STRUCTURAL AND STATISTICAL CONTENT VALIDATION OF COMPLEX IMAGES Using texture structure modeling and fuzzy neural network

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Abstract: This research work is on the complex image structure. Statistical and adaptive technique is used on complex texture regions for analysis. Filled and partially filled regions of see through register security feature of an Indian currency have been extracted using image segmentation. Statistical and geometrical properties of various regions of the segmented image of see through register have been defined and their corresponding values have been analyzed using a machine learning technique viz. Neuro-Fuzzy System. This paper has proposed some approaches to check whether some criteria we have defined meet or satisfy them using our proposed methodology or not**.**

***IndexTerms* - SD region area, image open, segmentation, texture structure, region sector, neurofuzzy system.**

I. INTRODUCTION

The Indian currencies are made of complex texture regions with some significant features so that it cannot be counterfeited. The Indian currency contains many security aspects among them the see through register is one important among them. The counterfeited currencies also try to mimic this feature but it does not demonstrate exactly the behaviors what it should be according to the standards defined by government and standardization bodies. This work demonstrates a step wise abstraction procedure of some essential content based structures from the original and the sample currency's see-through register region. The features abstracted by the adopted procedure bears some significant properties which can easily discriminate fake notes from the original notes. A Fuzzy Inference System(FIS) model is developed to test the feature properties by some inference rules adopted in the model. Artificial Neuro-Fuzzy Inference System(ANFIS) technique is used to train the FIS using training data set and checking dataset. The dataset is created using the abstraction methodology adopted in the work. Testing data set collected from the sample notes are fed into the model. The detection process by the fuzzy inference system puts the sample notes into three categories- original, fake and doubtful.

II. OBSERVATION

The motivation of the work goes from the opacity or transparency of images captured by a camera and from the filled, partially filled or the regions filled with less opacity in a currency. Some feign currencies tend to show some discontinuity in the filled security feature regions. Sometime although it appears to be continuous but the intensity varies abruptly or smoothly in the whole region. The see-through security feature region have been taken as the base in this paper for investigation. I have used as a reference the old 500 currency note as a reference which is now obsolete in the market after demonetisation decision of Indian government. We can take it as a reference the old genuine currency and a fake currency used at that time as a reference for experiment and can try to explore the potential issues and vulnerabilities of the old currencies. In the following figure the see-through register section of 2 sample currency notes,(first one original and second one counterfeited) have been shown,

Fig. original and counterfeited region of see through register region of currency

III. LITERATURE SURVEY AND THEORITICAL FOUNDATION

Some of the basic concepts related to the experiment and the algorithm used for discriminating image is mentioned below,

3.1 Structural content analysis

If there is inter relation among pixels and they form a close special distribution in an image then they can describe some structural information. These dependencies convey important information regarding the structure of the objects in the human visual perception. [9]

3.2 Contrast Stretching

Sometimes we need to increase the intensity value of some pixels in certain area or region of an image for greater visibility if they are not clearly visible. Contrast enhancement processes adjust the relative brightness and darkness of objects in the scene to improve their visibility. The contrast and tone of the image can be changed by mapping the gray levels in the image to new values through a gray-level transform. The mapping function reassigns the current gray level GL to a new gray level GL´. [13]

A high-contrast image spans the full range of gray-level values; therefore, a low-contrast image can be transformed into a high-contrast image by remapping or stretching the gray-level values such that the histogram spans the full range. The contrast stretch is often referred to as the dynamic range adjustment (DRA). The simplest contrast stretch is a linear transform that maps the lowest gray level GL_{min} in the image to zero and the highest value GL_{max} in the image to 255 (for an eight-bit image), with all other gray levels remapped linearly between zero and 255, to produce a high-contrast image that spans the full range of gray levels. This linear transform is given by, [13].

$$g'(x,y) = INT\left\{\frac{255}{GL_{max} - GL_{min}}[g(x,y) - GL_{min}]\right\}$$

Where, the INT function returns the integer value. If we wish to remap the image to a gray-level range defined by a new minimum GL'_{min} and a new maximum defined by GL'_{max}, the linear transform, [13]

$$g'(x,y) = INT\left\{\frac{GL'_{max} - GL'_{min}}{GL_{max} - GL_{min}}[g(x,y) - GL_{min}] + GL'_{min}\right\}$$

The linear transform for contrast enhancement spreads the gray-level values evenly over the full contrast range available; thus, the relative shape of the histogram remains unchanged but is widened to fill the range. The stretching of the histogram creates evenly distributed gaps between gray-level values in the image. Note that although the linear transform will increase the contrast of the image, the steps between the populated gray-level values increase in contrast as well, which can result in visible contouring artefacts in the image as shown below,

Fig. See through register security feature portion of the RGB Image of an Rs 500 denomination

Fig. Gray Scale Image of the see through register security feature portion of an Rs 500 denomination

Fig. Contrast stretched Image of the see through register security feature portion of an Rs 500 denomination we can see the artefacts are clear(the distinct lines)

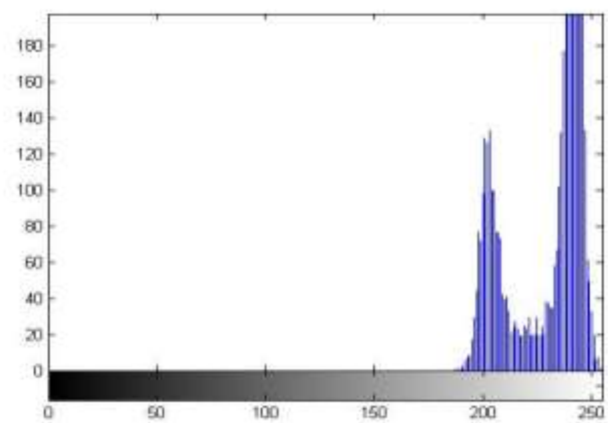


Fig. Histogram of the Gray Scale Image of the see through register security feature portion of an Rs 500 denomination

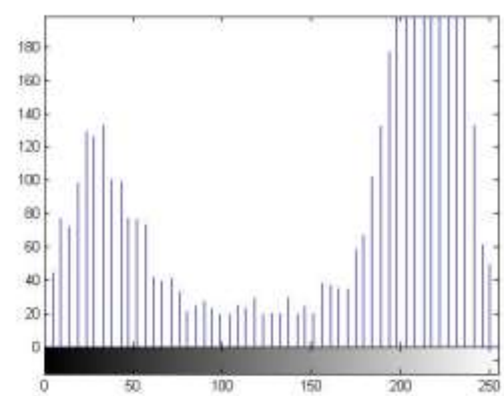


Fig. Histogram of the contrast stretched Image of the see through register security feature portion of an Rs 500 denomination

3.3 Image Segmentation and Image binarization

Segmentation is a process of dividing an image into different disconnected regions or objects. Segmentation algorithms work into two ways[7]

i) Based on discontinuity of intensity in an image

ii) Based on similarity of intensities in an image

Based on discontinuity special masks are designed to detect points, lines and edges. Region based segmentation works on continuity of intensity in certain area in an image. Regions after segmentation when thresholded it becomes a binary image containing present or absent i.e. intensity of 0 or 1.

3.3 Image morphology

Image morphology is a technique used as a tool for extracting image components that are useful in the representation and description of region shape, such as boundaries, skeletons, etc. Opening is an example of image morphological operation. Morphology is the study of shape. Mathematical morphology mostly deals with the mathematical theory of describing shapes using sets. In image processing, mathematical morphology is used to investigate the interaction between an image and a certain chosen structuring element using the basic operations of erosion and dilation. Mathematical morphology stands somewhat apart from traditional linear image processing, since the basic operations of morphology are non-linear in nature, and thus make use of a totally different type of algebra than the linear algebra [15]. Morphological techniques probe an image with a small shape or template of elements called a structuring element or mask.

3.4 Correlation and convolution between two images

Correlation and convolution are displacement function, i.e. they are used to slide the filter mask(structuring element) across the image. Convolution is same as correlation except that the filter mask is rotated 180 degree before computing the sum of products.

3.4 Erosion and Dilation

The erosion of f by a flat structuring element b(or a mask) at any location (x, y) is defined as the minimum value of the image in the region coincident with b when the origin of b is at (x,y). Therefore, the erosion at (x, y) of an image f by a structuring element b is given by[14]

$$[f\Theta b](x,y) = \min_{(s,t)\in b}\{f(x+s, y+t)\}$$

where, similarly to the correlation, x and y are incremented through all values required so that the origin of b visits every pixel in f. That is, to find the erosion of f by b, we place the origin of the structuring element at every pixel location in the image. The erosion is the minimum value of f from all values of f in the region of f coincident with b.

3.5 Opening and closing operation on an Image

The opening of a binary image f by structuring element b is defined as the erosion of f by b followed by a dilation of the result with b

$$f \circ b = (f\Theta b) \oplus b$$

Similarly, the closing of f by b is,

$$f \bullet b = (f \oplus b)\Theta b$$

Application of opening operation on an image is shown as below,

Fig. The gray scale image first eroded then opened by a 5x5 structuring element

3.6 Fuzzy logic and fuzzy set theory

In fuzzy set an member ship value of an element is in the range [0,1]. i.e $0 \le \mu(x) \le 1$. Where x is an element of the fuzzy set and $\mu(x)$ is called the membership function which maps membership grade of the element in the range [0,1]. Generally a fuzzy set is described as a pair (A, μ) where A is a set and U is a universal set such that A $\subseteq$ U and

$$\mu_A : U \to [0,1]$$

So, for each member x $\in$ A, the value $\mu(x)$ is called the grade of membership of x in (A, μ)[16]. For the finite set A={ $x_1, x_2, ...x_n$ }, the fuzzy set (A, μ) is often denoted by $\{\mu(x_1)/x_1, \mu(x_2)/x_2, ..., (\mu_n)/x_n\}$. Say $x \in A$ then x is a fuzzy variable and is said to be not included in the set A if $\mu(x) = 0$ and fully included if $\mu(x) = 1$ and x is a fuzzy member if $0 < \mu(x) < 1$.[17]

Membership functions can be of different types. Some commonly used membership functions for image processing purpose are, triangular, trapezoidal, Gaussian, sigmoid, bell shaped, S-shaped(splined based, left open), Z-shaped(splined based, right opened). Some common membership functions commonly used in practice is as under, we are considering x and y as input variables and a,b,c as constants,

AND(prod): AND(x,y)=x*y
OR(sum): AND(x,y)=x+y
OR(probor): OR(x,y)=x+y-xy

Generally Sugeno Model of fuzzy system follows the two type of output membership functions for output variables which will be discussed shortly,

Linear(x.y)=z
z=ax+by+c
where z is the output variable.

Constant(x,y)=z
z=c
where a=b=0

Fuzzy proposition, connectives and multi-valued logic

Propositional variables which assumes true or false value in conventional logic. One area of logic referred to as propositional logic which deals with combination of propositional variables using logical connectives also called logic functions like $\wedge$(AND or Conjunction), $\vee$(OR or disjunction), $\neg$(NOT or negation), $\Rightarrow$(if.. then or implication), $\Leftrightarrow$(if and only if or bijection), ⟸(inhibition)[16], ⊽(NOR or not or)[16] etc. which stands for another new arbitrary proposition[19]. Conventional logic cannot deal with the events or conceptions which are neither actually true or nor actually false, hence the truth value is undetermined at-least prior to the event[16]. E.g. the statement "A security feature of an Indian currency is preset in a particular bank note" is not fully true because each and every aspect and properties of the security feature may not be present or incorporated by a counterfeiter in to the feature. So we cannot say that the feature is fully present in the note also we cannot say that it is not present because some aspect or properties of the feature may match with the original currency. Multi valued logic have three types of values true(or 1, one), false(or , zero) and an intermediate value which between 0 and 1 and which conveys the meaning of not fully true or not fully false[16].

Inference rules and predicates

Logical propositions are connected with logical functions or connectives to form logical formulas. E.g $(x\wedge \sim y)\vee \sim (x \wedge y) \vee y$ .When a logical formula is always true it is called a tautology(e.g. x$\Rightarrow$(x$\vee$y) when it is always false it is called a contradiction[19]. Tautologies are facts. There can be some logical formulas which are called premises or hypothesis and from these premises we can infer or deduce some another propositional formulas which is called conclusions. There are many deduction procedures. These deduction procedures are called inference rules. Inference rules are nothing but some tautologies[19]. E.g.

$$(x \wedge (x \Rightarrow y)) \Rightarrow y \text{ [Modus pones]}$$

$$(\neg x \wedge (x \Rightarrow y)) \Rightarrow \neg x \text{ [Modus Tollens]}$$

The inference rule for generalized modus pones(forward chining) rule for fuzzy logic can be expressed as,

$$\begin{array}{c} x \\ x \Rightarrow y \\ \hline \therefore y \end{array}$$

This is interpreted as follows,
Premise 1: x IS A
Premise 2: IF x IS A then y is B
Conclusion: y is B
Where, A and B are any two fuzzy set from the universe of discourse U.

Instead of dealing with a particular proposition we sometimes use the general form "x is P", where x stands for any subject from the universe of discourse U and P is called predicate which plays the role of a function defined on U. Say in our currency verification context we can say that "₹500 note is genuine" where x="₹500 note" is a subject variable which can assume ₹1000, ₹100 etc and P="is genuine" is the predicate. Another e.g. can be "In micro lettering feature of the 500 note RBI word is not distinct", "The optically variable ink shines blue upon tilting, so the note is genuine".

We can apply generalized modus pones rule for our Indian currency validation in fuzzy context like "The see-through register numeral when seen in light is continuous and if see through register numeral looks continuous then the feature is of a genuine note therefore the note is a genuine note". Where, the premises or the hypothesizes are,

x="the see-through register numeral when seen in light"

y="the feature is of a genuine note"

3.7 Artificial Neuro Fuzzy Inference System ANFIS

The basic structure of Mamdani fuzzy inference system is a model that maps input characteristics to input membership functions, input membership functions to rules, rules to a set of output characteristics, output characteristics to output membership functions, and the output membership functions to a single-valued output or a decision associated with the output. Such a system uses fixed membership functions that are chosen arbitrarily and a rule structure that is essentially predetermined by the user's interpretation of the characteristics of the variables in the model[22].

Sometime we want to apply fuzzy inference to a system for which we already have a collection of input/output data that we would like to use for modeling, model-following, or some similar scenario. We do not necessarily have a predetermined model structure based on characteristics of variables in our system. In some modeling situations, we cannot determine what the membership functions should look like by looking at data[21]. Rather than choosing the parameters associated with a given membership function arbitrarily, these parameters could be chosen so that it can shape the membership functions to the input/output data in order to account for these types of variations in the data values[22]. In such cases, we can use the Fuzzy Logic Toolbox neuro-adaptive learning techniques incorporated in the anfis command in matlab. The neuro-adaptive learning method works similarly to that of neural networks. Neuro adaptive learning techniques provide a method for the fuzzy modeling procedure to learn information about a data set.

The acronym ANFIS derives its name from adaptive neuro-fuzzy inference system. Using a given input/output data set, anfis constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a back propagation algorithm alone or in combination with a least squares type of method (hybrid). This adjustment allows our fuzzy systems to learn from the data they are modelling[22].

IV. SUGENO TYPE FUZZY INFERENCE MODEL

Fuzzy inference system has two inputs x and y and one output z. A first-order Sugeno fuzzy model has rules as the following[22],

Rule1:

If x is A1 and y is B1, then, $f1 = p_1 x + q_1 y + r_1$

Rule2:

If x is A2 and y is B2, then, $f_2 = p_2 x + q_2 y + r_2$

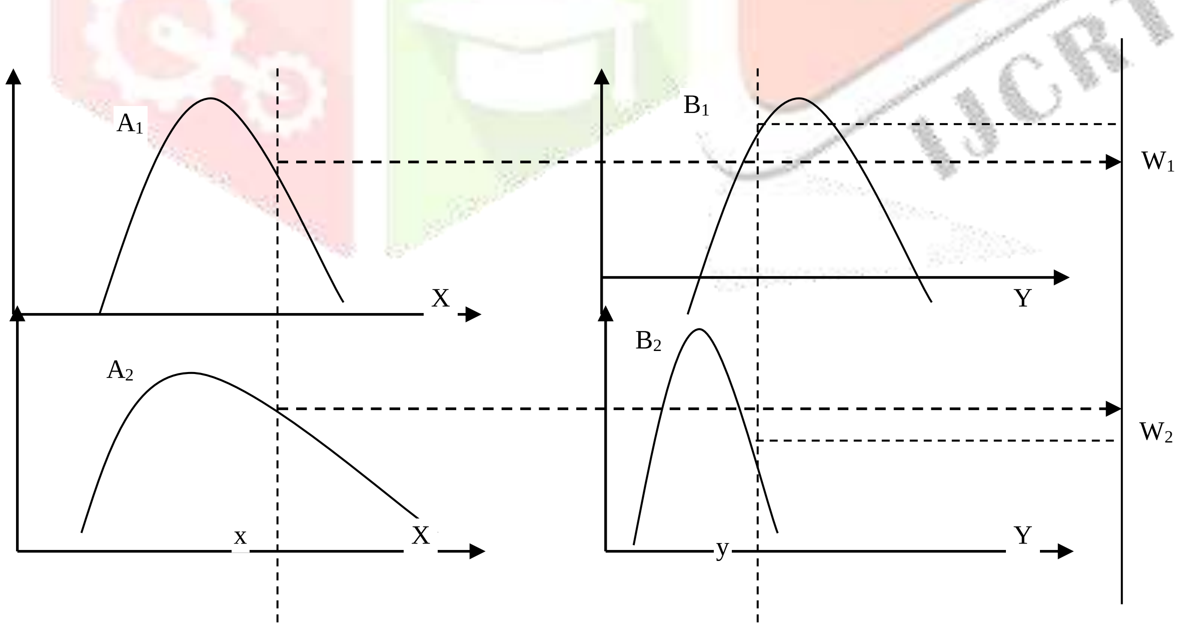


Fig. Membership function plot showing weight on each membership function

$$f1 = p_1 x + q_1 y + r_1 \qquad f_2 = p_2 x + q_2 y + r_2 \qquad f = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2}$$

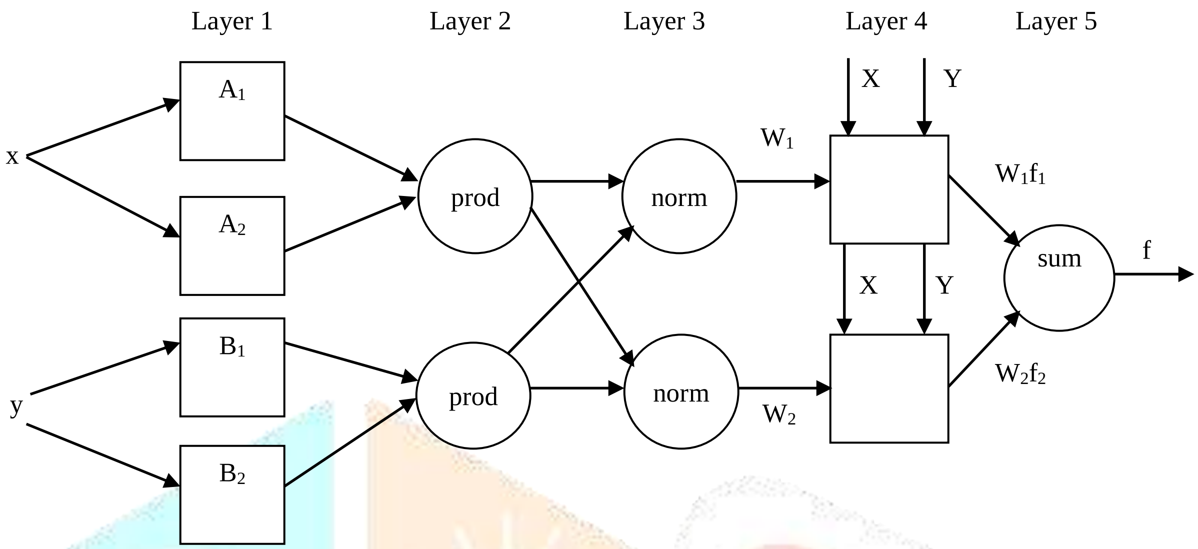


Fig - ANFIS Model Layout layerwise

In layer1 every node i is adaptive node with node function,

$$O_{1,i} = \mu_{A_i}(x) \text{ for i=1,2 or}$$

$$O_{1,i} = \mu_{B_{i-2}}(x) \text{ for i=3,4}$$

x or y is input node to i and A_i (or B_{i-2}) is a linguistic label associated with this node. Therefore $O_{1,i}$ is the membership grade of a fuzzy set (A_1,A_2,B_1,B_2)

Typical membership function is,

$$\mu_A(x) = \frac{1}{1+\left|\frac{x-c_i}{a_i}\right|^{2b_i}}$$

Where, a_i,b_i,c_i are the parameter set also called premise or hypothesis set.

In Layer 2 every node a fixed node labelled "prod" or product,

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{Bi}(y); i = 1,2$$

Each node represents the firing strength of the rule. Any other T-norm operator that perform the AND operation can be used.

In Layer 3 every node a fixed node labelled "norm". The i^{th} node calculates the ratio of the i^{th} rule's firing strength to the sum of all rule's firing strength.

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2}, i = 1,2$$

Outputs of layer 3 are normalized firing strengths.

Every node i in layer 4 is an adaptive node with a node function,

$$O_{4,1} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i)$$

Where, $\overline{w_i}$ is the normalized firing strength from layer 3 and $\{p_i, q_i, r_i\}$ are the parameter set in this node. These are also referred to as consequent parameters.
The single node in this layer is a fixed node labelled sum, which computes the overall output as summation of all incoming signal.

The ANFIS can be trained by a hybrid learning Algorithm. In the forward pass the algorithm uses least-squares method to identify the consequent parameters on the layer 4. The best fit in the least-squares minimizes the sum of squared residuals i.e the residual or error is the difference between an observed value and the fitted value provided by a model.
In the backward pass the errors are propagated backward and the premise parameters are updated by gradient descent

Error measure is an important aspect in Artificial Neuron Models. Error minimization is an optimization problem to find the best suited weights for the neurons.

Assume that a training data set has P entries then the error measure for the pth entry can be defined as the sum of the squared error,

$$E_p = \sum_{m=1}^{P} (T_{m,p} - O_{m,p}^{L})^2$$

Where, $T_{m,p}$ is the mth component of the pth target. $O_{m,p}$ is the mth component of the actual output vector. The overall error is[24],

$$E = \sum_{p=1}^{P} E_p$$

4.1 Error rate for each output in Sugeno Takazi ANFIS Model

In order to implement the gradient descent in E we calculate the error rate $\frac{\partial E}{\partial O}$ for the pth training data for each node output O.

The error rate at (L,i) is[24],

$$\frac{\partial E_p}{\partial O_{i,p}^{k}} = \sum_{m=1}^{k+1} \frac{\partial E_p}{\partial O_{m,p}^{k+1}} \frac{\partial O_{m,p}^{k+1}}{\partial O_{i,p}^{k}} \text{ where, } 1 \le k \le L-1$$

The error rate of an internal node is a linear combination of the error rates of the nodes in the next layer. To calculate error rate for each parameter, let α be one of the parameters[24],

$$\frac{\partial E_p}{\partial \alpha} = \sum_{O^* \in S} \frac{\partial E_p}{\partial O^*} \frac{\partial O^*}{\partial \alpha}$$

where S is the set of nodes whose outputs depend on α . The derivative of overall error[24] with respect to α is,

$$\frac{\partial E}{\partial \alpha} = \sum_{p=1}^{P} \frac{\partial E_p}{\partial \alpha} \text{, the update formula for } \alpha \text{ is } \Delta\alpha = \eta \frac{\partial E}{\partial \alpha}$$

If parameters need to be updated after each input-output pair(i.e online training) then the update formula is[24],

$$\frac{\partial E_p}{\partial \alpha} = \sum_{O^* \in S} \frac{\partial E_p}{\partial O^*} \frac{\partial O^*}{\partial \alpha}$$

With the batch learning (off-line learning) the update formula is based on the derivative of the overall error with respect to α [24],

$$\frac{\partial E}{\partial \alpha} = \sum_{p=1}^{P} \frac{\partial E_p}{\partial \alpha}$$

Gradient rule as described above is slow one. Hybrid Learning combines both gradient rule and least square approach. Let's consider that the adaptive network has only one output[24].
output = F(I, S)
I is the vector of input variables, S is the set of parameters, F is the function implemented by the ANFIS.

V. RESEARCH METHODOLOGY

The main idea behind the methodology is to verify the see through register security feature using structural property and statistical properties. First the algorithm exposes the foreground of the image then the binary set of pixels is extracted. Some statistical and geometrical properties of this binary image are determined. Values of these statistical and geometrical properties are then calculated. These are then analyzed in a fuzzy neural network.

Since the numerals of the see through register portion of an original note seems to be visible as a whole that is there is not much fragment on it, we can compare the following properties of the see through register feature of the sample note by exposing it under sunlight with that of an original one taken as a base in similar lighting conditions,

i) Maximum area of a segmented region in the feature
ii) Minimum area of the segmented region in the feature
iii) Range of area from large segment to small segment
iv) Total area of segmented region
v) Average area of segments
vi) Standard deviation of the segmented areas
vii) Maximum perimeter of a segmented region in the feature
viii) Minimum perimeter of a segmented region in the feature
ix) Range of perimeter from maximum to minimum segment
x) Total perimeter of segmented region
xi) Average perimeter of the segments
xii) Standard deviation of the segmented perimeters

We can choose any one of the measures from the above which seems to be convenient in the context but besides these four more measures we can incorporate additional four measures improving the performance of the four measures mentioned above can be proposed,

xiii) Mean of the four largest segmented areas
xiv) Standard deviation of the four largest segmented areas
xv) Mean of the perimeters of the four largest segmented areas
xvi) Standard deviation of the perimeters of the four largest segmented areas

We can incorporate the above four additional measurements on the basis of the fact that when segmentation is done on the see register portion of the sample note six distinct regions are formed and when an original note is segmented three whole regions consisting of the one "5" number and two "0" numbers are formed. But sometimes poor illuminations and reflection from other light sources can lead to 5 to 6 or 7 disconnected regions. So we have considered median of the numbers 3,4,5,6,7 for considerations i.e. 5. But if we arrange the segmented region areas in ascending order of areas then the largest areas can impact the result more so instead of 5 we can take 4 largest segmented areas.

5.1 Notations and terminology for the proposed algorithm

I_O represents original currency image,
I_F represents sample currency image may be a fake one,
I_{OGRAY} represents gray scale version of the original currency,
I_{FGRAY} represents gray scale version of the sample currency,
$I_{OBACKGROUND}$ represents the background of the see through register feature of original currency,
$I_{FBACKGROUND}$ represents the foreground of the see through register feature of original currency,
$I_{FFOREGROUND}$ represents the foreground of the see through register feature of sample currency,
$I_{OFOREGROUND(CONTS)}$ represents the contrasted foreground of the see through register feature of original currency,
$I_{FFOREGROUND(CONTS)}$ represents the contrasted foreground of the see through register feature of sample currency,
I_{OBW} represents the black and white binary image obtained from $I_{OFOREGROUND(CONTS)}$,
I_{FBW} represents the black and white binary image obtained from $I_{FFOREGROUND(CONTS)}$

VI. PROPOSED ALGORITHM

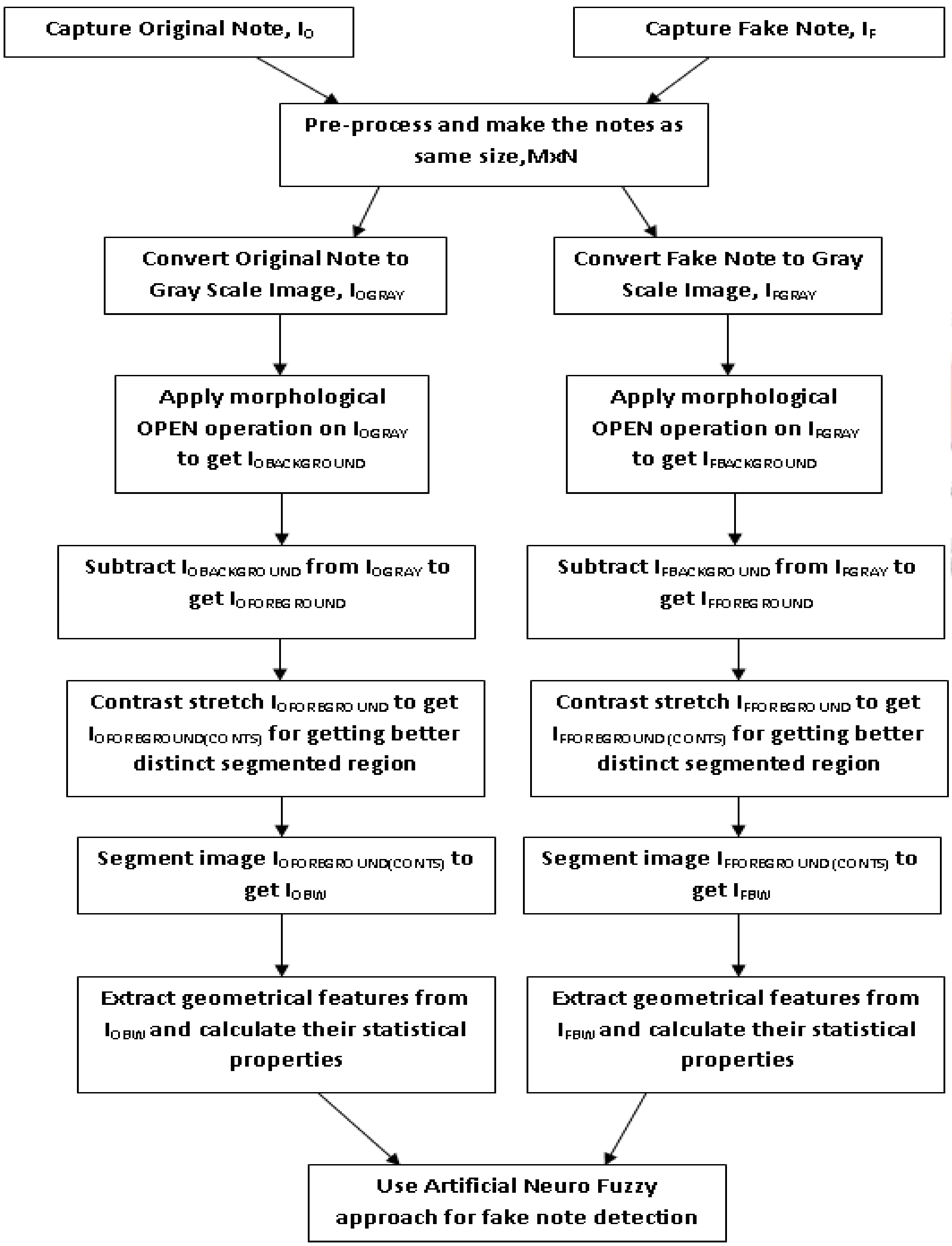
Description: An efficient procedure to extract the numeral digits from the see through register feature of a currency

Input: see through register portion of the
Output: Structural, geometrical and statistical properties of different segmented regions.
Step 1 Capture sample image $I_{S.}$
Step 2 Convert I_S to gray scale image $I_{S(gray)}$.

Step 3 Apply OPEN($I_{S(gray)}$) to get $I_{S(background)}$.
Step 4 $I_{S(foreground)}= I_{S(gray)} - I_{S(background)}$.
Step 5 contrast stretch $I_{S(foreground)}$ with a threshold value to get $I_{S(foreground\text{-}const)}$.
Step 6 covert $I_{S(foreground\text{-}const)}$ to binary image I_B.
Step 7 Extract region properties like number of region areas, total segmented region area, maximum region size, minimum region size, average area size, standard deviation of areas, area range, minimum perimeter region, maximum perimeter region, average perimeter size, standard deviation of areas, perimeter range, standard deviation of 4 largest regions, standard deviation of 4 largest perimeters.

Observation in step 5 gives a key distinguishing feature of the proposed approach.

6.1 Flow diagram of the proposed methodology



6.2 ANFIS Model for fake Currency Prediction

We have taken two features of an Indian currency of denomination Rs 500 into consideration for testing, the "optically variable ink numeral" and the "see through register". The values of properties extracted from the 2 features by the procedure for verification of see through register and the proposed interchanging color verification algorithm using dominant color as discussed earlier are taken as input to the ANFIS model.

The following section elaborates the use of statistical measurements as input to a fuzzy system model which are being used to forward the study from data towards inferences. The detail of methodology is given as follows,

I) Inputs

Our ANFIS model takes 6 input variables,

i) MSE (Mean square error interchanging color verification algorithm)
ii) SD_Intensity (Standard deviation of intensity interchanging color verification algorithm)
iii) Skewness (Skewness of the histogram of the green channel from the image obtained from interchanging color verification algorithm)
iv) Max_segmented_area (Maximum segmented area from the procedure for verification of see through register)
v) SDFourLargeSegmentedArea (Standard deviation from 4 largest segmented area from the procedure for verification of see through register)
vi) SDFourLargestPerimeter (Standard deviation of 4 largest segmented perimeters from the procedure for verification of see through register)

II) Membership Functions

The type of membership function for fuzzyfication of the crisp values of the 6 inputs mentioned as above are as follows,

i) more (Sigmoid function for MSE)
ii) variesmore (Sigmoid function for standard deviation of intensity)
iii) increases (Tapizoid function for skewness)
iv) more (Sigmoid function for maximum segmented area)
v) sizedifferssmore(Sigmoid function for standard deviation from 4 largest segmented area)
vi) more (Sigmoid function for standard deviation of 4 largest segmented perimeters)

III) Output variables

The output variable is taken as "currency", since there can be only one output variable in case of Suggeno type fuzzy model. The output variable has three output functions as below,

i) Original(for original currency)
ii) Fake (for fake currency)
iii) Doubtful (undeterministic)

IV) Output Functions

Output membership function for output variable is taken as linear. i.e for our 6 inputs it is like, au+bv+cw+dx+ey+fx+g=0 where (u,v,w,x,y,z) are the 6 variables and a,b,c,d,e,f,g are constants.

V) Fuzzy Inference Rules

There are three fuzzy rules proposed for 3 output variables,

a) If(MSE is more) and (SD_Intensity variesmore) and (Skewness is inceases) and (max_segmented_area is coversmorearea) and (SDFourLargeSegmentedArea is differsmore) and (SDFourLargestPerimeter is longer) then currency is original
b) If(MSE is more) or (SD_Intensity is variesmore) or (Skewness is inceases) or (max_segmented_area is coversmorearea) or (SDFourLargeSegmentedArea is differsmore) or (SDFourLargestPerimeter is longer) then currency is fake

c) If(MSE is not more) or (SD_Intensity is not variesmore) or (Skewness is not inceases) or (max_segmented_area is not coversmorearea) or (SDFourLargeSegmentedArea is not differsmore) or (SDFourLargestPerimeter is not longer) then currency is doubtful

We have taken AND method as “prod” i.e. simple product, OR method as “probor” i.e. probabilistic or, for defuzzification we have taken “wtaver” i.e. weighted average function.

6.3 ANFIS Model for fake Currency Prediction

The following ANFIS model is generated using matlab software,

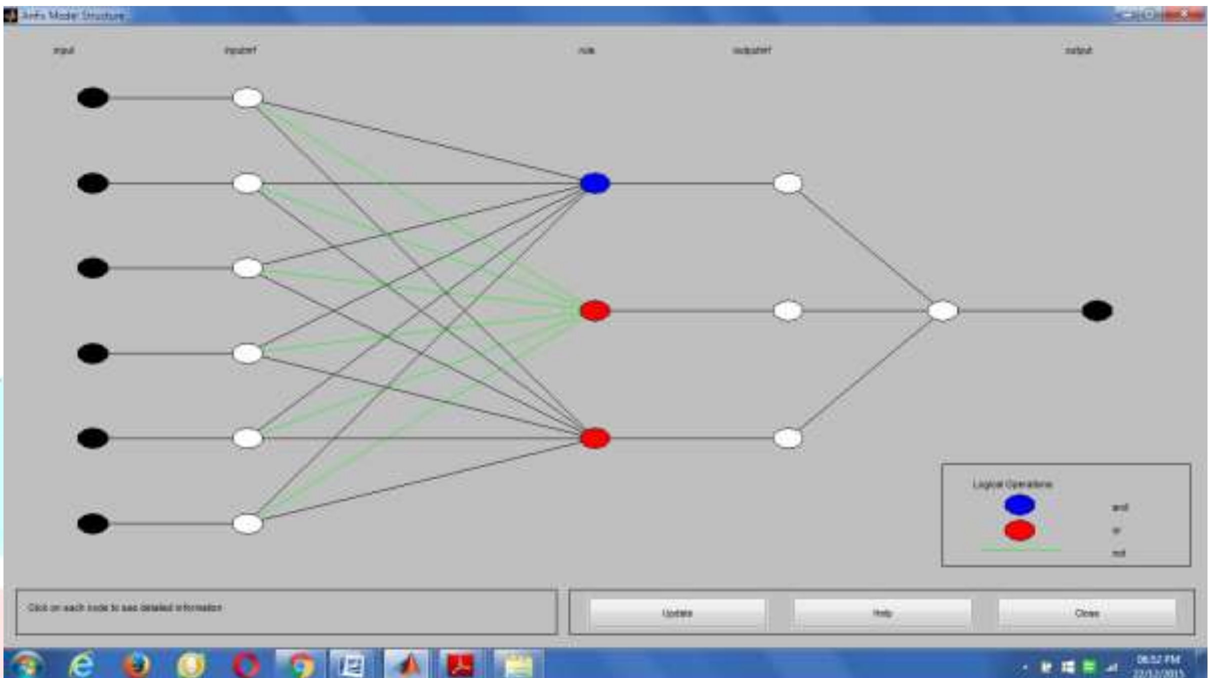


Fig: ANFIS model structure proposed

Description:

Black circles: Inputs or output variable

White circles: Input member functions

Blue circles: AND operations

Red circles: Probor operations

Green line: NOT operand

6.4 Source of data

Since no data set is available on the region parameters of Indian currencies. We have collected some original currencies and extracted the statistical geometrical (structural) features from the images by segmentation and region extraction technique. Training set can consists of currency notes of a particular denomination having clean or dusty or to some extent deformed or torn. These geometrical parameters consist of our training set to the ANFIS model. Testing set consists of the statistical geometrical (structural) features of the counterfeited currency of the same denomination. Checking set consists of the statistical geometrical features extracted from some clean and fresh currency notes of the same denomination so that the values can be reliable.

VII. RESULTS AND DISCUSSION

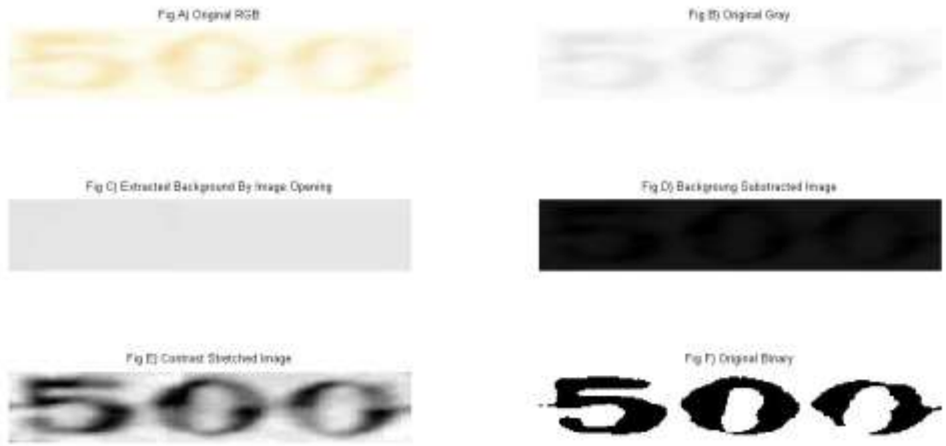


Fig: A) Original RGB note, B) Original Gray Scale, C) Extracted Background By Image Opening, D) Background Substracted Image, E) Contrast Stretched Image F) Original Binary

Tables

Original Currency Measurements

	Original Currency File Name	Maximum Perimeter (in pixels)	Minimum Perimeter (in pixels)	Range of perimeter (in pixels)	Maximum area (in sq. pixels)	Minimum Area (in sq. pixels)	Range of area	Total Area (in sq. pixels)	Average Area (in sq. pixels)	Total Perimeter (in Pixels)	Average Perimeter (in Pixels)	Mean of the four largest segmented areas	Mean of the perimeters of the four largest segmented areas	Standard Deviation of the four largest segmented areas	Standard Deviation of the four largest segmented region perimeters
1	DSC_0344_see_regist...	407	0	407	1706	1	1705	7383	321	1751	76	1134	248	575	130
2	DSC_0345_see_regist...	386	0	386	1536	1	1535	7676	334	1784	77	1209	250	394	185
3	DSC_0347_see_regist...	525	0	525	2959	1	2958	9186	399	2124	92	1579	336	985	181
4	DSC_0348_see_regist...	509	0	509	2441	1	2440	7550	328	1840	80	1303	297	867	185
5	DSC_0349_see_regist...	409	0	409	2910	1	2909	7932	345	1752	76	1398	275	1091	154
6	DSC_0350_see_regist...	524	0	524	2927	1	2928	7459	324	1749	76	1408	208	1151	199
7	DSC_0351_see_regist...	415	0	415	1746	1	1745	7396	322	1695	74	1140	233	618	124
8	DSC_0357_see_regist...	160	0	160	577	1	576	5667	246	1440	63	533	136	31	16
9	DSC_0358_see_regist...	164	0	164	563	1	562	5212	227	1335	58	531	137	25	18
10	DSC_0359_see_regist...	188	0	188	854	1	853	3349	148	854	37	575	140	69	18
11	DSC_0360_see_regist...	160	0	160	612	1	611	5073	221	1252	54	550	137	45	16
12	DSC_0361_see_regist...	148	0	148	523	1	522	4586	199	1203	52	510	134	11	11
13	DSC_0362_see_regist...	410	0	410	1446	1	1445	4751	207	1305	57	742	202	469	139
14	DSC_0363_see_regist...	437	0	437	3098	1	3097	7465	325	1527	66	1388	251	1284	148
15	DSC_0364_see_regist...	343	0	343	1458	1	1457	6326	275	1637	71	961	238	504	115
16	DSC_0365_see_regist...	152	0	152	731	1	730	5385	234	1289	56	996	136	103	13
17	DSC_0370_see_regist...	293	0	293	1241	1	1240	5336	232	1384	60	891	178	367	62
18	DSC_0377_see_regist...	702	0	702	5414	1	5413	9511	414	1793	78	1734	272	2453	287
19	DSC_0379_see_regist...	426	0	426	1742	1	1741	7748	337	1699	74	1357	267	569	127

Fake Currency Measurements

	Fake Currency File Name	Maximum Perimeter (in pixels)	Minimum Perimeter (in pixels)	Range of perimeter (in pixels)	Maximum area (in sq. pixels)	Minimum Area (in sq. pixels)	Range of area	Total Area (in sq. pixels)	Average Area (in sq. pixels)	Total Perimeter (in Pixels)	Average Perimeter (in Pixels)	Mean of the four largest segmented areas	Mean of the perimeters of the four largest segmented areas	Standard Deviation of the four largest segmented areas	Standard Deviation of the four largest segmented region perimeters
1	DSC_0347_see_regist...	114	0	114	522	1	521	2822	244	696	58	496	108	35	5
2	DSC_0348_see_regist...	118	2	116	518	2	516	3855	321	962	74	507	112	9	6
3	DSC_0349_see_regist...	114	2	112	518	2	516	3686	306	873	73	489	108	23	4
4	DSC_0352_see_regist...	114	0	114	518	1	517	3285	274	748	62	496	106	22	6
5	DSC_0357_see_regist...	114	0	114	518	1	517	3487	291	832	69	470	106	33	6
6	DSC_0358_see_regist...	114	0	114	518	1	517	3487	291	850	71	464	107	36	5
7	DSC_0359_see_regist...	114	0	114	518	1	517	3040	253	743	62	463	105	39	7

Table1: structural parameter values

Discussion on the currency measurements:

From the above two tables generated in matlab software we can notice the values of significant structural properties along with the values of statistical properties from see through register feature of an original note and a fake note. Original note has more value of maximum perimeter, more total area, more total perimeter, more values of mean of the four largest segmented areas, mean of the perimeters of the four largest segmented areas, standard deviation of the four largest segmented areas, standard deviation of the four largest segmented region perimeters.

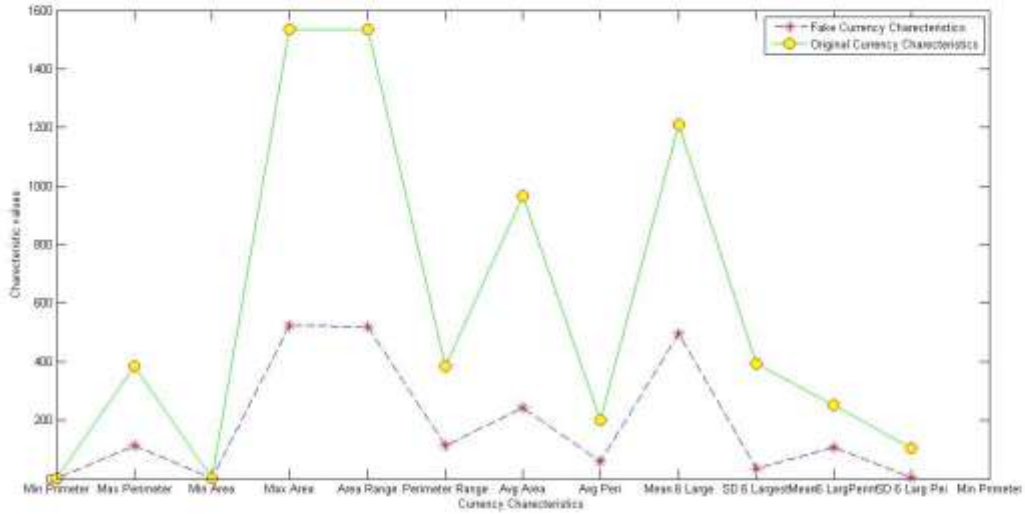


Fig: Histogram generated in matlab software comparing the structural/geometrical properties and their statistical measures of a fake and the original currency on the see through register feature portion

VIII. EXPERIMENT WITH THE SUGENO-TAKAZI MODEL

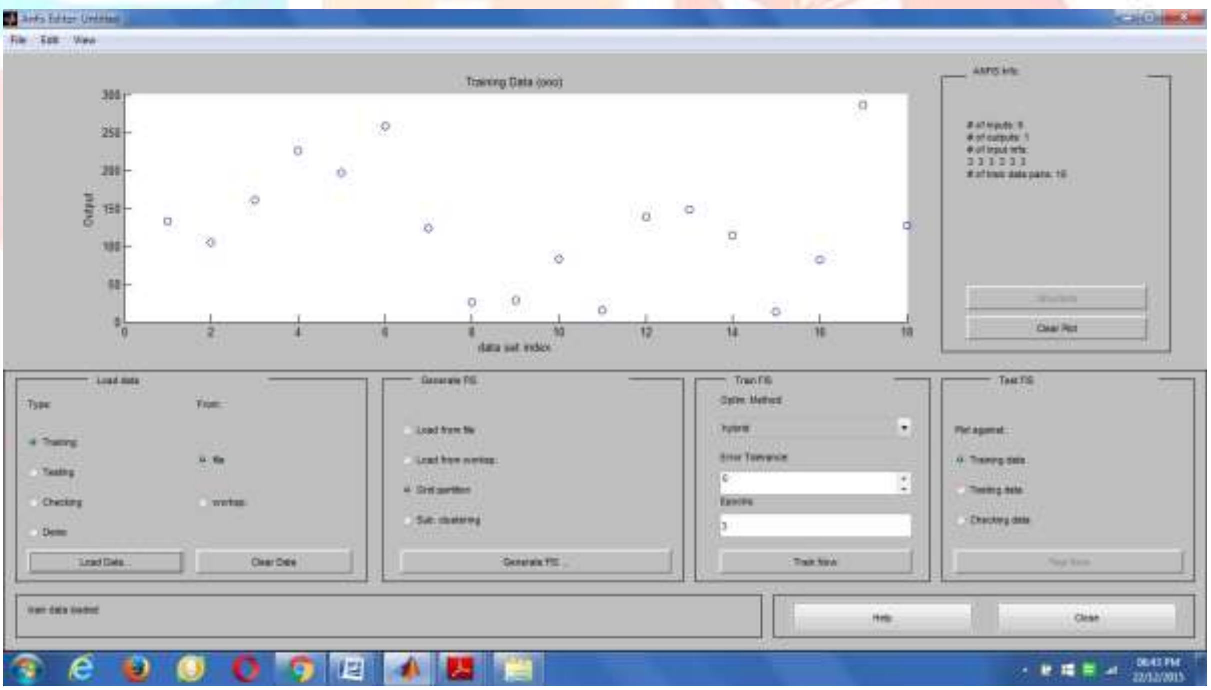


Fig: Training Data loaded

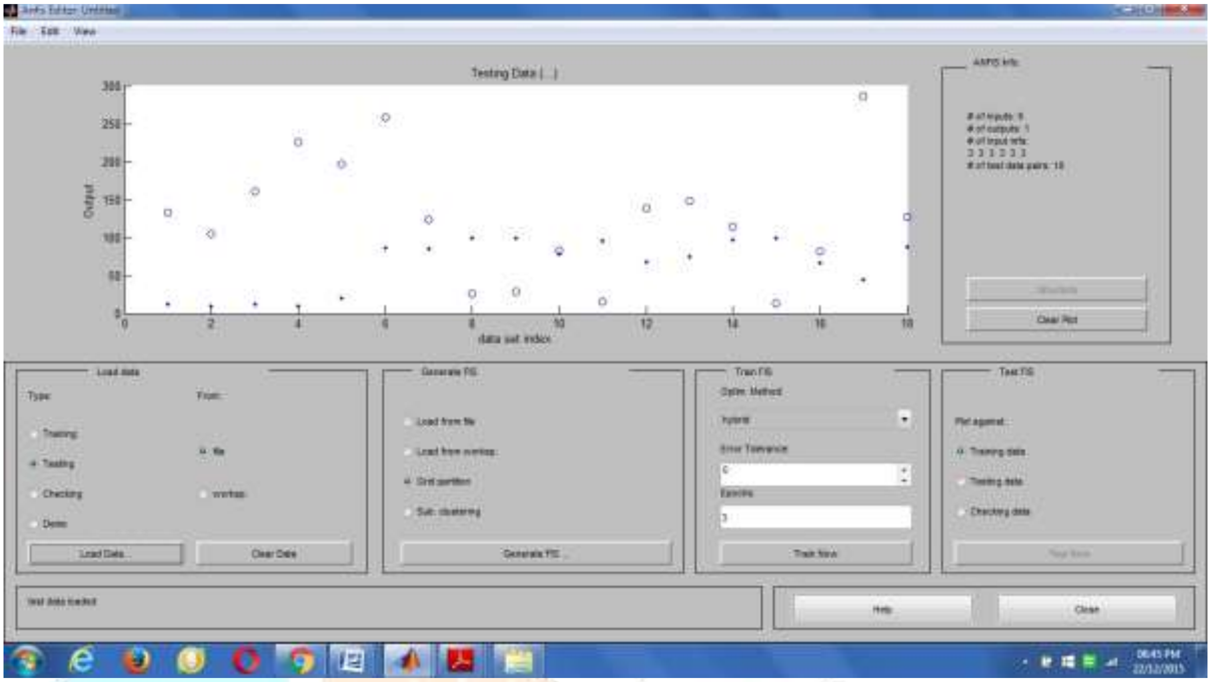


Fig: Training and testing data loaded

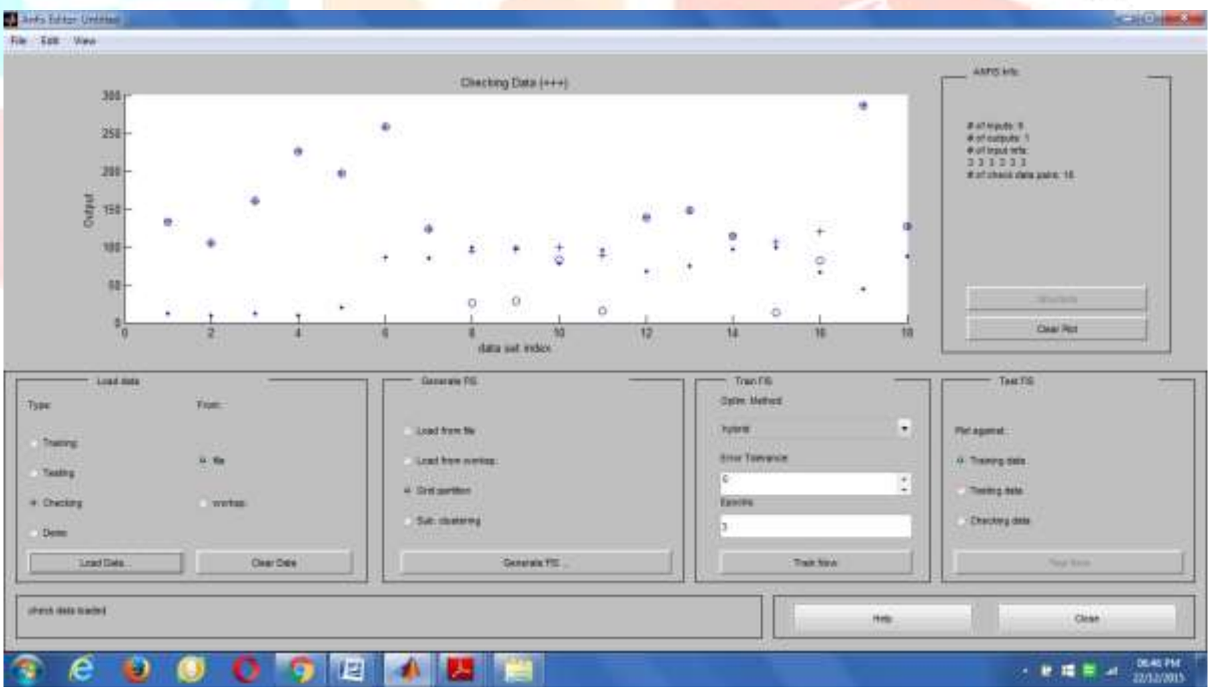


Fig: Training, testing and checking data loaded

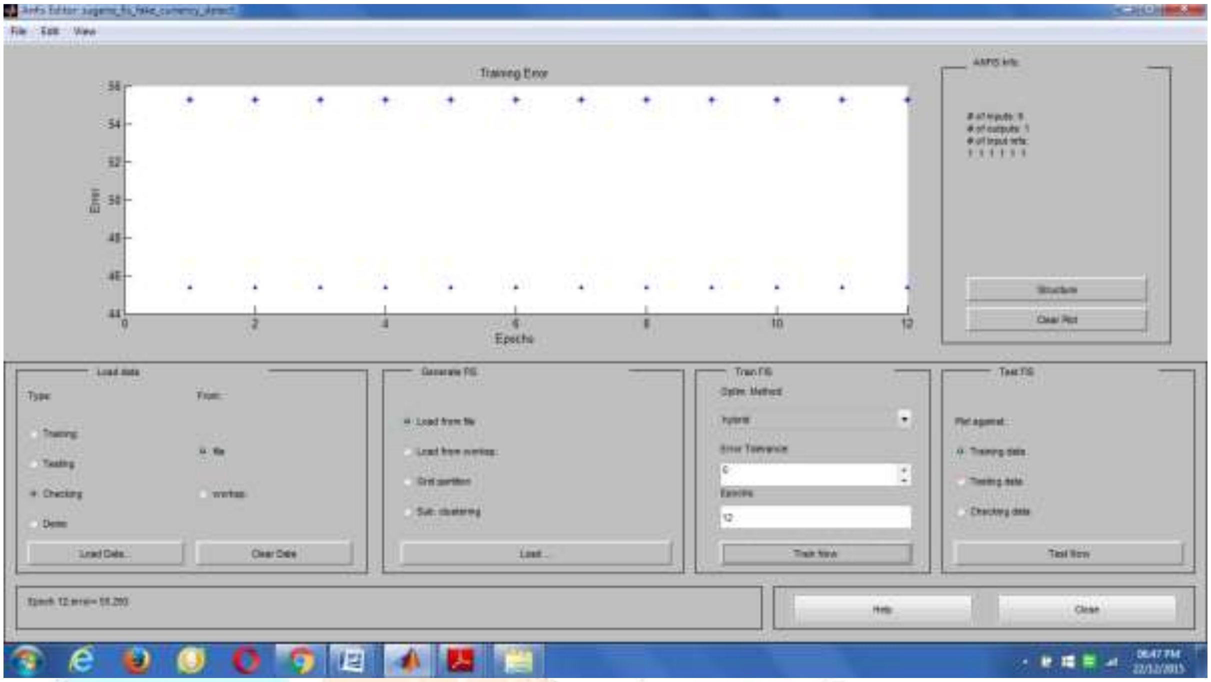


Fig: Training performed on 0 tolerance level and on 12 epoches

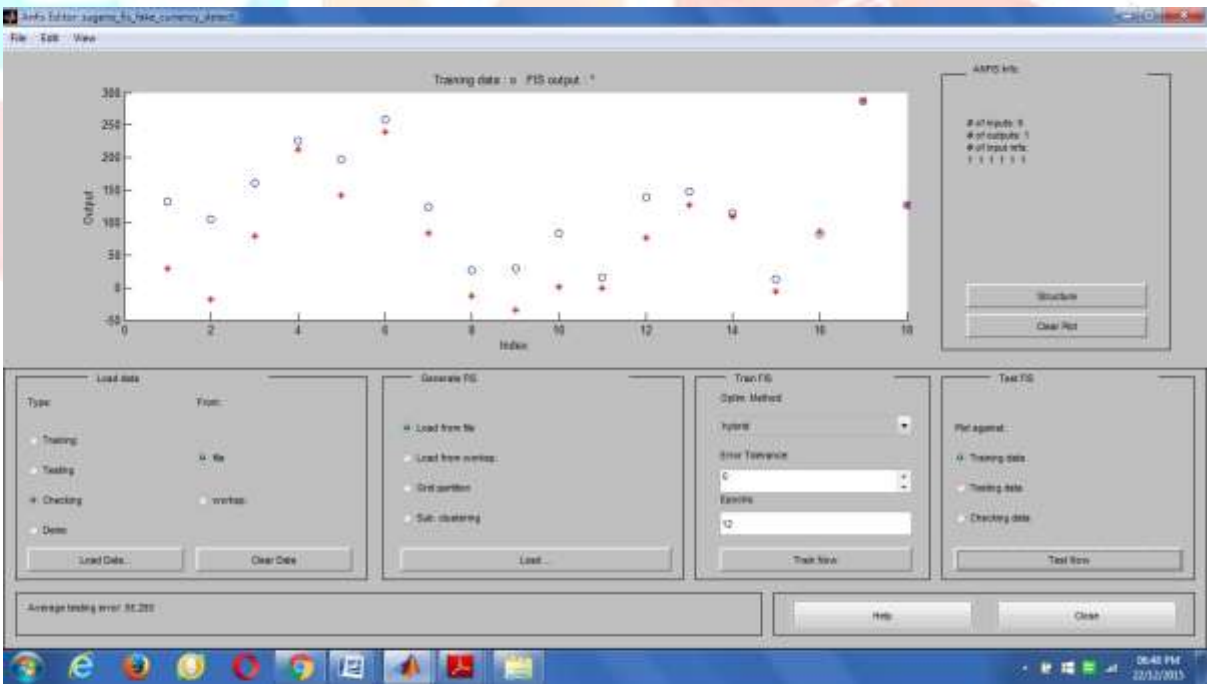


Fig: Plot output against training data

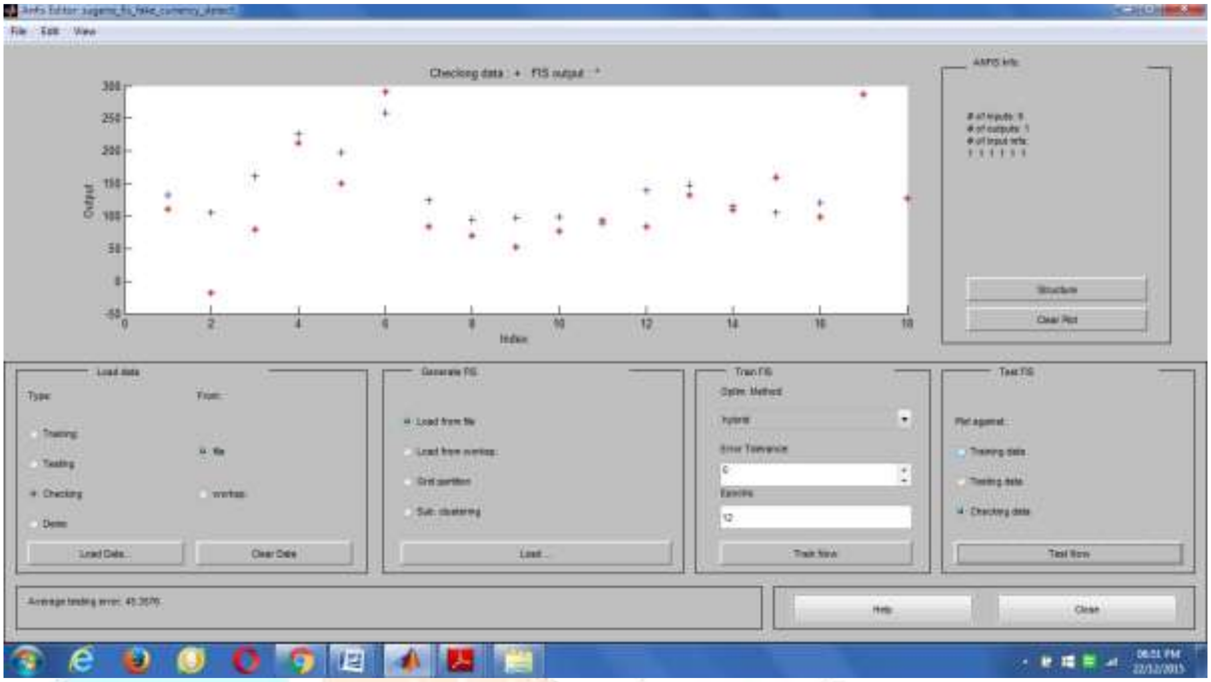


Fig: Plot output against checking data

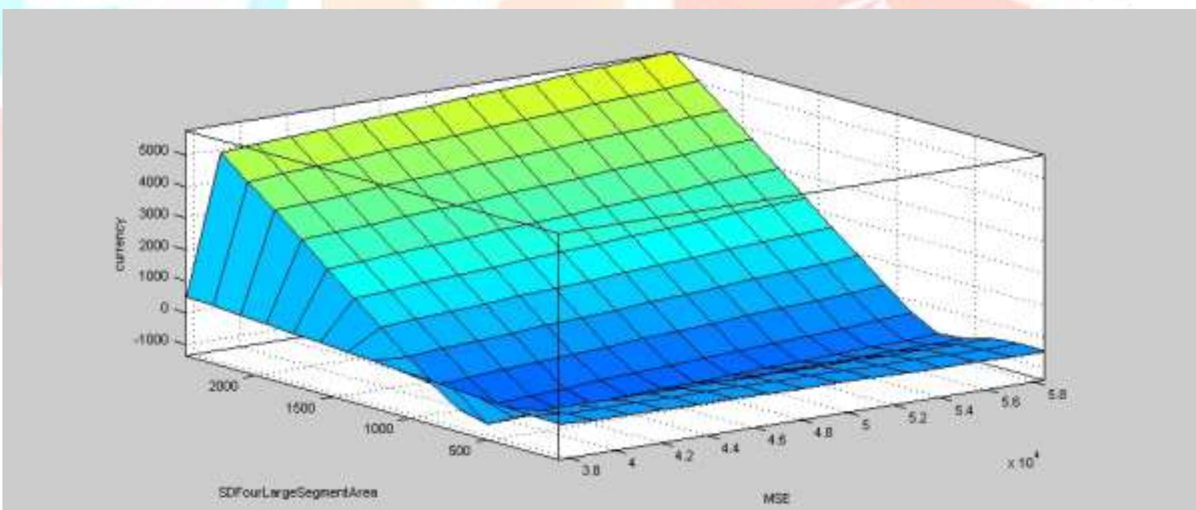


Fig: Surface diagram of MSE and Standard Deviation of Four Largest Segmented Area against output currency

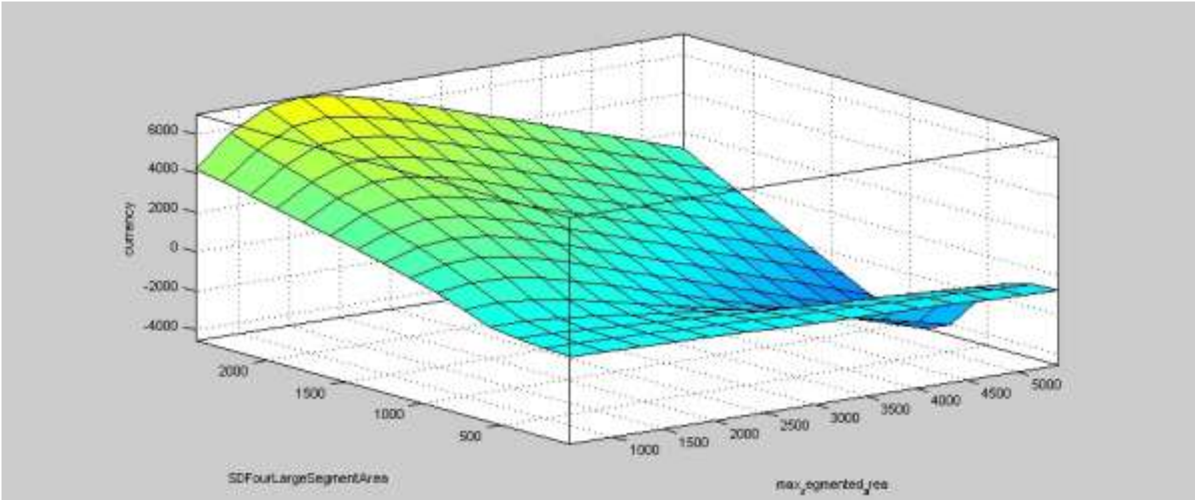


Fig: Standard Deviation of Four Largest Segmented Area and Maximum Segmented Area against output currency

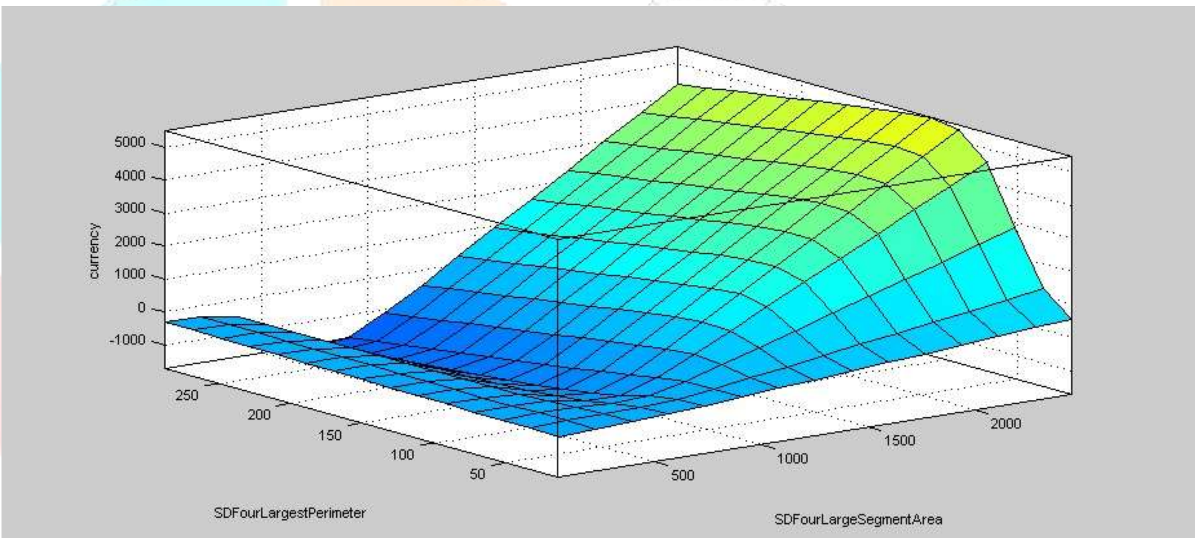


Fig: Standard Deviation of Four Largest Segmented Area and Standard Deviation of Four Largest Segmented Perimeter against output currency

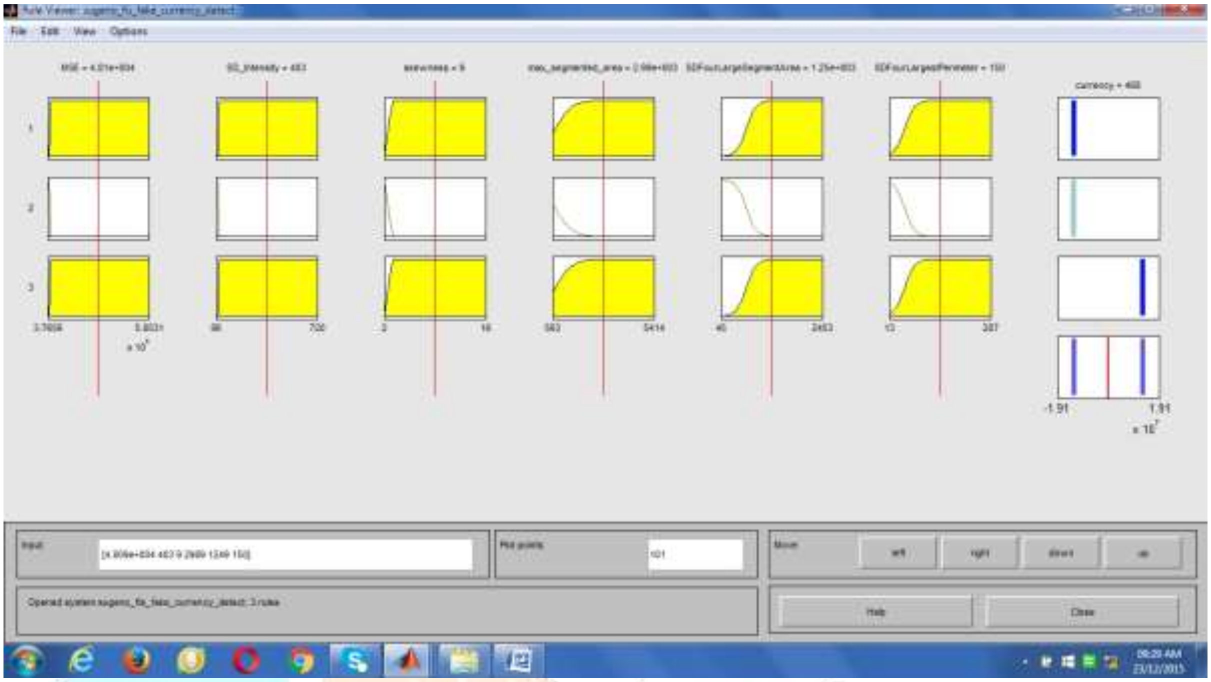


Fig: ANFIS Rule viewer with currency output

Discussion on the Result

Error Result found to be about 50 on 0 error tolerance and 12 epoches. The less error good the model design is and the learning is good. The error can still be minimized if we collect more samples. This test is done only on 18 training set data composed of antecedent and consequent pair i.e. input out output pair.

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