

# Calculating Density of a Tornillo Tree using Neural Networks on Linux

## ABSTRACT

. To calculate a mechanical property of a Tornillo tree such as density ( $\rho$ ) it is required to manipulate that tree physically. Conventional ways involve procedures to get the mass and the volume of wood samples, as primary criteria to determine the density. However, processing all the data obtained to get accurate values of density on each point of a tree, still involves manual and invasive techniques to measure physical samples.

. Researchers have attempted non-invasive methods by using lineal correlations bi-variables and matching parameters in pairs such as the diameter of a tree versus density, density versus moisture content or density versus wave velocity, among others.

. The primary aim of this paper is to predict density by using an innovative and noninvasive computational method using neural networks based on two inputs: content of humidity and the wave velocity taken by a tomography sensor.

. This research will provide valuable information regarding the application of a back-propagation neural network to predict an efficient approach to the value of a density with noninvasive methods on Linux.

**Key words.** neural networks – tornillo tree – content humidity – wave velocity – density – Linux

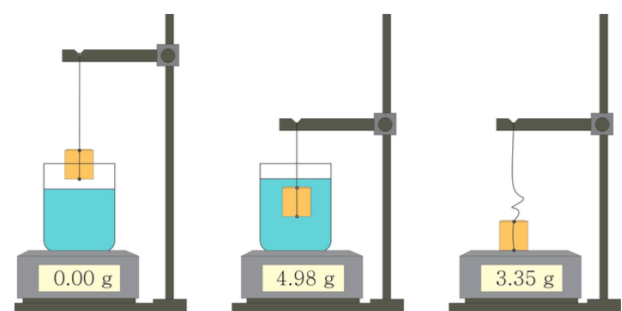
## 1. Introduction

There are more than 3000 types of trees discovered so far in the Peruvian jungle. Only 35 of them have commercial valuable and 12 are the most commercially valuable.(01) This study is focused in the species Tornillo, which is in the top two in massive growth in Peru, specially in Ucayali, Ayacucho, San Martin, Amazonas, Ancash, Cuzco and Madre de Dios; it is also, the most used in the wood market. Statistics also show that 55% of a tree is usable since the rest is taken to get the mechanical properties of the tree by traditional invasive physical methods. (02)This happens because generally the nature of a tree is orthotropic, but the Tornillo tree suffers lot of changes and is prone to be an anisotropic. The main motivation for this article is to propose a computational way to get mechanical properties without invasive physical manipulation.

To this purpose, a neural network has been designed with 5 neurons in the hidden layer (including a bias). The inputs are the velocity of a wave and the moisture content. To train the neural network, 126 samples of wood from Pucallpa have been treated in a traditional way. A current method to get density is described in the next section, and lately some research have been propose to match correlational bi-variables; that means pairing values of density, moisture content, velocity of a wave and the perimeter of a tree. The results are successful in learning and in validating the density predicted versus the density desired.

## 2. Current method to get density

Archimedes' principle is still used today to determine the density of metal, cast or melt specimens. This process is based on weighing a specimen, the weight of which is once determined in air and that is then weighted completely submerged in water as it is described in the figure. (03)



**Fig.01.- Traditional process to get density:  $\rho = m / V$**

Then, applying the  $\rho$  formula:  $70.05\text{g} / 28.02\text{g} = 2.5\text{g/cm}^3$ . However, that only corresponds to one sample of a tree that has previously been physically manipulated to be checked. For this study we had processed 126 samples and, before applying the Archimedes formula to each sample, we measured the Moisture Content (MC) and the Velocity of a Wave (VW) in the tree. These parameters were considered based on previous research in Brazil.(04)

### 3. Proposal method to get density

There are three remarkable stages in this new process to get the density: Collecting data, designing the neural network and data processing. For this purpose, we have working on four slides from two branches of a Tornillo tree that were divided into 127 samples.

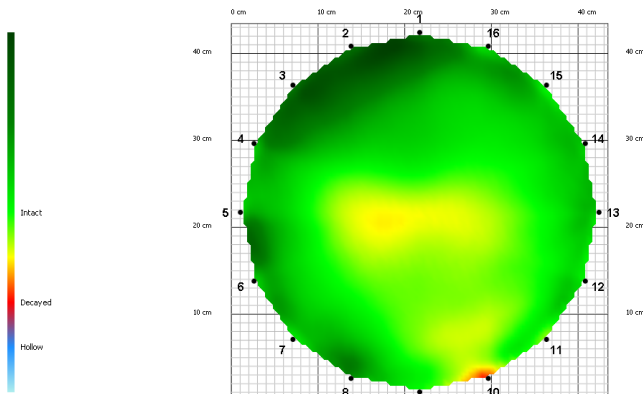


**Fig.02.- Samples of wood on slides of Tornillo Tree**

Three slides of eight, with numerable samples are shown in Fig.02 (each one of 2cm x 2cm x 1cm). A series of steps were performed to verify, organize, transform, integrate, and extract data in an appropriate output form: Density ( $\rho$ ) that includes MC.

#### 3.1. Collecting data

There were several methods of acquiring data. First of all, to get the velocity of a wave, a tomography with 16 sensors have were located in each slice, equally spaced, then stored in a table. Secondly, to get the mass, each sample was weighed in a laboratory scale (format it to 4 decimal places). Later, we can indirectly obtain the volume measurement. Finally, to obtain the moisture content: each sample was put into an oven at 103 +2 Centigrade(100C = boiling point of water) for (approximately) 24 hours) until getting a stabilized weight to apply the equation for determining % MC (moisture content) of the wood.(05)



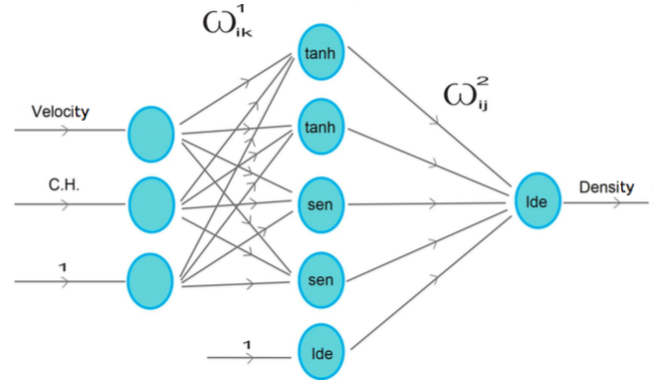
**Fig.03.- 16 sensors and the values of colors of the sample**

The figure 03 shows a tomography of one slide, and the points in the edges denotes 16 sensors that capture values of different colors on each sample. The coordinate translated has considered the order and position of each sample numbered as shown in figure 02.

The scale of colors taken inside by each sample is translated as the Velocity of Wave in a certain point. This process let to determine a mechanical value with non invasive method.

#### 3.2. Designing the neural network

A multilayer network was designed, since we have two inputs(velocity of a wave and the moisture content), and one output( $\rho$ ). All of them had been obtained previously. The hidden layer uses interactions through the hyperbolic tangent as sigmoidal and sinusoidal function.



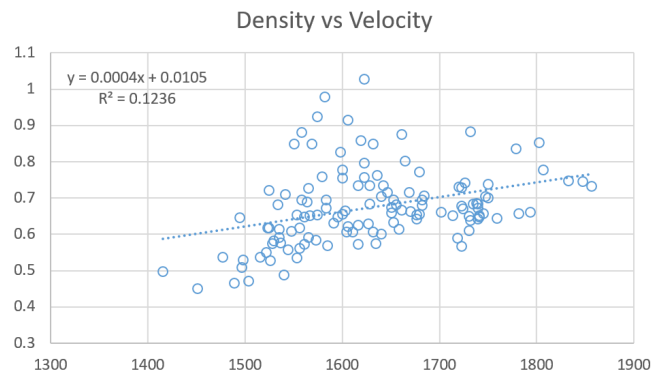
**Fig.04.- ARN Multilayer (2 inputs: MC, VW; 1 output:  $\rho$ )**

From the data previously collected, we take as inputs, the velocity of a wave and the moisture content; and the value of the density (considering as our output to feed the neural network. These are ten values of 126 samples.

Velocity of a wave	Moisture Content	Density ( $\rho$ )
1525.0000	0.5802	0.6170
1565.5000	0.8031	0.7267
1600.0000	0.9065	0.7783
1631.5000	0.9898	0.8494
1682.5000	0.5889	0.6943
1735.0000	0.5038	0.6836
1739.5000	0.5109	0.6839
1477.0000	0.4788	0.5375
1541.5000	0.9355	0.7104
1568.5000	1.2332	0.8493

#### 3.3. Data Processing

Correlation coefficient is a method that is commonly used in the lab to find a correlation between two variables. While trying to relate Density versus Velocity of the Wave as it is shown in the Figure5, we can see that the  $R^2$  is 0.1236:



**Fig.05.-  $R^2$  of Density ( $\rho$ ) versus Velocity of the Wave**

In a scale of 0-1, 0.1236 is a very low correlation coefficient. Another separate correlation was given by the combination of Density versus the Moisture Content.

We also observe that stabilization of  $R^2$  occurs after epoch 25 with a correlational coefficient above 0.8225, as shown in the figure below:

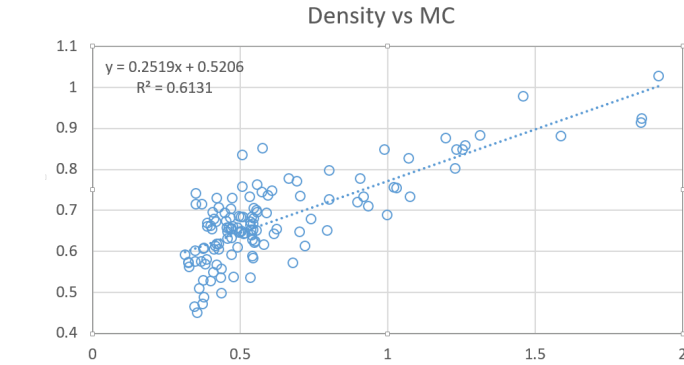


Fig.06.- $R^2$  of Density versus Moisture Content (MC)

Due to the Euler-Bernulli beam theory (theory of dynamic elasticity)(06) which provides a relationship between the Moisture content, velocity of the wave and density; we have taken both the MC and VW as input to have the density as output:

$$\frac{\partial^2}{\partial x^2} \left( EI \frac{\partial^2 w}{\partial x^2} \right) = -\mu \frac{\partial^2 w}{\partial t^2} + q \quad (1)$$

We have used 80% of the data to train the neural network, and 20% of the 126 samples to validate. The program was done in Octave(07) on Fedora to predict density input as MC and VW:

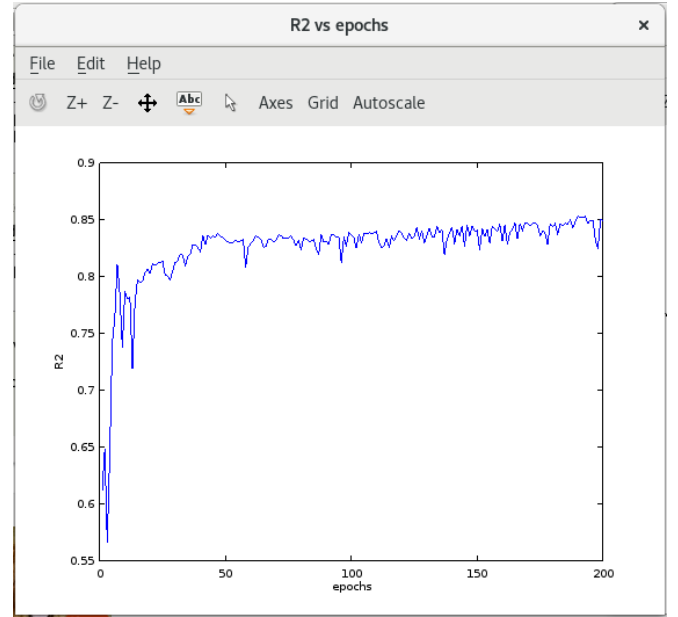


Fig.09.- Curve of learning through epoch

We record the sign (and therefore stability) determining parts of the left-hand sides of the inequalities

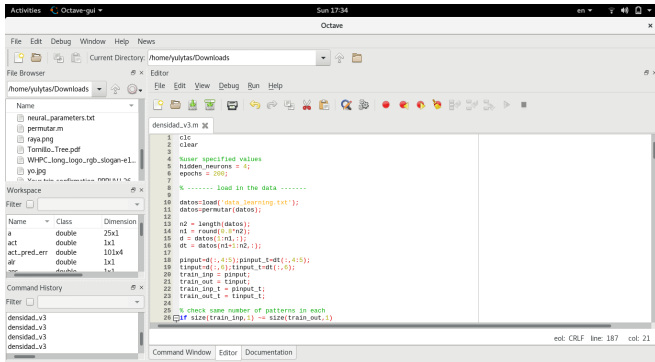


Fig.07.- Octave running on Fedora 25 and GNOME 3.22

The  $R^2$  between Density Desired and Density Predicted is 0.8720 in average while running:

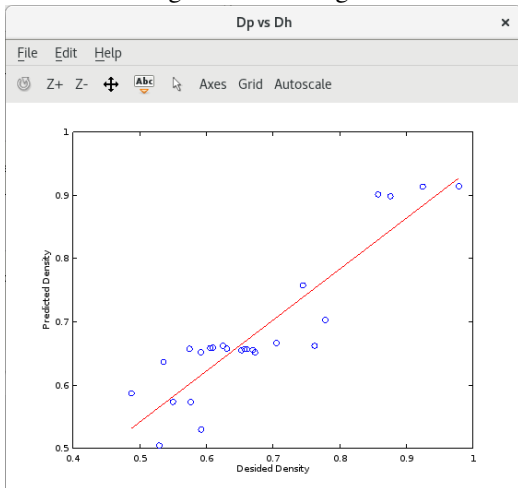


Fig.08.- Comparison Density Desired and Density Predicted

## 4. Conclusions

1. The correlation coefficient  $R^2$  between Density Predicted versus Density Desired is above 0.75, reaching values of 0.90 in the stochastic formula.
2. Based in the Euler-Bernulli beam theory, it was proven practically through the neural network that there is a closely relationship between the moisture content (MC) and velocity of wave (VW) to calculate a Density (including MC).
3. The majority of neural network research are programmed in Matlab, however this experience has used Octave on Fedora 25 and GNOME 3.22. Free Software have supported scientific basis as Neural Artificial Network research.

## References

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