# Hybriding Fuzzy Logic with Wavenets

*Bushra H. Aliwi*
*Department of Mathematics*
*BABYLON UNIVERSITY*
*bushra_aliwi@yahoo.com*

Most works are on wavenets (wavelets with Neural Networks NNs. ),that wavelets as activation functions in NNs,or work on Fuzzy Logic FL through NNs for Artificial intelligent applications in Fuzzy Wavenets.

The trails for development are not stopped at point ,below show some trials ;

- Suggest a feed forward network exploit a wavelets and fuzzy logic properties in one method .
- Evade the previous problems and errors in each way alone and implement it on a patterns recognition such images .
- Perform a suggested method(s) through experiments to recognize an images (or geometric curves figures or movable images) .
- Recognize in patterns space and then more robust in patterns recognition application .
- Recognize the patterns even in presence the noise in patterns versions .
- Perform a suggested method(s) through experiments to improve its efficiency in recognizing colored images and geometric curves) to proving that the recognition is independent on colors .

The fuzzy wavenets is combining wavelet theory with NN and fuzzy logic in a single method specially wavenets that in which the dilation and translation factors are fixed (not optimized) and only weights are optimized through learning

This not all thing, it is different in many structures sides .The sides that represent a modification on a proposed traditional methods. are;

- *Firstly in the training set structure as a set of categories ;*

$S=\{1^{st}\ category, 2^{nd}\ category, 3^{rd}\ category, \ldots, i^{th}\ category, \ldots, N_c^{th}\ category\}$

*Each category is consist of a set of patterns as versions of figure characterize that category ;*

$i^{th}\ category = \{1^{st}\ pattern, 2^{nd}\ pattern, \ldots, j^{th}\ pattern, \ldots, N_p^{th}\ pattern\}$

- *The main concept which is an important side is activation function nature* as a summation of two continuous functions with real values in outputs space ,*wavelets as in wavenets with membership function;*

$$\psi_{m,n}=\psi(2^{-m}(x-n))$$

$$f_{m,n}=f(2^{-m}(x-n))$$

$$?_{m,n} = \psi_{m,n} + \varphi_{m,n}$$

*The structure of activation function is depends on fact that the wavelets can be decomposed into a sum of a scaling functions, but with some special properties that a scaling functions associated to these wavelets must be ;*

- *Symmetric ,*
- Every where positive ,
- and with a Single Maxima .

- *Network architecture ;which represented in using a single output layer neuron ,and in chose the desired output .*

- *In last; the output values structure and a taken decision depending on it .*

**Note :** *There is ability to implement any functions from wavelets or MFs .*

**Note :** *Choice of a MF is lifted for user ,in condition; satisfies previous properties .*

The suggested method is used for pattern recognition problem.

Patterns with many features ,multidimensional wavelets use , and used a single scaling for wavelets that is a single dilation and translation parameters in all dimensions ,so it be a single_scaling multidimensional wavelet MF has this property ,too

A network trained through a back propagation algorithm BP, which is successful algorithm in training of multilayered networks.

A weights values were chosen randomly for connections in a network.

A weights values file is single for patterns categories .

# Network Structure

The structure of a fuzzy_wavenet for the suggested method is a **multilayered feedforward** neural network, that is the layers are fully connected .It is consist of three layers (**input layer** ,**single hidden layer** , and **output layer** ) .

**Input layer** includes many neurons due to that patterns in training set are with many features studied .

**Hidden layer** consists of many neurons ,due to multidimensionality of inputs which are patterns features values, and this number was determined before start learning .

**Output layer** consists of single neuron ,that its output compute on weighted sum of outputs for hidden neurons by applying a non linear function ,this different from **WNN which implement linear function .**

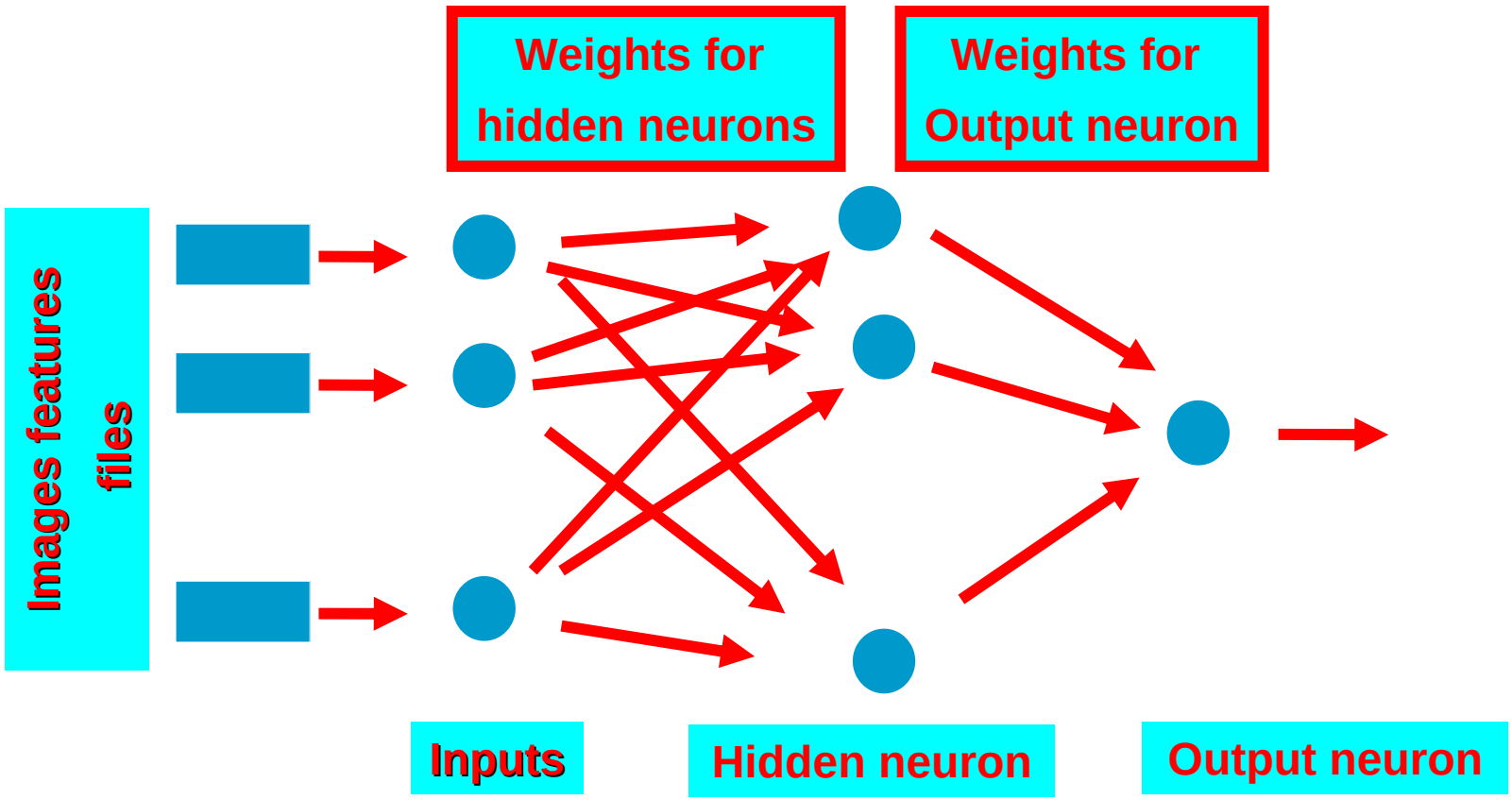
Through the chosen structure with this single neuron is led to many things ;

-Firstly **minimization in number of elements of matrix weights between hidden layer and output layer** ,and

-**Minimization in number of computational operations** ,

-Also **minimize outputs values** ,

-In addition to that all **decreasing in the effort** .

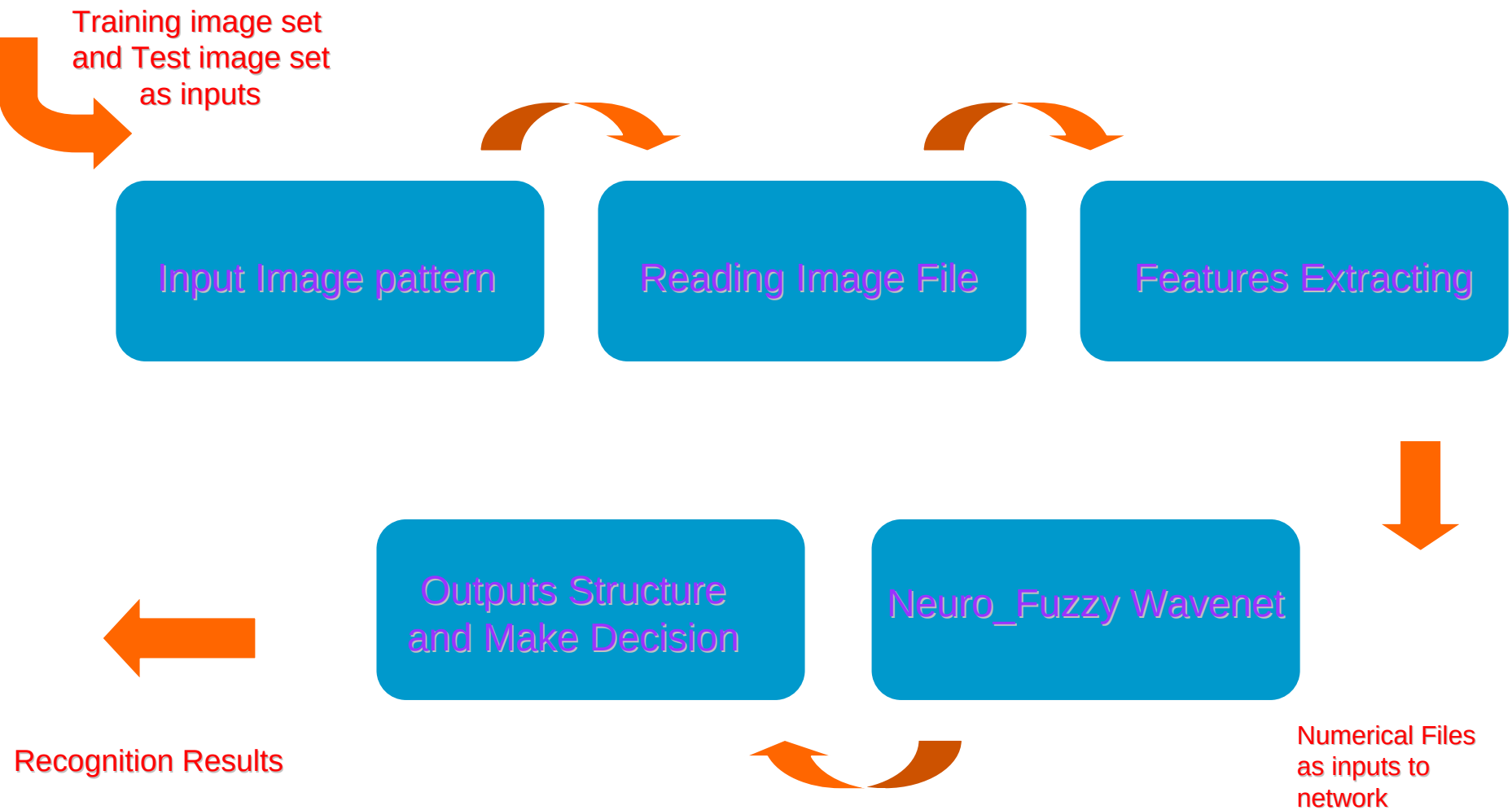



Network Structure

# *Stepping Method*

The Steps start when prepare a set of images (or set of images categories) that to work on ,and then implement the method through its steps as would explain exactly in figure below;

# Method Diagram

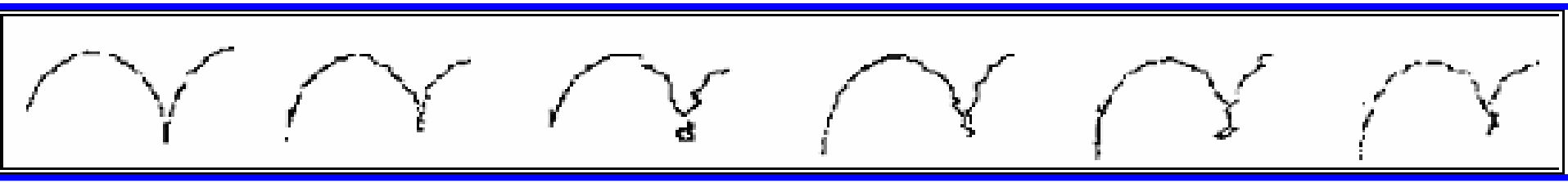


# Training Set

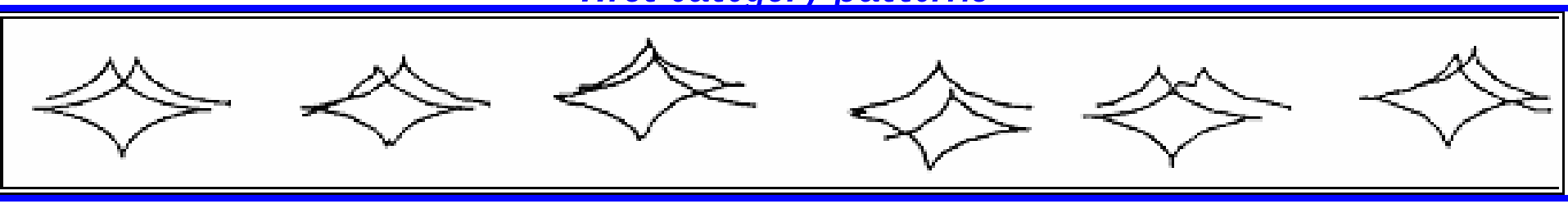
The method will training through set of experiments on a set of images categories for geometric curves, with *2D*_dimensions, for example just curves can drawn with hands(if possible) in black and white, and colored images used the same images with colored .

Most images in these networks are with format "*Bit Map format* "BMP, which is most commonly used than other formats and it is corresponds with window systems .

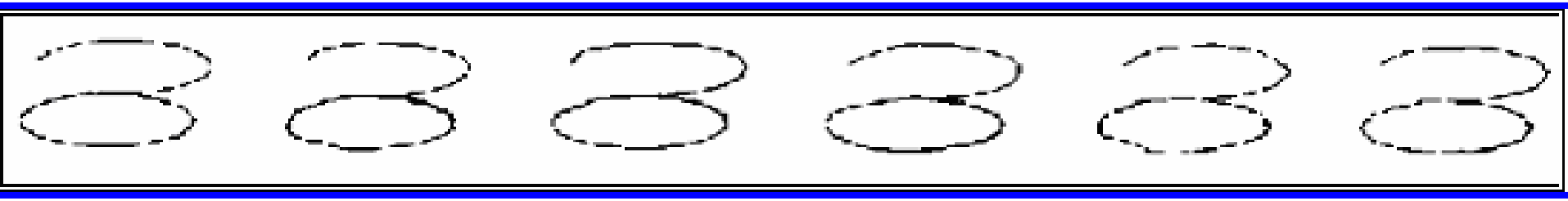
The Statistic Features are; *Mean* ,*Standard deviation*, *Skewness*, *Energy*, and *Entropy* .



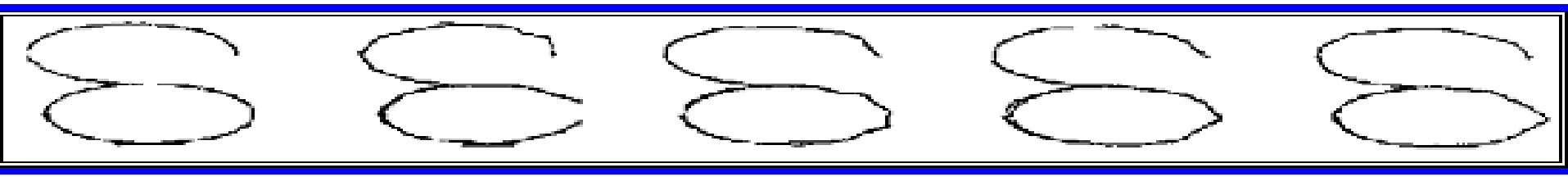
*first category patterns*



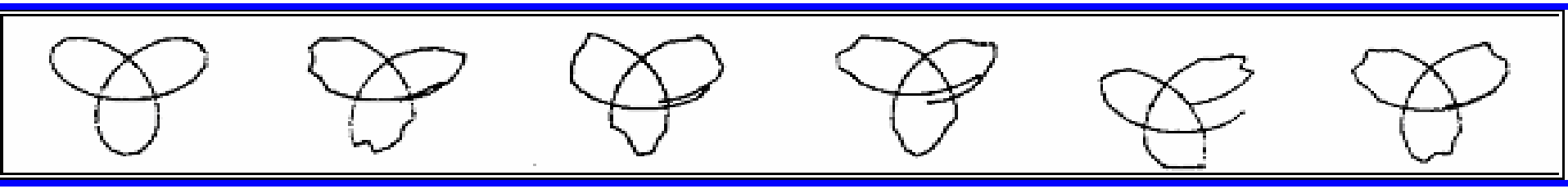
*second category patterns*



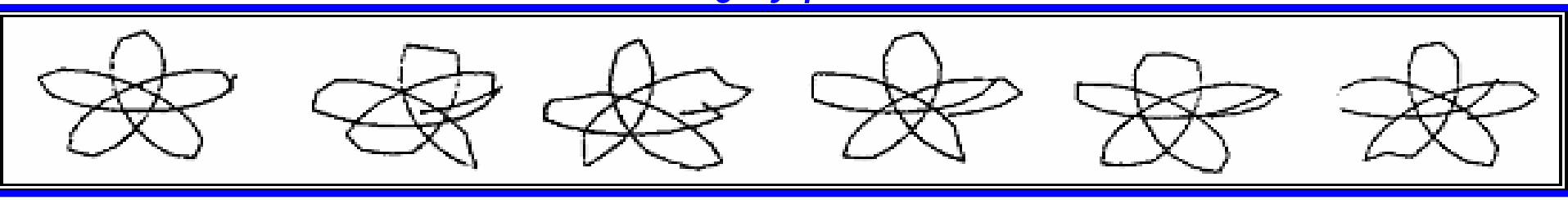
*third category patterns*



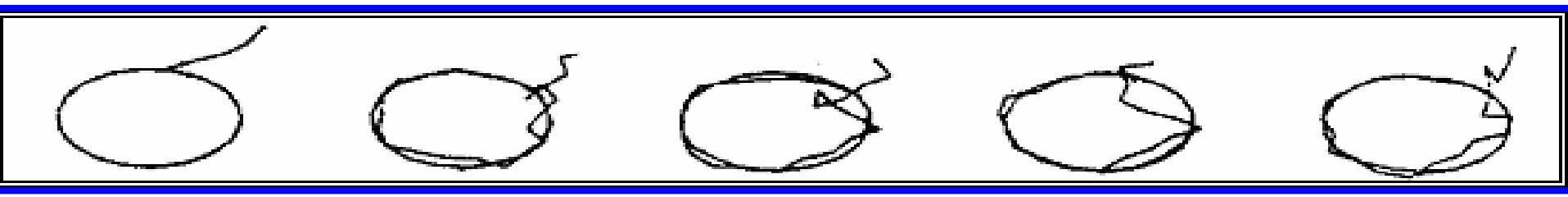
*fourth category patterns*



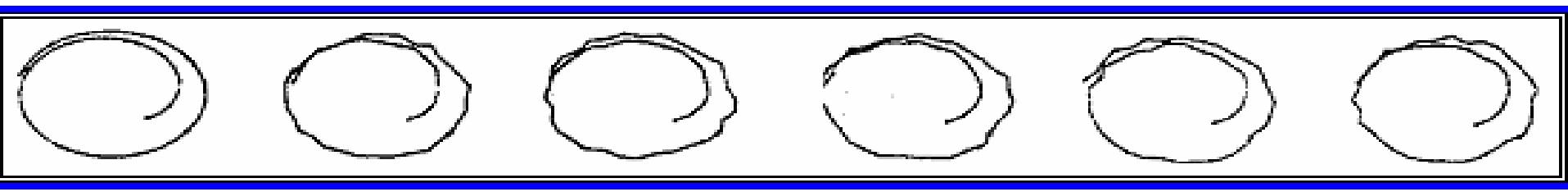
fifth category patterns



sixth category patterns



seventh category patterns



eighth category patterns

Activation function used in this work is sum of **Mexican hat wavelet** ,which is a second derivative Gaussian function (wavelet side) ,and **Gaussian membership function** ,all satisfies previous discussed properties ,then the form is;

$$(1-x^2).e^{-x^2/2}$$

$$e^{-x^2/2}$$

$$e^{-x^2/2}$$

$$\Phi=(1-x^2).e^{-x^2/2}+e^{-x^2/2}$$

A **single scaling multidimensional wavelets** used to construct a translated and dilated versions of mother wavelet .

Since **MFs** work as scaling functions ,and it work commmunicate with wavelets ,and single scaling_ multidimensional is implemented on it too.

*A basic, necessary and important thing that must heeded to it is that when divide network range into set of real closed intervals these intervals represent* ***Decision Regions*** *,that is a network can make decision or response for inputs in these regions.*

*A values in outputs space that be out closed intervals (range) or between intervals or out of range ,represent non decision regions or on other decision regions (intervals), named as* ***Error Regions***

Input pattern(s) if entered to be recognized to its category its output value(s) must at less be within closed interval of patterns outputs values for this category ,so pattern(s) output(s) (to be tested) must be in the interval(s) of category(s) in training set .

A network must find convergence between outputs into one interval ,that is able to identify category of pattern(s) under test .

**Note :** *When the network fail in converge to any one from these intervals ,then it is fail in recognize that pattern(s) .*

**Note :** *The output(s) of pattern(s) must belongs to just one closed interval for some category, and it is must not belong to two (or more) closed intervals of categories at all.*

# The Experiments

In this side of work ,suggested method accomplish on a training set, each category has a standard figure(image) characterize this category , while all other patterns in the category are fuzzifies copies for that figure ,and then testing ability of network in recognize patterns under work in these experiments, and (if developed) on more complex problems .

The patterns that will worked on are sets of images for geometric curves Hand drawn divided into categories.

To show efficiency of discussed method ,it performed with different ways at set of experiments with different ideas.

The considered set of $N_f$ features (that were extracted from each image), detector as;

$N_f = 5$ ,and $(f_1, f_2, f_3, f_4, f_5)$

Desired outputs values for categories were proposed with increasing order in $[0,1]$ with a categories;

| | |
|---|---|
| *First category* | $d_1 = 0$ |
| *Second category* | $d_2 = 0.15$ |
| *Third category* | $d_3 = 0.25$ |
| *Fourth category* | $d_4 = 0.35$ |
| *Fifth category* | $d_5 = 0.5$ |
| *Sixth category* | $d_6 = 0.65$ |
| *Seventh category* | $d_7 = 0.75$ |
| *Eighth category* | $d_8 = 1$ |

A dilation and translation values were supposed with constant values for all functions in the network. with integer values fixed at $n=6$ ,and $m=2$ for all experiments .

*Note:* The choice of desired outputs values for categories is effort on order of categories intervals. If choice desired values randomly, position of intervals is also be randomly .

Here suppose desired values increasingly ,so we noted that intervals were ordered increasingly in line decision in figures that communicated with experiments .

# *First Experiment*

The method was performed with its essential idea. *5* (input layer) neurons, *5* (hidden layer) neurons, and with single (output layer ) neuron.

The number of patterns in each category is *6* patterns,with available error value appropriate for training chosen through

trials–error way.

## *Second Experiment*

In similar way used in first experiment the method accomplished through increasing number of **hidden neurons** .

Number of hidden neurons were increased from *5* neurons into *8* neurons in this experiment .

A proposed available error value is modified from *0.0008* in first experiment into *0.0004* at training in this experiment

## *Third Experiment*

Here idea is proposed to show effect of increasing number of patterns in each category ,through implementing on categories of training set with same proposed training parameters values ,and other essential parameters in first experiment.

The number of patterns were increased to be *56* patterns ,with *7* patterns in each *8* categories .

*Note :The seventh pattern that added to each category through this experiment is also a version from a standard figure for that category,that is versions number is increased at each category .*

## *Fourth Experiment*

A **fourth experiment** idea is proposed for effective of increasing in number of **hidden neurons** in a network structure at a **second experiment** ,and increasing the **number of patterns** in each category from a training set at **third experiment .**

So number of hidden neurons increased to ***8*** neurons ,which used in second experiment .Also increasing number of patterns in each category at training set to ***7*** patterns for each category .

## *Fifth Experiment*

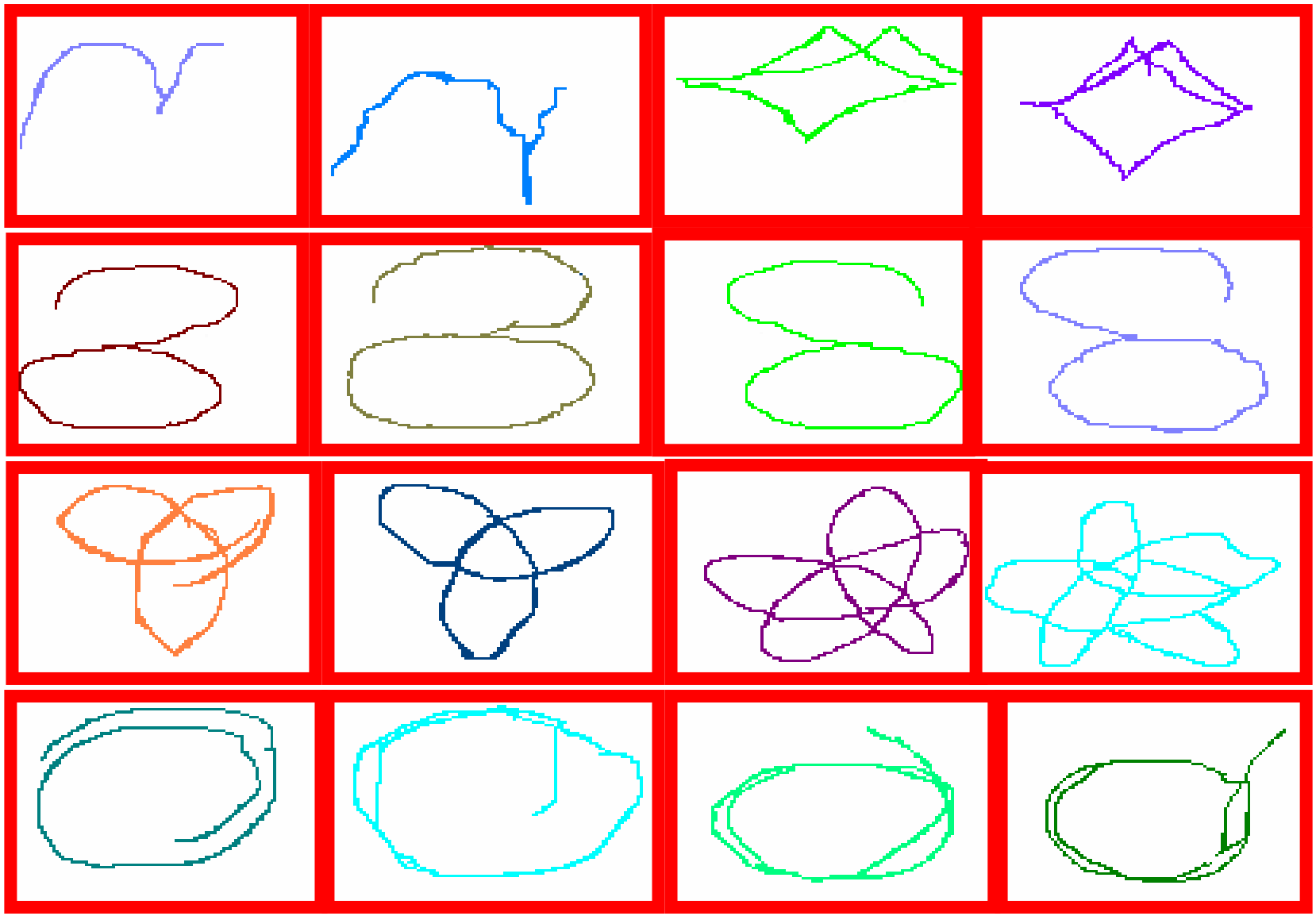
The idea is to perform the method on colored images for same patterns, drawn by colored lines over white background for each image , different colors were used for different images in same category .

Parameters values were proposed in way to match the change in images data.

The aim from this experiment is chiefly to prove that work efficiency is independent on colors .

**Note :** *Patterns order is the same one used in previous experiment.*

Also an available error will change or it increased to assimilate the changes in data values



*Some samples form the colored images*

We note through learning this network ;a real doing for network in recognize images in training and testing set and for all categories .

Also note that increasing efficiency of network with increasing in number of hidden neurons for all categories, with decreasing in iterations number

A network efficiency has been increased to good rate through increasing number of Images (patterns) in training set .

All recover on a good success in accumulation between ideas of experiments ,that add a goodness for work and then results of learning network .The main thing is increase ability to pattern recognition .

The network proven an excellent ability in dealing with colored images in spite fail a network in recognize some patterns it may be so noisy(fuzzed) to recognition or not in that category ,a largest available error value that used for this job is *0.001* even it larger than that used for uncolored images .

We have shown that ,when use colored images leads to results that are much more independent from colors even it different for coloring .

Also for all experiments we noted existing a deviation in parameters values for learning .

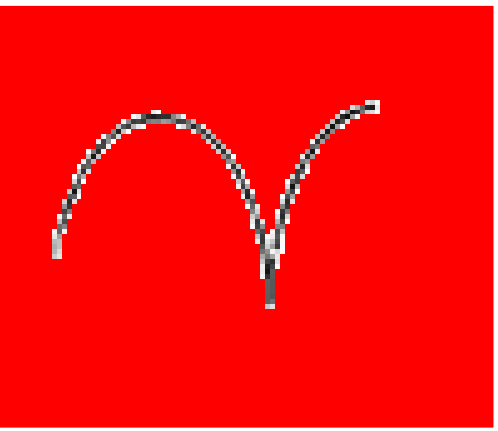
After training ,the network displayed an ability to generalize ,that is to recognize images in testing set for all categories in performed experiments ,since it obeyed two techniques ,which represented as universal approximators(fuzzy logic and wavelets) in architecture of the network .

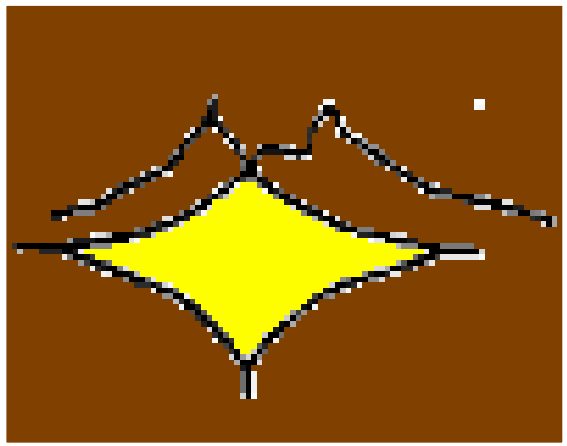
# More Works

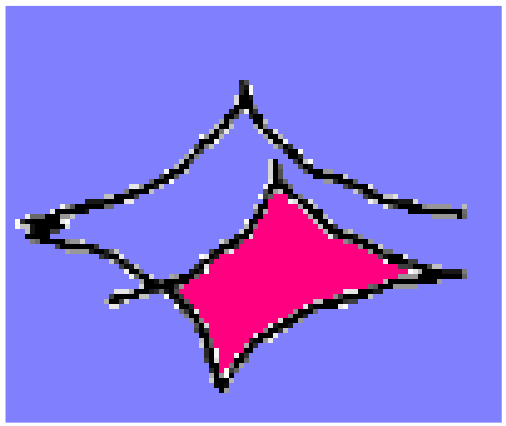
- Use an other continuous types of wavelets or membership functions such sine or cosine functions .

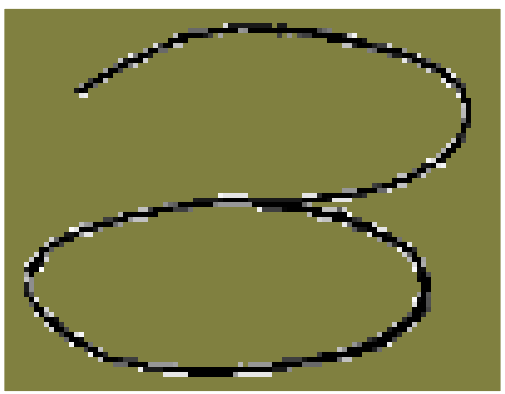
- Use non linear functions as a relation between wavelet(s) function(s) and membership function(s) .

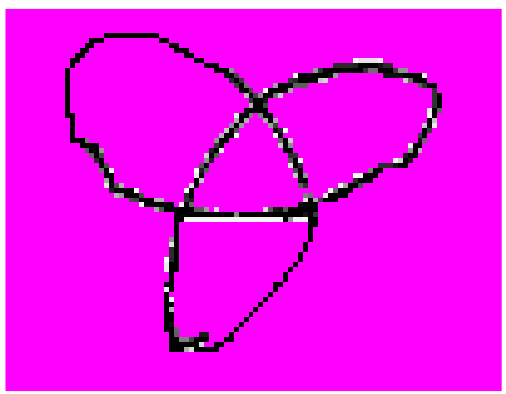
- **Perform the method on colored images ,that is colored backgrounds with different colors and different coloring ways at coloring the closed area that determined by curves in images at training set such ;**

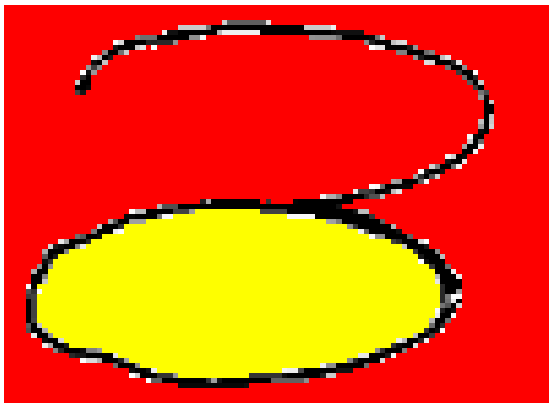


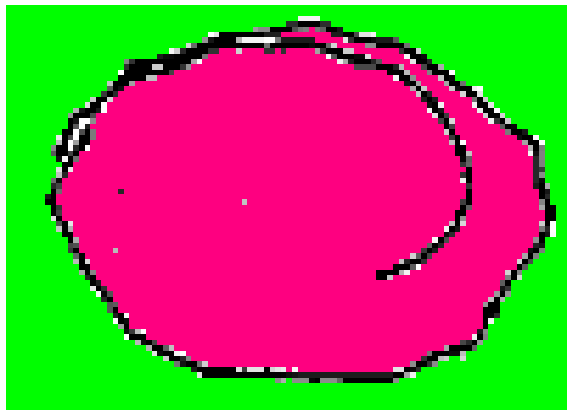


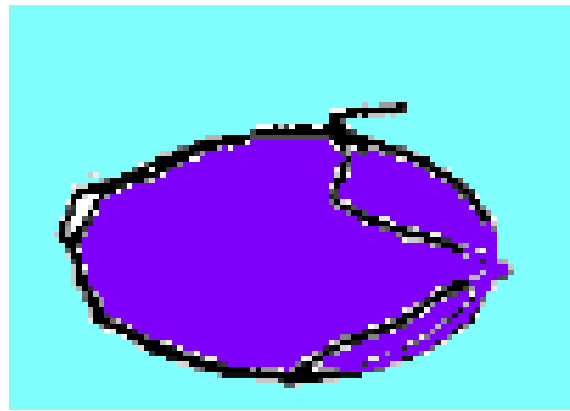


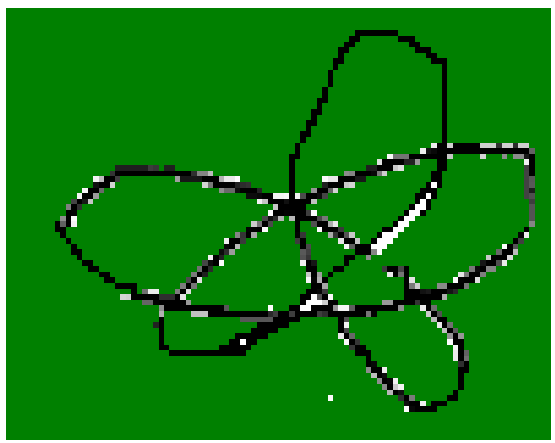


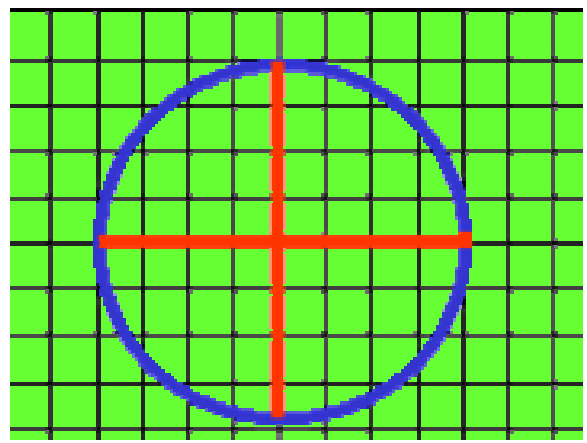


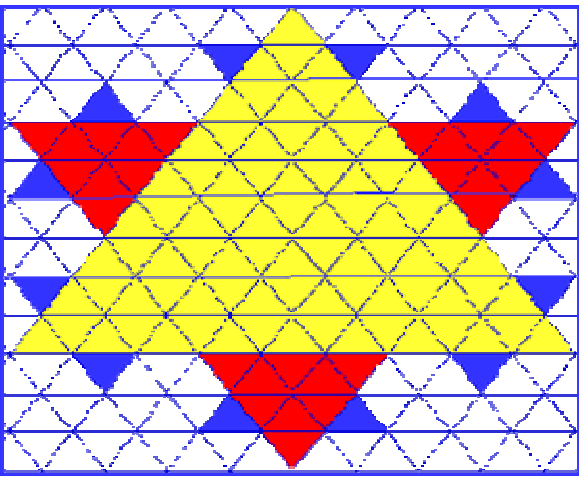


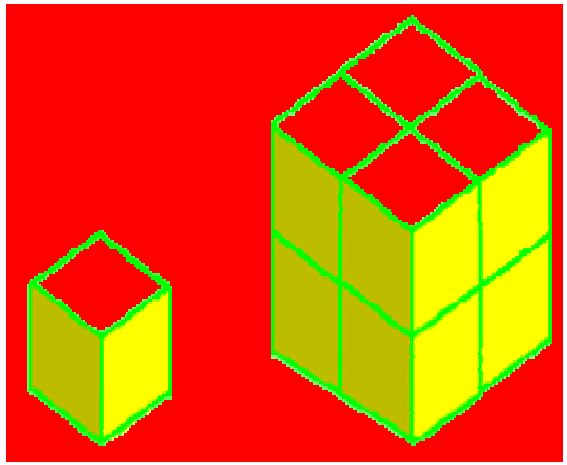


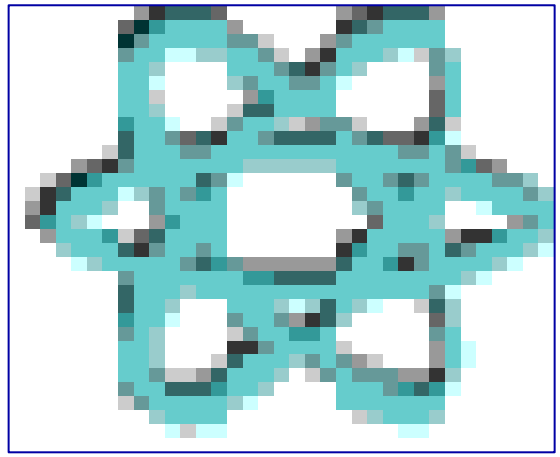


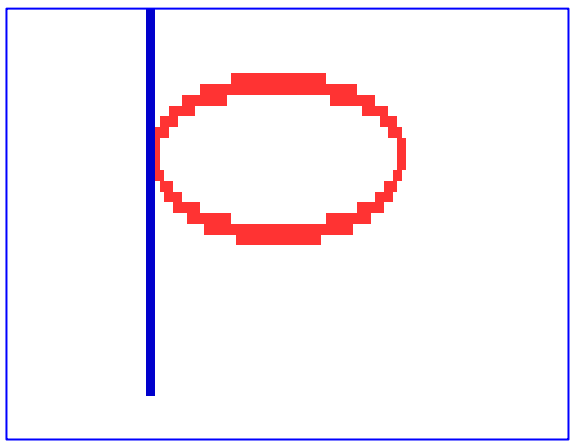


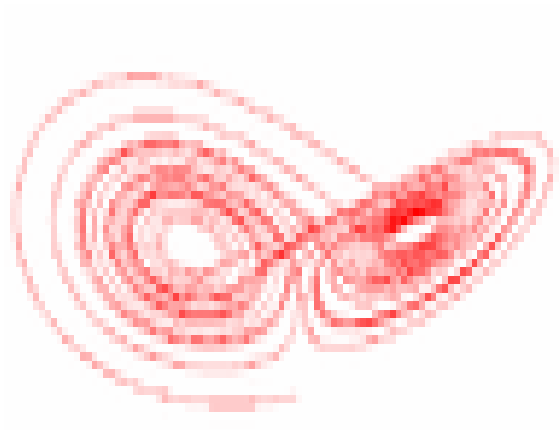




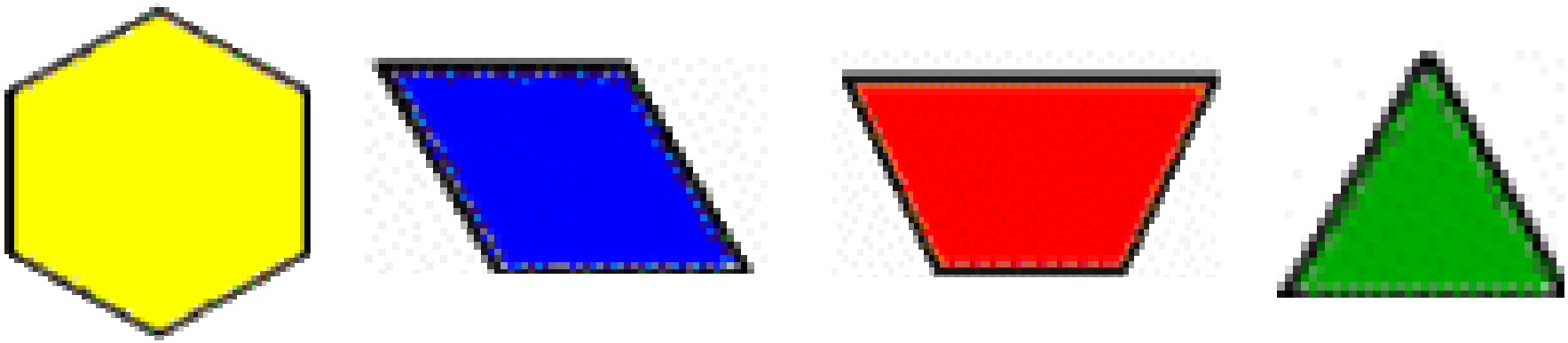




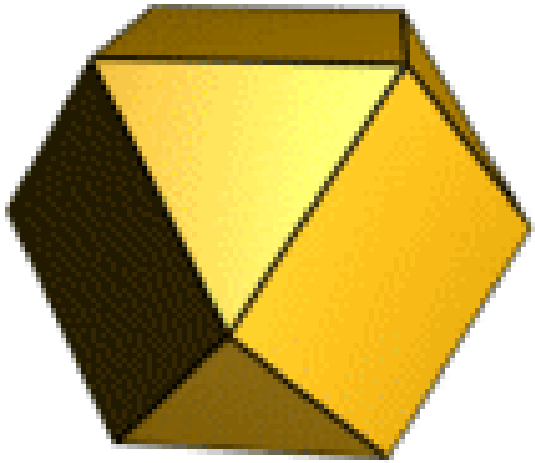


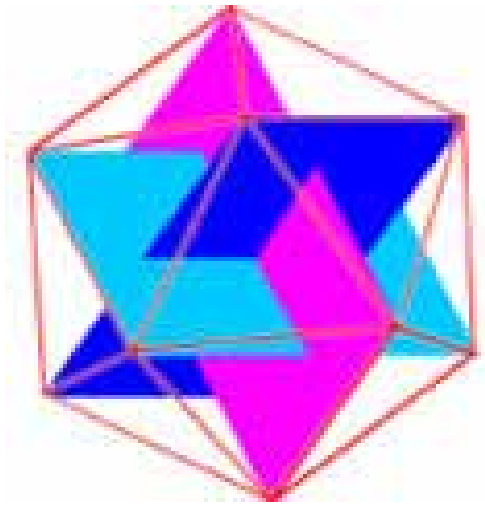


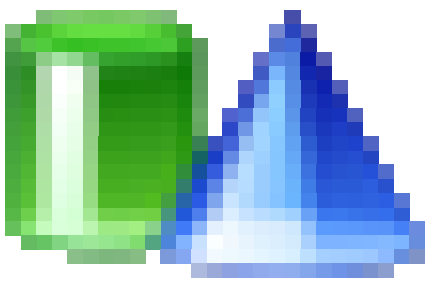
- Use images for different geometric figures with different colors or size in recognize images (movable images) constructed from these figures :

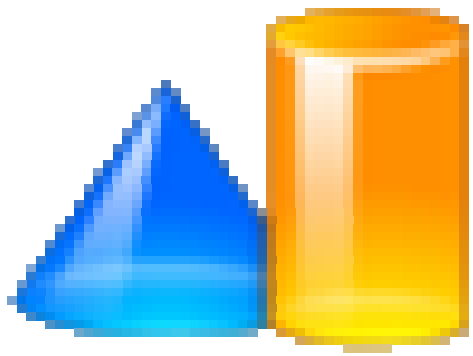


Fuzziness here calculated for images by level colors and for figures and size and constructed figures under test such :

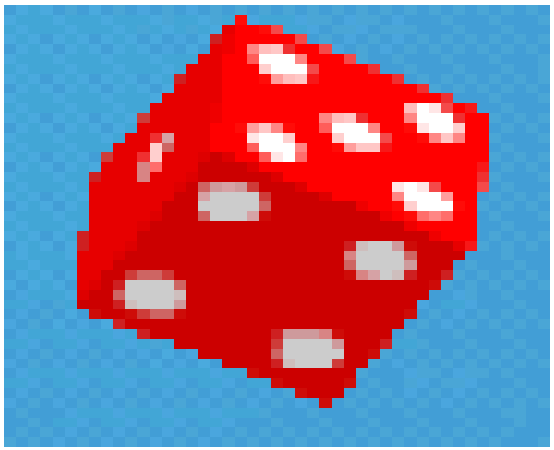


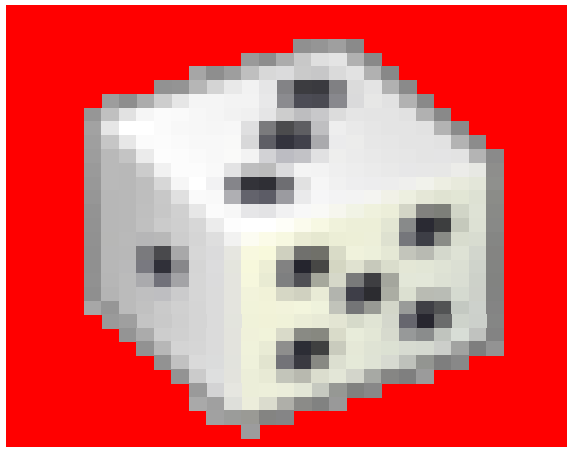






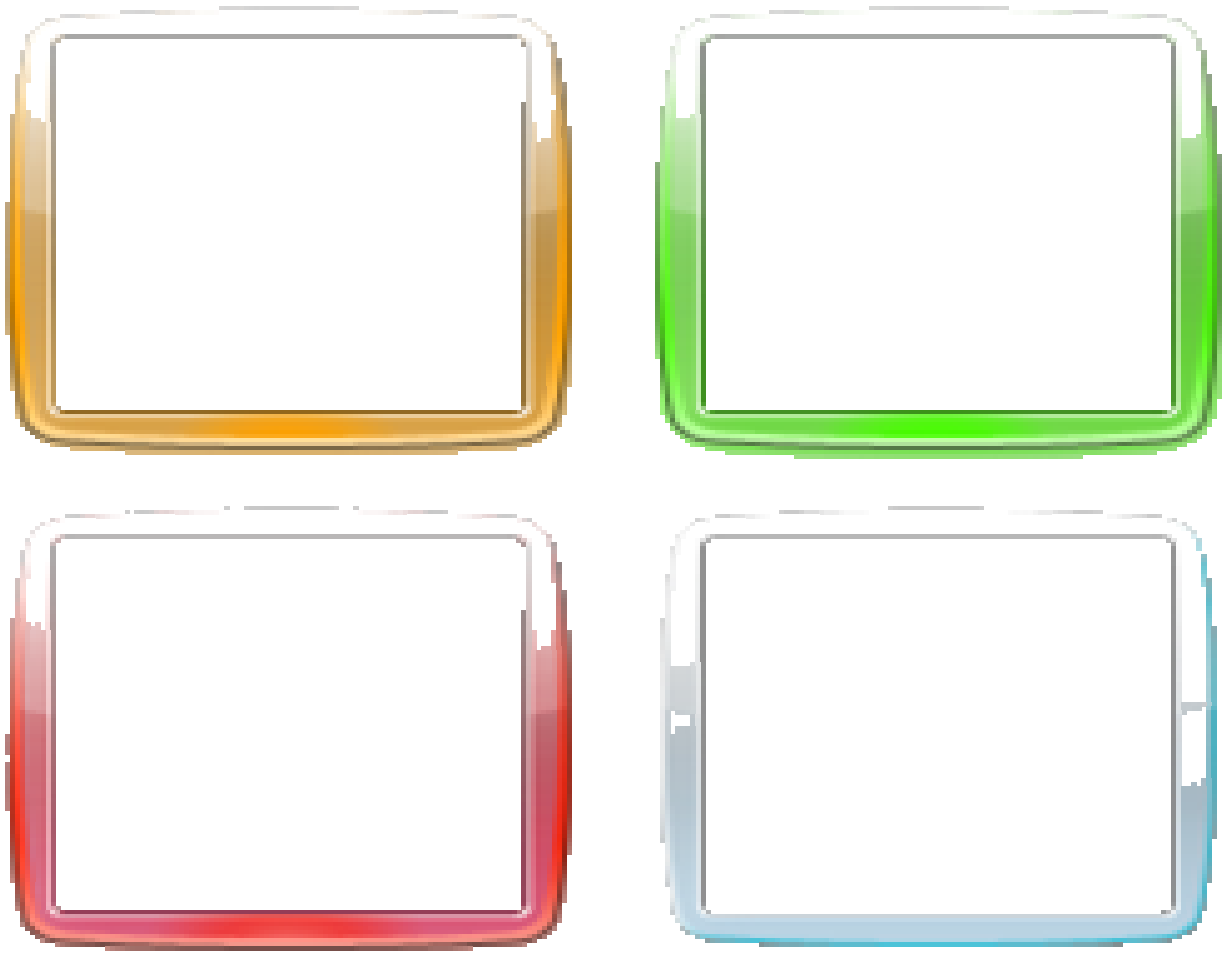
- Or for different images for similar things with different colors or size such this images and picture :





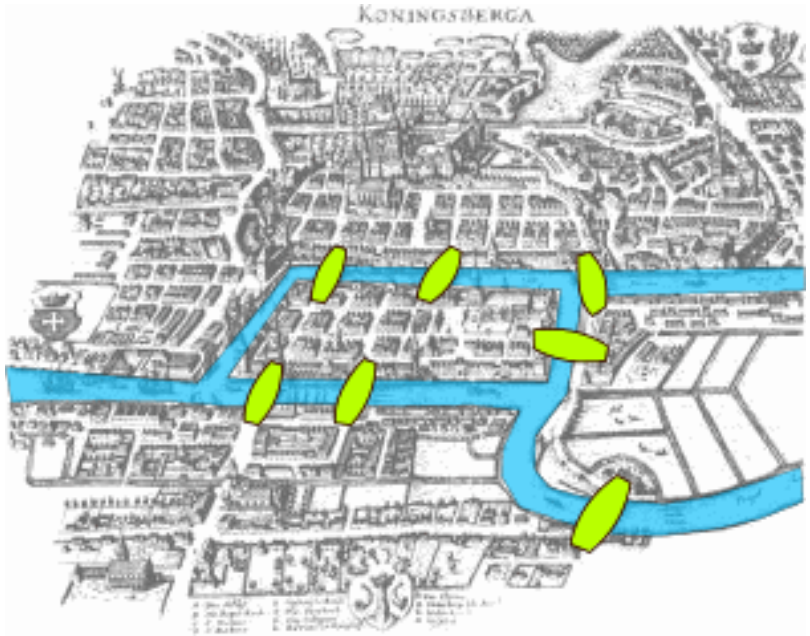
Picture of dice with less fuzziness

# Images for squares with differences colors and same size

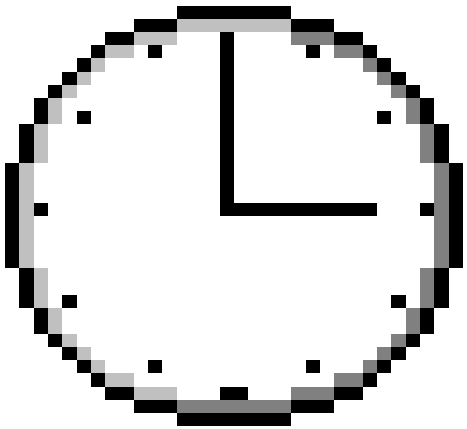


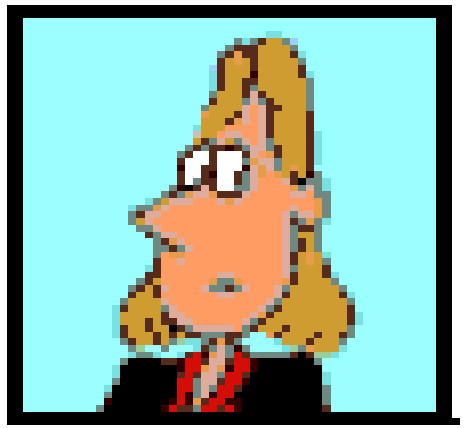
# Images for squares with differences colors and different sizes

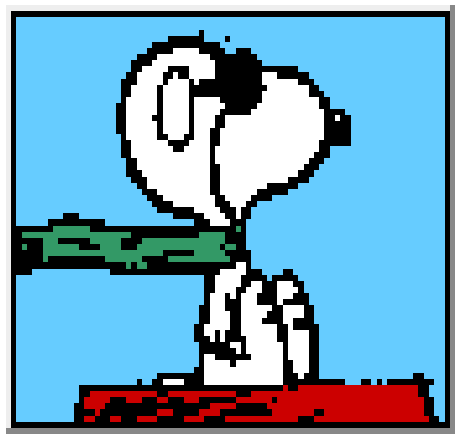
- Sure ,try to implement the suggested method on a more complex images (or not geometric curves) with different colors such maps of towns drawn by hands .



Perform the method with functions depends on time as depended variable ,which also exploit continuous wavelets, on movable images or videos .







*Finally, works in this way introduce to more works in this subject or that schemes associated with it ,and then gain at less trials to solve some problems .*

*Tanks for*

*your Attention*