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Agarwood Grading Estimation Using Artificial Neural Network Technique and Carving Automation

Muhammad Syafiq Afif Ishak[1], Yusmeeraz Yusof[1], Mohd Hafizi Ahmad[1], Nurul Ezaila Alias[1], Mohd Rashidi Salim[1], Mohd Fadli Rahmat[1], Mohd Afzan Othman[1], and **Mohd Amri Md. Yunus[2*]**

[1]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
[2]Department of Control and Mechatronic, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

[*]Corresponding author: amri@fke.utm.my

Abstract: Agarwood is a fragrant dark resinous wood formed when Aquilaria tress infected with a certain type of mold and appears like wood defects. It is the most valuable non-timber product has been traded in international markets because of its distinctive aroma, and can be processed into incense and perfumes. Agarwood grade is determined by several characteristics, such as black colour intensity, smell, texture and weight through visual inspection. However, this could lead to several problems such as false grading results. Traditionally, the carving process of separation of the uninfected Aquilaria wood that lacks of the dark resinous accomplished by using simple tools like knife and chisel. Hence, an expert worker is required to complete the task. In this paper, the Artificial Neural Network (ANN) technique is used to classify the Agarwood based on the features extraction from Gabor Filter and percentage of black colour estimation. At first, the images of seven groups of wood defects or knots are identified: dry, decayed, edge, encased, horn, leaf, and sound defect with total sample of 410 knots. Then, these images of knots are matched into three grade groups of Agarwood. Next, the experimental results show that the Agarwood can be classified into three grades groups based on knot and black intensity. A set of selected images of knots were used as trace patterns and carved on pieces of wood blocks by using a Computer Numerical Control (CNC) machine where the total time taken for each carving process was calculated. For each image, two Gabor Filter features and percentage of black colour were used as ANN inputs. In conclusion, the total accuracy of the experiments is 98% and the total time of carving is increased with the increased of grade group number.

Keywords: Agarwood grading system, Artificial Neural Network (ANN), Computer Numerical Control (CNC) machine

1. INTRODUCTION

In Malaysia, Agarwood is known as Depu, Gaharu or Cendana [1]. Otherwise, it also known as Agarwood or Eagleswood (British), Agar (India), Aloeswood (Bible), Adlerholz (German), Ahalim (Hebrew), Bais d'angle (Perancis), Ch'en Hsiang (China), Chan Krasna (Kemboja), Ghara (New Guinea), Ingkaras or Kaju Alim or Tanduk (Indonesia), Jin-ko (Jepun), Mai Kritsana (Thailand), Mai Ketsana (Laos), Ogoru (Assamese), Oud (Arab), Poa D'aquila (Portugis), Tengala (Brunei), and Tram Hurong (Vietnam) [1-5]. Agarwood is a fragrant wood that is usually derived from the infected timber of the genus Aquilaria Thymelaeceae or locally known as Karas [4, 6] and often occurs as dark coloured patches or streaks in the tree [5]. Karas or Aquilaria is the tree that will produce Agarwood. Meanwhile, Agarwood refers to products or goods resulting from physical injury and mechanical either naturally or man-made which is bacteria injection or inculated [1]. There are 28 species of Aquilaria found in the world [7]. Mainly, in Malaysia only 5 species of Aquilaria can be found which is Aquilaria Beccariana, Aquilaria Hirta, Aquilaria Malaccensis, Aquilaria Microcarpa, and Aquilaria Rostrata [1, 7]. But, there are also introduced new species in Malaysia which are Aquilaria Sinensis, Aquilaria Crassna and Aquilaria Crassna-Hybri [1]. Agarwood is an important non-timber forest product. Agriculturalist sees the plantation of Agarwood as a green 'gold mine' of the future, if there is a breakthrough in processing technology.

Agarwood is consumed for three main purposes which are medicine, perfume, and incense [3-5, 8]. For thousand years, Agarwood has been used for medicinal purpose and continues to be used in Ayurvedic, Tibetan, and traditional East Asian medicine [3]. It is used for treating pleurisy, asthma, rheumatism and jaundice. It is also known to be beneficial to the liver, lungs and stomach. Agarwood is used as incense in Buddhist, Muslims and Hindus religious ceremonies [8]. Both Agarwood smoke and oil are normally used as perfume in the Middle East [3]. Agarwood has become the most valuable non-timber forest product traded in the international market [8]. These species have been listed under Appendix II for Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITIES aims to ensure that the trade is well-regulated, and that it proceeds under a system of permits based on conditions of legality and sustainability [6].

Agarwoods are produced in three forms, namely woodchips, sawdust and oil. The higher-grade Agarwoods are sold in the marketing chain with minimal processing. Meanwhile, the lower grade Agarwoods are processed into oil through distillation. However, the manual carving process of getting a valuable core of Agarwood required experienced. The uninfected part of the wood is removed to ensure that the wood is categorized as a better grade and hence higher prices [8]. This process only required simple tools such as knife and chisel.

This paper discusses the development of a system for grading the Agarwoood using Artificial Neural Network (ANN) technique and the implementation of carving automation by Computer Numerical Control (CNC) machine for valuable core acquisition of Agarwood.

The rest of this paper organized as follow: In section II, the literature review on basic principle of Artificial Neural Network and Agarwood grading system are discussed. In section III, the methodology of this research is explained. Section IV discusses the result obtained from the experiments. In section V, the conclusion is expounded.

2. LITERATURE REVIEW

2.1 Basic Principle of Artificial Neural Network

The idea of neural network development was established based on biological neuron. The human brain is comprised of a network of neurons that are coupled with receptors (dendrites) and effectors (axons). A neural network is a highly-interconnected processing elements of large number of sample [9, 10]. A biological neuron is shown in Figure 1. By analogy from [11], the output processing element (axon) branches out and become the input to many other processing elements. These signals pass through connection weights (synaptic junction) that correspond to the synaptic strength of the neural connection. The input signal to a processing element are conditioned by the connection weights prior to being summed by the processing element.

Figure 2 illustrates the artificial neural that similar function as compared to biological neuron. The processing elements joined together to form an appropriate network with adjustable weighting function for each input. This processing element is organized in a sequence of layer. Each layer is connected to each other. Commonly, there are three or more layers. These layers are an input layer, an output layer and hidden layer. An ANN can be used to solve classification, clustering and regression of related problems [9, 11].

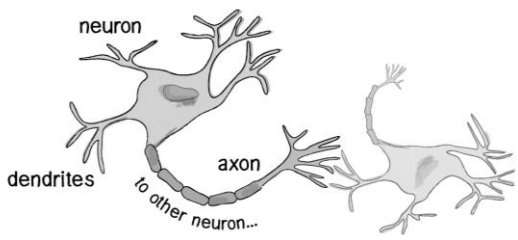

Figure 1. The depiction of a biological neuron.

2.2 Agarwood Grading System

In common Agarwood is graded in grade A, grade B, grade C and Grade D. The grading system varies in different countries. The process of grading is depending on the intensity of black colour, smell, texture and weight of Agarwood. These are the characteristics used by a human expert to grade any Agarwood. Moreover, there is no international and unified standard for Agarwood until now.

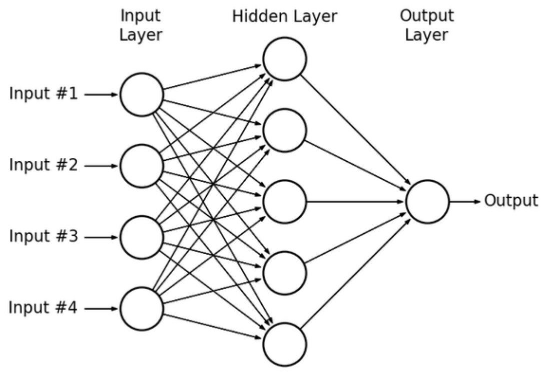

Figure 2. The generic ANN structure

Forest Department of Peninsular Malaysia (FDPM) has introduced their grading system which is based on the colour of Agarwood resin and their potential end use [7]. This grading system is represented in Table 1. Another grading system was introduced by Mazlan and Dahlan (2010) [12]. This system is divided into nine grades. In grade A and B, it has a subgrade which is break down into A1 to A10 and B1 to B10. This grading system is summarized in Table 2.

Table 1. Agarwood grading system by FDPM

Grade	Resin colour	Potential used
Super A	All colour with attractive shape	Decoration or esthetical value
A	Black or shiny black	Aromatherapy or burnt for fragrance
B	Brown or dark brown	Aromatherapy or burnt for fragrance
C	Whitish or yellowish	Essential oil.

3. METHODOLOGY

3.1 Project Overview

This study covers both simulation and hardware works. Where the simulation parts utilized MATLAB software for ANN and thresholding technique, while Inkscape software for *gcode* programming. Then, hardware part included CNC machine for automation carving process. The general block diagram for this project is shown in Figure 3.

After the process of ANN modelling using the standard images, a picture of wood is taken before the carving process. Then, the picture is converted into grey colour with 32 × 32 pixel size format. The image is also transformed by Gabor Filter to extract two features of mean and standard deviation. The grade estimation can be obtained from the ANN classification model which was estimated based on standard images of wood defects (knots), and matched it with appropriate Agarwood grade group member. After the grade is estimated, the image is segmented through thresholding technique into wanted and unwanted parts in the image segmentation process. Then, Inskscape software is used to compose the *gcode* for CNC machine. Lastly the process of carving utilized SpectraLight Machining Center. From the thresholded image, the CNC is automatically operated to remove unwanted parts which marked as blacked part of the final image.

Table 2. Agarwood grade found in Malaysia market

Grade	Resin coverage on the surface	Resin colour	Wood shape
Super king	Entire	Total black and shiny	Solid wood chunks (500g to 3kg)
Triple king	Entire	Total black and shiny	Solid wood chunks (200g to 500g)
Double super	90%	Less black and shiny	Solid wood chunks (50g to 200g)
Super	80%	Black and greyish	Solid wood chunks of mixed sizes
A (A1-A10)	Entire	Black turning into grey	Solid wood chunks of mixed sizes
AB	Entire	Black turning into brown	Solid wood chunks of mixed sizes
B (B1-B10)	Entire	Black turning into brown	Solid wood chunks of mixed sizes
C	50%	Grey	Varies in shapes and sizes
D	Entire	Grey and whitish	Varies in shapes and sizes

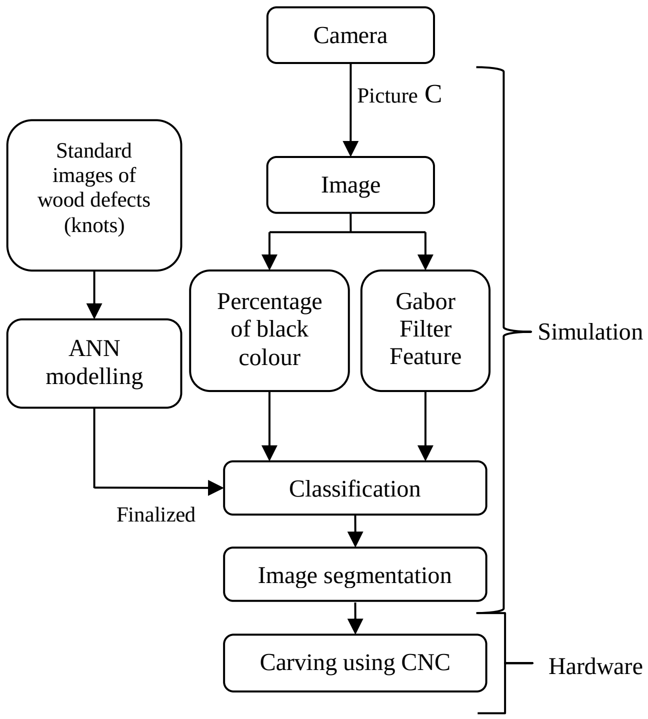

Figure 3. The project flow of this study

3.2 Sample Preparation for ANN

The sample of wood defect is taken from the University of Oulu Wood and Knot Database [13]. The defect on each sample is perceived as knots of wood. This knot consists of seven group which are decayed knot, dry knot, edge knot, encased knot, horn knot, leaf knot and sound knot. Figure 4 shows the difference shapes of knots used in this project. These knots will categorize into three grade which are grade 1, grade 2 and grade 3. Table 3 shows the grading system for this project.

Table 3. Sample Data

Grade	Type of knot	No of sample
1	Encased	49
2	Horn and edge	90
3	Dry, decayed, leaf and sound	271

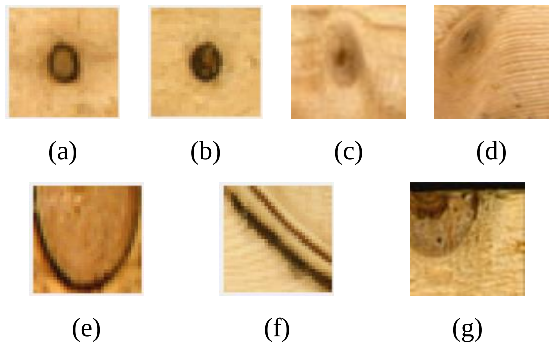

Figure 4. (a) Dry knot, (b) decayed knot, (c) sound knot, (d) leaf knot, (e) encased knot, (f) horn knot, (g) edge knot

This categorization is based on the shape and intensity of black colour of the knot. To match the defects level with Agarwood group grade: grade 1 is the good grade, grade 2 is the moderate grade and grade 3 is the lower grade.

3.3 Features Extraction

The features used are texture features extracted from knot image using a Gabor filter bank and also the percentage of the black colour of knot. The Gabor filters are 2D selective band pass filter which is frequency and orientation sensitive respectively [14]. Basically, using this filter, the filtered image is dilated, translated and rotated with regard to each other [14]. The mathematical definition is defined as:

$$G_{f,\theta}(x,y) = exp\left[\sqrt{-1}(xfcos\theta + yfcos\theta) - \frac{f^2(x^2+y^2)}{2\sigma^2}\right] \quad (1)$$

where x and y are the pixel coordinate of the image. f is the central frequency of the band pass. θ is the orientation of the filter and σ is the bandwidth. θ is varying to look for texture oriented in a particular direction. While, varying σ to change the support of the basis or the size of the image region being analysed.

Basically, each image is converted to grayscale and normalized to size 32 x 32 pixels. A set of Gabor filter is utilized with six frequencies (0°, 30°, 60°, 90°, 120°, 150°) and six orientations (2.828, 5.657, 11.314, 22.627, 45.255, 90.51). The image is converted with these set filter bank. The result is 36 filtered images. This will give a difference information for each image corresponding to the orientation and frequency. Then, the output image is linked together by row to build a features vector of dimension 1024 × 36.

Meanwhile, the percentage black colour of image is taken from this mathematical expression:

$$\%Black = \left(\frac{1-a}{b}\right) * 100 \quad (2)$$

where a is the number of non-zero matrix and b is the number of array elements. Therefore, mean, standard deviation and percentage black colour of each image are extracted and fed to the ANN classification.

3.4 Features Selection

Features selection can expand the generalization, so avoid the problem of dimensionality and diminish the computational requirement of the classifier [14]. This is a process of selecting or removing the number of features based on the data from features while maintaining or improving the classification accuracy. In this study, the features selection by considering the values of mean and standard deviation extracted from Gabor Filter and percentage of black colour. Some part of the data is removed after it was determined as outliers.

3.5 Artificial Neural Network (ANN) Classification Model

This study utilized try and error method and resulted in a three-layer ANN model structure. Figure 5 shows the architecture of a three-layers ANN. The dataset split into three parts which are 70% of dataset for training, 20% of dataset for testing and 10 % of dataset for validation. These parts were selected randomly from the original whole set of data.

The initialization of weight is selected form non-zero value between interval of [-1,1]. But this initialize value needs to re-select and go through the same training to reach global minima. During the training session, the weight is updated from train dataset and then validation dataset is applied to avoid over-fitting. For stopping criteria, the total number of neurons in hidden layer was varied until the Mean Squared Error (MSE) value approximately to 0.01 was achieved without disturbing the performance.

3.6 Input for ANN

There are three inputs for Artificial Neural Network. Two inputs are from the extracted features of Gabor Filter output and one input is from the total percentage of black colour. These inputs are means, standard deviation and percentage black colour of the sample. For this study, the total number of sample is 410. Each sample has values of means, standard deviation and percentage of black colour.

3.7 Hidden Layer and Note for ANN

Usually, the neural network is made up of one or more neurons layer interconnected between input layer, hidden layer and output layer. Depending on the design structure of network, each layer has the number of nodes connected to other nodes in the other layer. The propagation of information flow in single direction from input to the neurons output layer in the network training.

Inputs are received by the input layer, which performs as a data distribution center and fans out the inputs to the first hidden layer. Each hidden layer will first activate and transform the data before propagating them to the next layer. This process is repeated through each hidden layer until finally all of the outputs from the last hidden layer will be reunited in the output layer to produce the network outputs. For this study, the three Multi-Layer Propagates is used using the trial and error approach.

3.8 Threshold

Each image will go through thresholding in order to differentiate between the wanted and unwanted parts. In this process, image will be converted to black and white where black is unwanted part and white is wanted part. The threshold weight range on the scale between 0 and 1. Each threshold weight will produce different coverage of blacked area of the image.

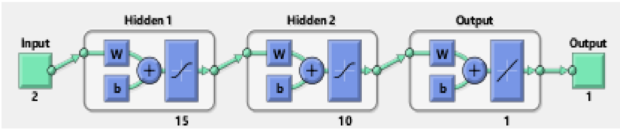

Figure 5. Three-layer ANN.

3.9 Computer Numerical Control (CNC) Machine

The type of CNC machine utilized in this study is SpectraLight 0200 Machining Center as shown in Figure 6. This machine is used for carving process in acquiring valuable Agarwood core. This machine is a three-axis milling machine that can be run directly from computer and accepts standard EIA RS-274D G&M code programming. The work area is limited to 13 inches × 2.75 inches (330 mm × 70mm). It can travel about 8.5 inches (216mm) along X-axis, 4.5 inches (114mm) along Y-axis and 5.5 inches (140mm) along Z-axis. For this project, the *gcode* for CNC machine is generated by Inkscape software.

4. RESULT AND DISCUSSION

This This experiment was implemented in MATLAB R2016a and computer Lenovo Ideapad z585 with a processor of AMD A6-4400M APU with a Radeon HD Graphics of 2.70 GHz and a 4 GB RAM. The separation of group for grading system is based on the percentage of black colour and shape for each wood knots. By using the Eq. 2, the percentage of black colour of dataset can be categorized into three groups with specific knots corresponding to the mean and standard deviation. The results are shown in the Table 4. The input data for classification is represented in three-dimension graph in Figure 7.

Figure 6. SpectraLight 0200 Machining Center.

Table 4. Classification based on percentage of black color

Grade	Type of knot	Percentage of black colour (%)
1	Encased	51-100
2	Horn and edge	31-50
3	Dry, sound, decayed and leaf	0 -30

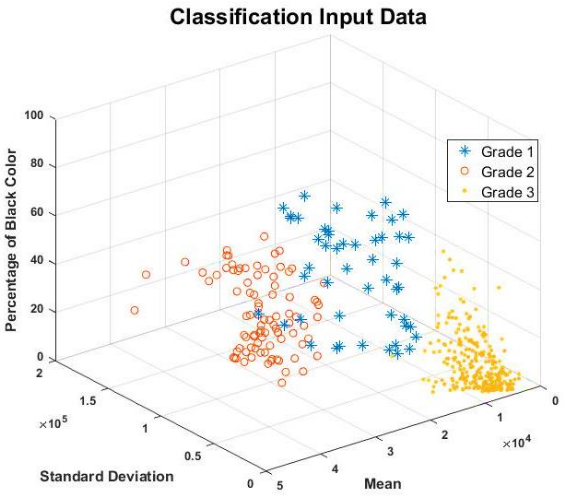

Figure 7. Three-dimension classification input data.

For ANN, the experiment was carried out by varying the number of neurons in both hidden layers. First experiment involved varying the number of neurons in the first hidden layer but fixing the number of neurons in second layer. Second experiment involved varying the number of neurons in the second hidden layer but fixing the number of neurons in the first layer. Both experiments were tested on the same dataset of training, validation and testing. The activation function is sigmoidal with scalar output 0 (false) and 1 (true). The result for the the first and second experiments are shown in Table V and VI, respectively.

From Table 5, the testing accuracy is increased each time when the number of neurons in the hidden layer 1 is increased. But at 16 neurons, the accuracy is slightly decreased. From Table 6, the testing accuracy is increased when the number of neurons in the hidden layer 2 is increased but slightly decreased when the total number of neurons reached 11. Overfitting of data had caused the decreased in the accuracy. Therefore, the results shown that the best ANN structure is with three input neurons, 15 first hidden layer neurons, and 10 second hidden layer neurons. There are 3 out of 85 number of sample error classifications for this testing accuracy where the dataset was selected randomly. The final ANN model structure applied for this experiment is shown in Figure 8.

The carving process was carried out by SpectraLight 0200 Machining Center using cylinder drill with diameter size of 3.175 mm. The test sample was prepared using regular wood with dimension of 8cm×6cm and thickness of 2cm. The size of working area is set to 6cm×6cm. The results of carving process are shown in the Table 7. The result for sample after carving 1mm depth shown in Figure 9.

The results in Table 7 show that the removed wood weight and time taken are increasing with the increasing number of grade. But, the removed wood weight depends on the covered black areas of Agarwood. If the total black area is large, the removed wood weight is less. This also will affect the total time taken to complete the carving process. From this experiment, the carving process can be accomplished by using CNC machine to minimize the total time taken to complete the process.

Table 5. Result for varying number of neurons in first hidden layer

Network Structure			Mean Squared Error	Clustering Accuracy (%)	
Input	***Hidden 1***	***Hidden 2***		***Training***	***Testing***
3	9	5	0.01	100	92.41
3	10	5	0.01	100	95.78
3	11	5	0.01	100	96.72
3	12	5	0.01	100	97.33
3	13	5	0.01	100	97.51
3	14	5	0.01	100	98.11
3	15	5	0.01	100	98.21
3	16	5	0.01	100	97.46

Table 6. Result for varying number of neurons in second hidden layer

Network Structure			Mean Squared Error	Clustering Accuracy (%)	
Input	***Hidden 1***	***Hidden 2***		***Training***	***Testing***
3	15	6	0.01	100	93.12
3	15	7	0.01	100	94.03
3	15	8	0.01	100	96.30
3	15	9	0.01	100	98.50
3	15	10	0.01	100	98.54
3	15	11	0.01	100	97.91

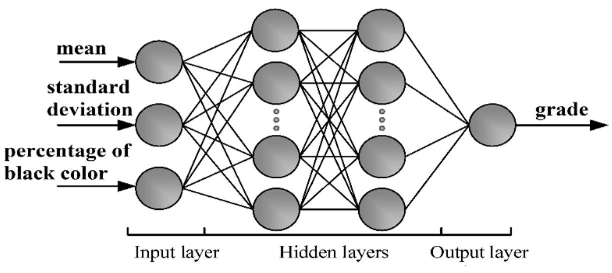

Figure 8. ANN structure used

Table 7. Result for carving experiment

Sample type	Depth drill	Weight removed	Time taken
Grade 1	1mm	0.84g	4m 35s
Grade 2	1mm	0.91g	5m 44s
Grade 3	1mm	1.05g	6m 55s

5. CONCLUSION

In this paper, a three-layer Artificial Neural Network is utilized, built from 3 number of input neurons, 15 number of first hidden layer neurons, 10 number of second hidden layer neurons and 1 output. The inputs were extracted from Gabor filter (mean and standard deviation) and percentage of black color. The data was classified into three grades based on percentage of black color and wood knots. The results of ANN are satisfied with an accuracy of 98.54%. The carving process was accomplished by using a CNC machine. The removed wood weight is proportional to the blackened areas (image processing) prior the carving process. The time taken to complete also depends on the covered black area of and complexity of the shape.

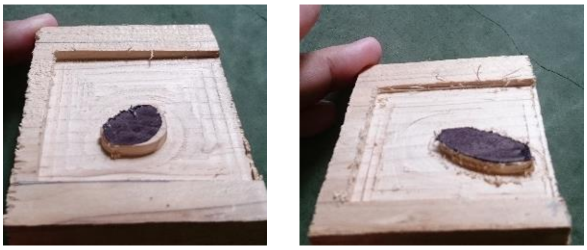

Figure 9. Sample results after 1mm depth carving

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