ray method or video scanning method (Clauson and Wilson, 1991), relevant information could also be achieved by use of light microscope and hand lenses (Hoadley, 1980). Apart from the potential provided by use of hand lenses, these techniques also provide excellent measurement sensitivity. However, these methods have several drawbacks, i.e. they require special equipments and tools, and their processing can be relatively slow. Determination of the growth ring structure (meaning growth ring width, earlywood width and latewood width) could therefore be carried out by other possible ways. Geometric measurement is one of these. Since the appearance of both earlywood (*E*) and latewood (*L*) in the transverse section is viewed as a rectangular size, the radial width of both *E* and *L* could be measured geometrically according to the Euclid`s second theorem, which is occasionally used for determining areas of rectangles and squares (Posamentier *et al*, 1977; Berger, 1987). In this study, therefore, the Euclid`s second theorem was adjusted for the determination of the growth ring characteristics by use of a small portion of transverse section. In this manner, the results were compared to the results of video scanning method for sensitivity and processing time.

2 MATERIALS
2 MATERIJALI

This investigation was carried out using Sitka spruce (*Picea sitchensis* /Bong./ Carr.) due to its narrow structure. The air-dried defect free 5 cm thick disc was cut from 10 twenty-year old trees of Sitka spruce at 2 m above ground line. After the measurements of the disc diameter and sapwood zone, as seen in Figure 1, the transverse face of the discs was divided into 3 sections, and 2 rectangle samples of 15 mm in tangential width and 30 mm in radial length were separately produced from east and west locations.

As difficulties with orientation were encountered in identifying the zones of both earlywood and latewood on the transverse section, the smoothing process was also performed to make the surfaces clean with a fresh single edged razor blade (Stainless, TAAB). The samples were then conditioned in a constant temperature and humidity room set at 20 °C and 65 % relative humidity. Thereafter, the video scanning method (VSM) was carried out according to the descriptions of Clauson and Wilson (1991) to measure the actual radial width of each earlywood (*E*) and latewood (*L*), and the Euclid`s second theorem was then applied to measure geometrically the approximate mean radial width of both *E* and *L*.

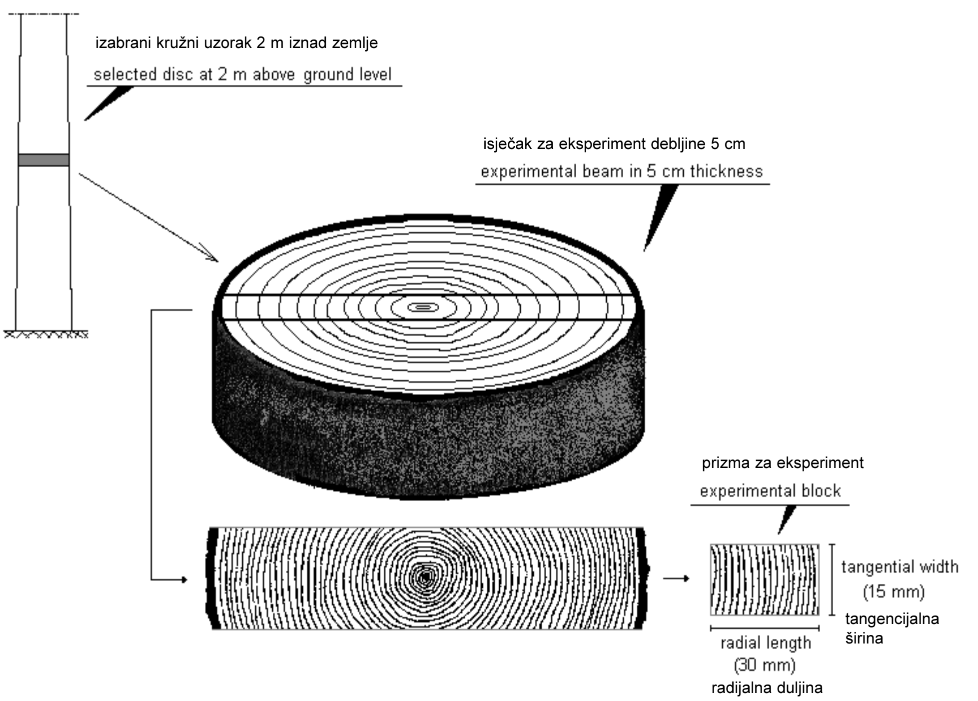

Figure 1
Initial location of the experimental beam and preparation of the experimental block for the determination of growth ring widths by Euclid's equation
Slika 1.
Shematski prikaz uzimanja uzoraka koluta iz trupaca i uzimanja uzoraka za mjerenje pomoću EDP-a

3 METHODS
3 METODE

3.1 Video Scanning Method (VSM)
3.1 Metoda digitalne analize (MDA)

A Seescan image analyser (TPL 3V47) connected via a video camera (P-40) to a light scope (Copycat light box) was initially used for analysing the growth ring structure. This system, demonstrated in Figure 2, allows the user to directly measure the distance between any two points located across individual zones of either earlywood or latewood, by use of a mouse.

For collecting data, the same cross sections (as used for the Euclid`s second theorem) were scanned with a colour video camera and digital processing system. The performance specifications of this video system (that can also be referred to as optical systems) included a frame size of 512 by 512 pixels, an effective linear resolution of 0.00236 mm per pixel for 30 by 15 mm wood samples and a dynamic colour intensity range of 5 bits.

The radial width of each experimental sample across both ends was firstly measured on the screen by clicking to two points using the mouse. The radial width of each earlywood (*E*) and latewood (*L*) was then measured in the same way.

3.2 Euclid`s Second Theorem (EST)
3.2 Euklidov drugi poučak (EDP)

The number of growth rings on the valid area of the transverse surface in each sample was counted manually using X10 lens. Thereafter, the diameter of the samples was radially and tangentially measured with a micrometer, and growth ring width of each sample was then measured according to the Euclid`s second theorem (Fig. 3).

In the first step of the calculation, the cylindrical cross section area of the original disc, wherefrom the experimental sample was initially taken as a beam from east to west direction, was reshaped as a square area to measure the total growth ring width consisting of earlywood and latewood. The geometrical design of Euclid`s second theorem was then rebuilt according to the half distance of the original disc. As shown in

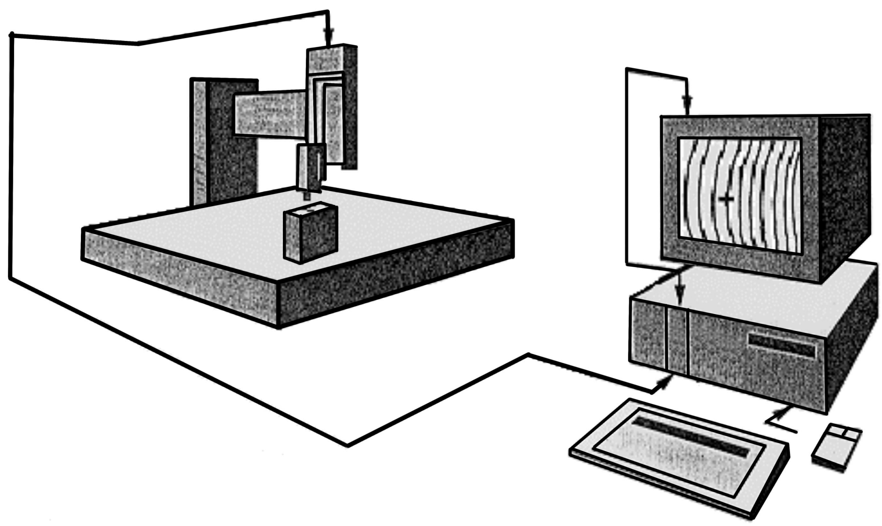

Figure 2 *Diagram of the equipment used for measuring tree growth-ring width by video scanning method showing subsystems (Schmidt et al, 1996)*
Slika 2. *Shematski prikaz opreme korištene za mjerenje pomoću (MDA) (prema Schmidt et al, 1996)*

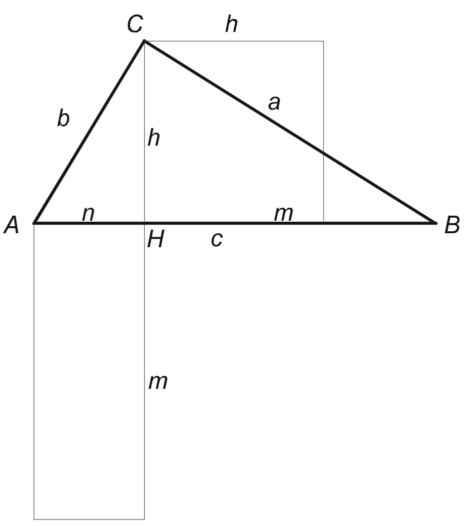

Figure 3 *Survey of the geometrical appearance and the related parameters of the Euclid`s second theorem*
Slika 3. *Geometrijski prikaz trokuta i odgovarajućih parametara Euklidova drugog poučka*

Meaning of the symbols *(Značenje oznaka):*
ABC is a right-angled triangle at *C, AC (*side*) = b, BC (*side*) = a, AB (*hypotenuse*) = c, CH (*altitude relative to the hypotenuse*) = h, AH (*projection of *AC* on the hypotenuse*) = n,* and *BH (*projection of BC on the hypotenuse*) = m*
ABC - pravokutni trokut, stranica AC = kateta b, stranica BC = kateta a, stranica AB = hipotenuza c, CH - visina okomita na hipotenuzu c = h, dužina AH - projekcija katete b na hipotenuzu c = n, BH - projekcija katete a na hipotenuzu c = m

Figure 4, the distance of the half of the original disc diameter is marked as d, where the total ring width of earlywoods (E) and latewoods (L) is separately grouped by the vertical line h, which is called the starting value (d/10) in this study.

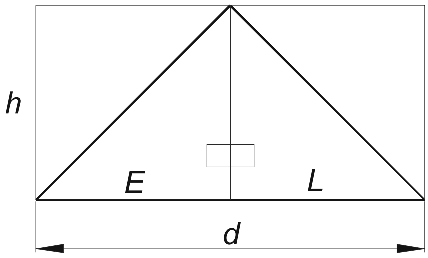

Figure 4
Re-shaped geometrical appearance of the Euclid`s second theorem according to half distance of the original disc diameter (d), where E shows the total amount (radial width) of the earlywood and L is for latewood
Slika 4.
Grafički prikaz Euklidova drugog poučka primijenjen na ispitni uzorak: d - promjer ispitnog koluta, E - ukupni udio zone ranog drva u promjeru uzorka, L - ukupni udio zone kasnog drva u promjeru uzorka

It is known from the Euclid`s second theorem that $h^2 = n \times m$, and $c = n + m$. Therefore, if $n = E$, $m = L$, and $c = d$ are the vectors that satisfy $h^2 = E \times L$, and $d = E + L$. This confirms the assumption that E and L are positively definite under the condition $E = Ex$ and $L = Ly$. Consequently, $h = (E + L)/2$ has only one solution.

If $h^2 = t$ and $h^2 = E \times L$ then

$$t = E \times L \Rightarrow E = t/L.$$

If $d = E + L$ and $d = (t/L)+L$ then

$$t + L^2 = d \cdot L \Rightarrow L^2 - d \cdot L + \mathrm{t} = 0.$$

If we define $L^2 - d \cdot L + t = 0$ by $\Delta = b^2 - 4ac$, assuming that $b^2 = k$ be integers with $0 < a$ and $c < k$ then $\Delta \geq 0$ and consequently

$$L_1 = (- b - \sqrt{\Delta})/2a \Leftrightarrow L^2 = (- b + \sqrt{D})/2a.$$

Since $L_1 = l_1$ and $L_2 = l_2$ from the equation

$$d = E + L \Rightarrow E = d - L$$

then L_1 and L_2 imply that

$$E_1 = d - L_1 \Leftrightarrow E_2 = d - L_2.$$

Since $E_1 = e_1$ and $E_2 = e_2$

$$e_1 = d - l_1 \Leftrightarrow e_2 = d - l_2.$$

After determining the correct measurement of the amount of both earlywood (E) and latewood (L), the root parameters are checked according to the actual situation on the transverse area of each experimental sample. For example, if $E > L$, the roots of earlywood parameters (e_1 and e_2) are controlled by the roots of latewood (l_1 and l_2), and the highest e is chosen with its l. Thus, according to the numerical result the right parameters (e_1 or e_2 and l_1 or l_2) are accepted as the running values for the remaining calculation.

If S is the diameter of the experimental sample, the percentage of S may be defined at half distance of the selected disc diameter as follows:

$$S(\%) = (S \times 100)/d.$$

If e' is the total earlywood in S, if l' is the total latewood in S and if e_1 and l_1 are the running values, e' and l' may be defined as follows

$$e' = (S \times e_1)/d \Leftrightarrow l' = (S \times l_1)/d,$$

If g' is growth ring width, then $g' = e' + l'$.

Now the calculated error may be defined as follows:

$$w = S - g'$$

The total earlywood (e) and latewood (l) may then be defined as follows:

$$e = e' \pm m/2 \Leftrightarrow l = l' \pm m/2$$

This implies that

$$g = e + l \Rightarrow S$$

The net width of each earlywood (e_{each}) and latewood (l_{each}) may now be determined as follows:

$$e_{each} = e/e_{no} \Leftrightarrow l_{each} = l/l_{no}$$

The rate of e over l my be defined as

$$r = e/l.$$

And finally the percentage of e and l in the growth ring width may be defined as

$$e(\%) = (e \times 100)/g \Leftrightarrow l(\%) = (l \times 100)/g.$$

4 RESULTS
4 REZULTATI

The experimental results of the mean radial width of both earlywood (E) and latewood (L) on the transverse section of the samples are given in Table 1, where the mean results are listed for both the Euclid`s second theorem (EST) and the video scanning method (VSM).

As clearly shown in Table 1, the

Table 1
The mean radial width of earlywood (E) and latewood (L) measured geometrically and directly by the Euclid`s second theorem (EST) and by video scanning method (VSM).
Tablica 1.
Srednje vrijednosti širina zone ranoga (E) i kasnog (L) drva mjerene MDA i izračunane EDP metodom

No. of tree *Br. stabla*	D_d (cm)	**No. of *E* and *L*** *Broj zona E i L*		**Mean radial width** - *Srednja širina zone* (mm)			
				EST / EDP		VSM / MDA	
		E	L	E	L	E	L
1	9,5	5	5	3,29	1,75	3,31	1,78
2	9,7	5	5	3,94	2,12	3,90	2,15
3	10,0	5	5	3,87	2,14	3,83	2,17
4	11,2	6	6	3,17	1,87	3,11	1,80
5	11,4	5	5	3,80	2,25	3,95	2,12
6	12,5	6	6	3,08	1,93	3,12	1,97
7	13,3	6	6	3,07	1,95	3,09	1,96
8	13,6	6	6	3,07	1,96	3,03	1,99
9	13,8	6	6	3,08	1,97	3,03	1,93
10	15,3	6	6	3,17	1,85	3,14	1,82

D_d – disc diameter *(promjer ispitnog diska)* results of growth ring width characteristics (radial width of both *E* and *L*) obtained by EST are closely parallel to those obtained by VSM. For each scanned sample, various statistical tests showed no significant differences (at 95 percent confidence level) between the means and variances of the growth ring width characteristics as generated by the two methods mentioned above.

The experimental results showed that the EST measurements were only comparable to mean values of both *E* and *L* in small transverse area of the samples (with short distance of radial and tangential widths). On the other hand, the VSM was suitable for measuring the actual radial width of each *E* and *L* (regardless of whether the scanned surface on the transverse area was small or large). Furthermore, in comparison with the Euclid`s second theorem, the video scanning method proved much slower in collecting data.

5 DISCUSSION
5 DISKUSIJA

Although, the mean radial width results, obtained by the Euclid`s second theorem (EST) of both earlywood (*E*) and latewood (*L*), are comparable to those of the video scanning method (VSM), more accurate results can be provided essentially by the VSM.

The potential of using EST for the determination of the growth ring structure is limited by the dimension of the experimental sample. In this case, to perform the EST efficiently, the distance of the radial and tangential widths must be equal to or less than 30 and 15 mm, respectively. Thus, it can be stated that the EST may be theoretically used to measure the mean width of *E* and *L* based on approximate values.

However, since there are no other investigations as to the analysis performed by the EST, the result of this research has to be tested on other wood species and further evidence is required to confirm this hypothesis.

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6 REFERENCES

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