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Original article

Development of Varsaw: a software for dimensional optimization in sawing

Desarrollo de Varsaw: un software para optimización dimensional en el aserrado

Desenvolvimento do Varsaw: um software para otimização dimensional em serragem

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SUMMARY

Cuban sawmills have technological limitations for controlling the sawing process, necessitating the use of innovative resources. To address this problem, a software tool was developed to optimize the dimensions of sawn timber planks, reducing waste and deviations. Several aspects were considered in the development of the software, including the calculation of the sawing variation index and optimal cutting dimension, the calculation of the total sawing volume, and programming tools. One hundred and fifty samples of *pine* planks were used to validate the software. *caribaea* var. *caribaea* from the Combate las Tanerías sawmill in Guane. The sawing variation index and optimal cutting size were calculated manually and compared with the results generated by the software, which were consistent with the results.

Keywords: sawmill, control, dimension, software, variation.

RESUMEN

Los aserraderos cubanos presentan limitaciones tecnológicas para el control del proceso de aserrado, lo que hace necesario recurrir a recursos innovadores. Con el objetivo de darle solución a este problema se desarrolla una herramienta de software para optimizar las dimensiones de tablones de madera aserrados de forma que se reduzcan los desperdicios y desviaciones. Para el desarrollo del software se tuvieron en cuenta varios aspectos como el cálculo del índice de variación de aserrado y dimensión óptima de corte, el cálculo del volumen total de aserrado y herramientas de programación. Para la validación del software, se utilizaron 150 muestras de tablones de *Pinus caribaea* var. *caribaea* del aserradero Combate las Tenerías en Guane. El índice de variación de aserrado y la dimensión óptima de corte se calcularon manualmente y se contrastaron con los resultados generados por el software, los cuales fueron congruentes con los resultados.

Palabras clave: aserrío, control, dimensión, software, variación.

RESUMO

As serrarias cubanas apresentam limitações tecnológicas para o controle do processo de serragem, necessitando do uso de recursos inovadores. Para solucionar esse problema, foi desenvolvida uma ferramenta de software para otimizar as dimensões das tábuas de madeira serrada, reduzindo desperdícios e desvios. Diversos aspectos foram considerados para o desenvolvimento do software, como o cálculo do índice de variação da serragem e da dimensão ótima de corte, o cálculo do volume total de serragem e as ferramentas de programação. Para a validação do software, foram utilizadas 150

amostras de tábuas de Pinus caribaea var. caribaea da serraria Combate las Tenerías, em Guane. O índice de variação da serragem e a dimensão ótima de corte foram calculados manualmente e comparados com os resultados gerados pelo software, que foram consistentes com os resultados.

Palavras-chave: serraria, controle, dimensão, software, variação

INTRODUCTION

Wood is a globally relevant renewable natural resource that forms the basis of an industry with an annual economic value of over US$400 billion, representing approximately 2% of global GDP (FAO, 2022). In an increasingly diversified market, demand for high-quality wood is experiencing sustained growth, as it directly impacts the durability, aesthetics, and functionality of derived products. These characteristics, in addition to being decisive for competitiveness in the sector, can justify the assignment of higher prices, reflecting their added value in industrial and commercial applications (McDonnell *et al.*, 2024).

In Cuba, the timber industry is a historical pillar with a strategic socioeconomic role, supporting productive activities and contributing to local development. Sawmills like "Combate las Tenerías" in Guane play an essential role in the national supply of planks that can be transformed into derived products. (Hernández Hernández *et al.*, 2020). However, sawmills face critical challenges, including technological obsolescence of equipment and limited sawing control software (Delgado *et al.*, 2012) . The Cuban sawmill industry faces persistent problems associated with dimensional variation in the thickness of planks. This inconsistency, derived from operational and technological factors, negatively impacts production efficiency, generating material waste, increased operating costs, and compromising the standardized quality of the final product.

There are several software alternatives internationally for sawing control, among the most important are:

- W oodEye (www.woodeye.com), which is a real - time scanning and optimization system for sawing lines.

- Autolog Sawing Optimization (www.autolog.com): Solution for the automated management of the sawing process.
- Springer Microtec (www.springer-microtec.com): Software for sorting and optimizing logs before sawing.

However, all of these are proprietary and expensive software, which hinders their use in domestic production.

At the national level, in 2010, Leckoumdzoun registered a software program, "Control", for quality control in sawing processes, with authorship attributed to the University of Pinar del Río (Leckoundzou , 2011) . However, this software is not functional on modern computers, being limited to the Windows operating system and a 32-bit architecture.

This research aims to develop software that automates the calculation of the Sawing Variation Index and determines the optimal sawing size, adaptable to different wood species and sawmill configurations.

MATERIALS AND METHODS

Software development requires the rigorous implementation of fundamental mathematical formulas that guarantee its functionality: calculating the optimal sawing dimension, determining the Sawing Variation Index (SVI), and estimating the total volume of processed wood. First, the mathematical formulation of equations for the sawing variation index and optimal dimension, derived from previous studies, is carried out. The programming process also translates these algorithms into executable code using numerical analysis techniques in Python. Finally, experimental validation compares the software results with empirical data and the reference software "Control," ensuring operational reliability.

This integrated approach ensures that each feature meets criteria of technical precision, industrial efficiency, and statistical validity, establishing a strong link between theory and the operational needs of Cuban sawmills.

Sawing variation index and optimal dimension

To calculate the total sawing variation, the mathematical formula of (Álvarez Lazo *et al.*, 2020) Equation 1 is used:

$$St = \sqrt{\overline{Sd}^2 + Se^2} (1)$$

Where:

St: Total sawing variation (mm)

Sd: Standard deviation of the sawing process in each piece (mm).

$\overline{Sd}$: Arithmetic mean of the standard deviation of the sawing process in each piece (mm)

Se: Standard deviation of the sawing process between pieces (mm)

$$Se = S^2(\overline{x})$$

$S^2(\overline{x})$It represents the variance of the means of the thicknesses of each sampled piece.

To determine the optimal sawing dimension, the formula proposed by Brown (1986) cited by (Álvarez Lazo *et al.*, 2020 Equation 2) was used :

$$D_0 = \frac{DF + TC}{(1 - \%C)} + Z \cdot St (2)$$

Where:

D_0: Optimum cutting dimension of green wood (mm).

DF: Final dimension (mm).

TC: Brushing tolerance on both sides of the assortment (mm).

DF: Final dimension (mm).

$\%C$: Shrinkage allowance for wood. For shrinkage tolerance, the tangential shrinkage value is used.

Z: Minimum acceptable dimension factor.

Procedure for calculating wood volume

For a sample of Mpieces and $n$measurements per piece, each piece will be denoted by the letter$p$ and will be indexed by the variable $i$con $i \in \mathbb{N}, i \leq M$, (p_i). Each piece $p_i$has width a_i, length l_i, and thickness g_i. The thickness will also be indexed by the letter $j$con $j \in \mathbb{N}, j \leq n$(g_{ij}) (Figure 1).

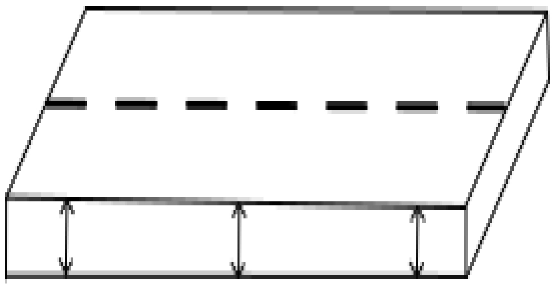

Figure 1*- Representation of the measurements on one side of the board*

Source: *Own elaboration*

Each piece is analyzed $p_i$as two subpieces, one p_{i1}consisting of length l_i, width $\frac{a_i}{2}$and thickness g_{ij}, with $j \leq 3$, likewise the second subpiece p_{i2}, consisting of length l_i, width $\frac{a_i}{2}$and thickness g_{ij}, with $3 < j \leq 6$. In this way, the piece is being divided in half the width for the analysis, obtaining approximately two cubic pieces (Figure 2).

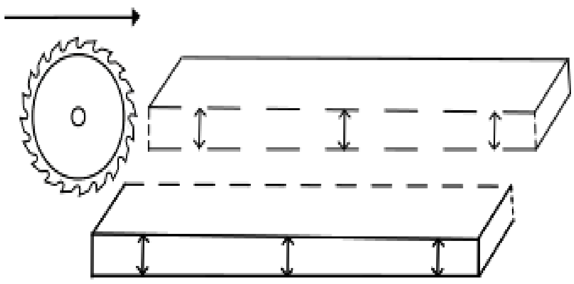

Figure 2*- Representation of the board divided in half its width with the measurements of its sides.*

Source: Prepared by the authors.

The area of the edges of each of these two subpieces is called and A_1respectively A_2. The volume of each of these two subpieces would then be obtained $V_1 = \frac{a}{2} A_1$as and $V_2 = \frac{a}{2} A_2$. To calculate each of these areas, since their heights vary, numerical integration is used using Newton Cotes' formula (Sauer, 2012) Equations 3, 4, and 5.

$$A = I(g_{ik}) = \int_0^{n/2} \left\{ g_{ik} + \Delta g_{ik}\binom{s}{1} + \Delta^2 g_{ik}\binom{s}{2} + \cdots + \Delta^{n/2} g_{ik}\binom{s}{n/2} \right\} \frac{l_i}{2} ds (3)$$

Where:

$$S = 2 \cdot \frac{x - x_0}{l_i} (4)$$

Therefore, the following is used as a formulation for calculating the total sawing volume:

$$V_T = \frac{1}{2} \sum_{i=0}^{M} a_i \left(I(g_{i0}) + I(g_{i3}) \right) (5)$$

Software development

The software developed was called VarSaw, an acronym derived from " Variation " and " Sawing ", whose main objective is to automate the calculation of the Sawing Variation Index and offer an intuitive tool to determine the optimal sawing dimension, adaptable to different wood species and sawmill configurations. To do this, the previously established formulations for calculating sawing variation, optimal dimension and total volume of processed wood were integrated.

The development of VarSaw incorporated numerical analysis methods to ensure the accuracy of calculations, mitigating errors associated with floating-point arithmetic during iterative computational operations. This approach ensures numerical stability and reliability of results, even in scenarios with high dimensional variability or large volumes of data (Panchekha *et al.*, 2015).

VarSaw software It features an intuitive and functional graphical user interface, designed to facilitate interaction with operators and technicians. Key features include the ability to import thickness measurement data from text files or spreadsheets, the automatic calculation of relevant descriptive statistics, the generation of distribution graphs to visualize measurement dispersion, and an optimization module that allows you to explore different sawing dimensions.

Data is loaded from *.xlsx files (spreadsheets) or .csv* database files. These files must contain structured data in a table format, where each column *n*represents a specific measurement per plank, corresponding to the previously defined variables or parameters. Each row corresponds to an $m$individual plank. The measurements recorded in the table must be expressed in millimeters *mm*, ensuring the consistency and accuracy of the data for processing.

The software development was implemented using the *Python 3.13.2 programming language, selected for its versatility and scalability. The CustomTkinter* library was used for the graphical interface, ensuring cross-platform compatibility and adaptability. Graph generation was handled by *Matplotlib*, while numerical data processing and associated calculations were implemented with *NumPy*. Advanced statistical analyses were supported by *SciPy*, ensuring precision in optimization methods and result validation.

Case study:

Pinus was selected caribaea , processed at the Combate las Tenerías sawmill. The pieces were randomly selected from continuous production over six workdays, taking approximately one plank for every 20 minutes of production. Sampling was performed before any sorting or planing process according to (Álvarez Lazo *et al.*, 2020).

For thickness measurement, a standardized manual method was used: six measurements were taken on each plank, three per side, distributed equidistantly along the length of the piece. The measurement points were marked following a uniform spacing protocol, ensuring that each measurement was taken perpendicular to the surface of the side, using a calibrated instrument. In total, 900 thickness data points were recorded, 150 planks × 6 measurements per unit, providing a solid basis for comparing the software's accuracy with traditional methods.

To determine the sample size, a probability sampling approach was applied under the assumption of an infinite population, justified by the daily production scale of the sawmill, so simplified statistical formulas for large populations are used, where the sampling fraction is negligible. As an estimator of the population dimensional variation, the arithmetic mean of the thickness measurements per board was used. For the sample adequacy, the formulation (Knight , 2000) Equation 6 is used:

$$n_0 = \left(\frac{Z_{\alpha/2} \cdot \sigma}{E}\right)^2 (6)$$

Where:

n_0: Initial sample size.

$Z_{\alpha/2} = 1.97$: Critical value Zcorresponding to a confidence level of 95%y 149degrees of freedom.

σ: Population standard deviation.

$E = 0.5$: Margin of Error.

RESULTS AND DISCUSSION

Software

VarSaw software is designed to calculate the Sawing Variation Index (SVI) for any wood species by processing data from Mpieces of wood with $n$measurements per side of each piece. The results are stored in a structured database, allowing retrieval for comparative analysis, future optimization, or integration with predictive models. In addition, the software includes a dimensional optimization module that determines the optimal sawing dimension D_0, using, and, as independent variables of the model DF, $TC$with z, as dependent variablesD_0

Additionally, it generates a scatter plot that visually quantifies the magnitude of deviations from the nominal dimension, facilitating the technical interpretation of the results and informed decision-making.

Figure 3. *- Initial software window*

Source: *Prepared by the authors.*

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In Figure 3, the initial interface of the software can be seen, which allows the user to access the sawing variation creation menu or select one and perform the analysis.

Figure 4. - *Sawing variation creation interface.*

Source: Own elaboration

Figure **4** shows the sawing variation creation window. You can assign a name to the variation identifier, select or add a species and environment, and upload variation data from a local spreadsheet or database file in CSV format.

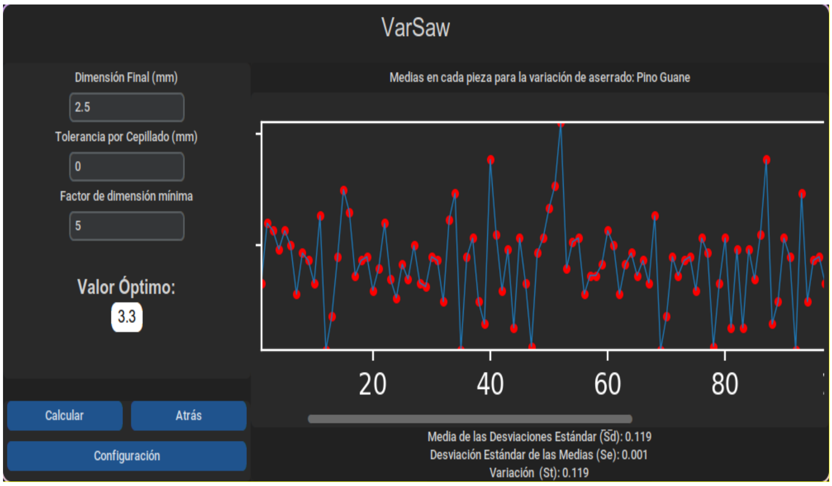

Figure 5. - *Main software interface*

Source: Own elaboration

Figure **5**shows the software's main interface, which displays the sawing variation analysis and a graph of the measurement means. It also shows the optimal value for the sawing dimension.

The software fully meets all established objectives with effectiveness and efficiency, ensuring the required control through an intuitive and ergonomically designed interface. The tool features a modernized design compared to the previous "Control" software, particularly due to its visual simplicity, comprehensive functionality, and ease of use.

Key Features:

- Intuitive interface: Facilitates navigation and data management, improving the user experience.
- Significant modernization: Offers a more up-to-date look compared to previous software, optimizing readability and accessibility.
- Comprehensive compliance with objectives: The system is designed to address all functionally defined requirements, ensuring precise and effective process control.

This approach not only improves usability, but also reinforces its relevance as an advanced technological solution (Figure 6).

Figure 6. - *Main window of the Control software*

Source: (Leckoundzou, 2011)

VarSaw software It demonstrates operational efficiency in data management, highlighting its ability to import measurement sets from files in multiple formats. This functionality contrasts significantly with the manual recording system used by Control, which requires sequential and error-prone entry of each piece of data individually (Figures 7 and 8).

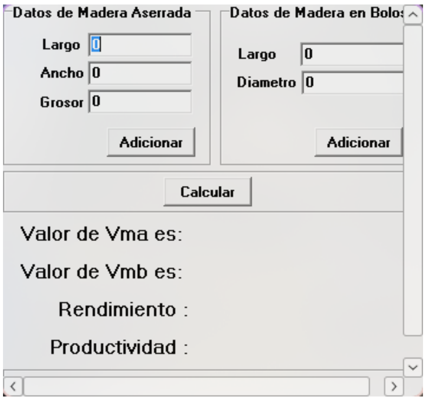

Figure 7. *- Control software interface for adding data.*

Source : *(Leckoundzou , 2011)*

Varsaw It is a modern software, capable of running on modern computers and with great scalability, while Control is not executable on modern 64-bit computers.

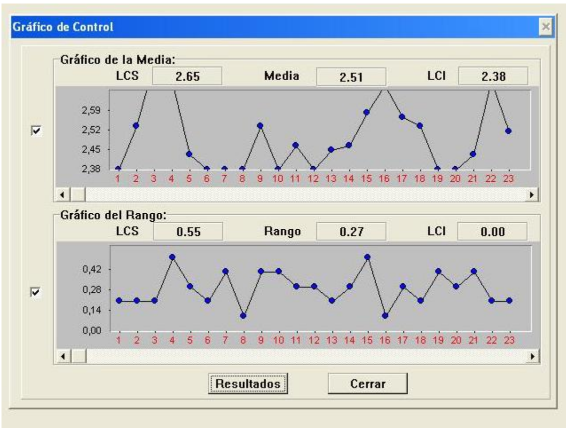

Figure 8. - *Main interface of the Control software.*

Source: (Leckoundzou, 2011)

Validation of the results obtained by the software

To validate the results obtained by the software, various statistical indicators were calculated from the data collected at the Combate las Tenerías sawmill. The manually obtained results are presented in Table 1

Table 1Statistical analysis of manual data*

Nominal Dimension	2.5 *cm*
Optimal Dimension	3.3 *cm*
Arithmetic mean of all measurements	2.4 *cm*
Maximum arithmetic mean of the measurements per piece	3.05 *cm*
Minimum arithmetic mean of the measurements per piece	2.03 *cm*
Maximum standard deviation of measurements per piece	0.38 *cm*
Minimum standard deviation of measurements per piece	0.00 *cm*
Arithmetic mean of the standard deviations per piece	0.11 *cm*
Standard deviation of the means of the measurements per piece	0.18 *cm*

From the data, the total sawing variation for the *Pinus species was calculated. caribaea.* Equation 7

$$St = \sqrt{\overline{Sd}^2 + Se^2} = \sqrt{0.118^2 + 0.0125^2} = 0.11881717160286984 \quad (7)$$

The results generated by the VarSaw software (Figure 5) They demonstrate agreement with the values obtained by manual calculation of the key indicators.

From the sawing variation index obtained, the optimal sawing dimension is calculated for a nominal value of the DF*Pinus* species. *caribaea* under the conditions of the Combate las Tanneries sawmill in Guane.

To obtain the optimal size, it is necessary to know the values of, $\%C$, $z$and St. The value $\%C$is the percentage of tangential shrinkage of the species. For *Pinus caribaea* This value is $\%C = \frac{7.6}{100}$, according to the studies of (Ibáñez Drake *et al.*, 2001). For this, $z$the value of can be used $z = 5\%$according to Zavala (1991) and Najera (2011) cited by (Álvarez Lazo *et al.*, 2020) . Therefore, obtaining the optimal sawing dimension would be given by the formula Equation 8:

$$D_0 = \frac{DF+TC}{1-\frac{7.6}{100}} + 5 \cdot 0.118(8)$$

Where there are two independent variables $DF$and TC, with one dependent variable D_0. In the case under consideration, the desired or nominal dimension is 2.5 cm, with a planing tolerance of 0 cm. Thus, obtaining a cutting dimension of Equation 9:

$$D_0 = 3.3\ cm(9)$$

Considering that the optimum value for sawing is 3.3 cm, and that this value is considerably above the nominal dimension of 2.5 cm, it is inferred that there is a mismatch between the capabilities of the machinery and the sawing process.

The manual volume calculation generated an approximate result of 18185 cm^3, with a notable variability in volume between pieces (Figures 9 and 10).

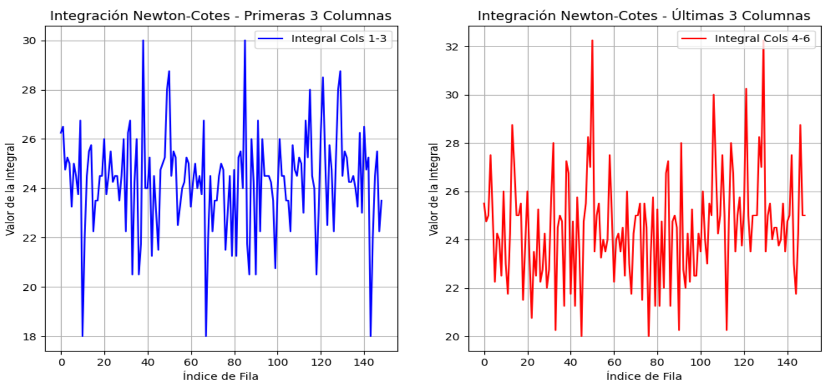

Figure 9. - *Numerical integrations by pieces.*

Source*: Own elaboration*

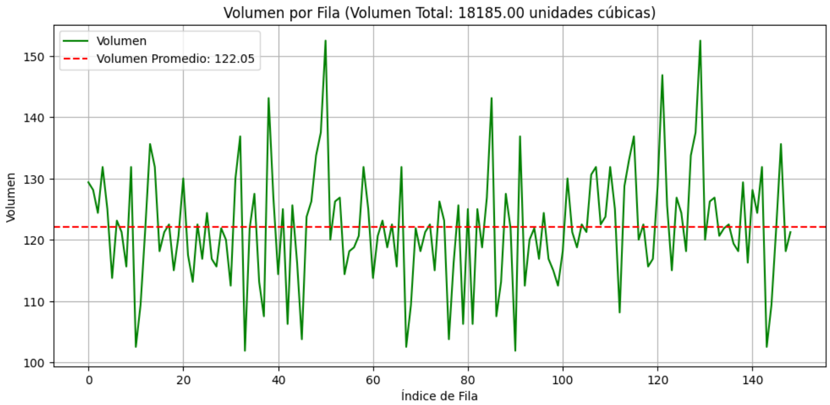

Figure 10. *- Volume variation for each piece*

Source: *Own elaboration*

The volume matches that obtained by the software; this correspondence validates the software's accuracy and confirms its reliability in replacing traditional dimensional analysis methods under real-life operating conditions.

It is an intuitive tool that streamlines decision-making and facilitates the adoption of quality protocols tailored to the technological and operational capabilities of sawmills. It is a functional tool for performing quality controls.

CONCLUSIONS

VarSaw The sawing dimensions are optimized to obtain planks with the smallest possible deviations, and a formula is created to calculate the total sawing volume.

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Conflicts of interest:

The authors declare no conflicts of interest.

Authors' contributions:

The authors have participated in the writing of the work and analysis of the documents.