Remote Plant Monitoring and Controlling System Using Digital Image Processing by Neural Network and Fuzzy Logic

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Abstract
A high speed digital image pattern matching circuit which recognizes an image pattern, and discriminates whether the recognized image pattern matches with a desired reference pattern and where pattern matching occurs. For discriminating whether a desired pattern is matched, an input pattern to be retrieved is digitally-modelled as two thresholds. The digitally modelled input image signal is blocked to have the same size as the reference pattern and compared with the reference pattern. The compared result is again compared with the thresholds for discriminating whether pattern matching occurs or not. The high speed digital image pattern matching circuit of the present invention utilizes two thresholds for modelling, thereby simplifying the input digital image signal in hardware and making processing speed very fast.

1. Introduction

Technology refers to the collection of tools, including machinery, modifications, arrangements and procedures used by humans. Engineering is the discipline that seeks to study and design new technologies. Technologies significantly affect human as well as other animal species' ability to control and adapt to their natural environments. The term can either be applied generally or to specific areas: examples include construction technology, medical technology and information technology.

Modern technology is the modification, making, usage and knowledge of tools in order to solve a problem. It affects human and other animal species. Modern technology has affected the society and its surroundings in various ways.

Needs for modern technology in agricultural field

"Use of latest technology can increase production and farmers can earn handsome profits," said AARI Director General Dr. Abid Mahmood in an interview to The Express Tribune. By applying modern techniques, China is getting 39 maunds of wheat per acre, which is the highest average production in the world, while Pakistan's average per acre yield is 26 maunds.

Pictorial Representation

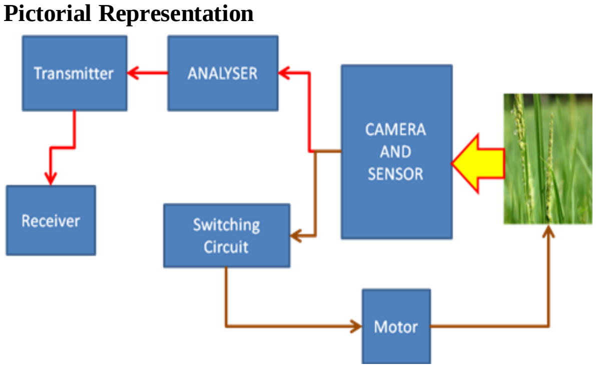

Fig: 1. Block Diagram

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"There are few farmers in Pakistan who are using modern techniques, right from pesticides to fertilizers and are getting 70 maunds per acre," Mahmood said. "Pakistan has good agricultural land but farmers lack the resources needed to switch to modern technology," he said, adding with government support they could, however, achieve higher yields than developed countries.

2. Neural Techniques

The objective of the neural technique is to train the network to recognize face from picture. To teach the neural network we need training data set. The training data set consists of input signals assigned with corresponding target (desired output). The neural network is then trained using one of the supervised learning algorithms, which uses the data to adjust the network's weights and thresholds so as to minimize the error in its predictions on the training set. If the network is properly trained, it has then learned to model the (unknown) function that relates the input variables to the output variables, and can subsequently be used to make predictions where the output is not known. This technique provides the best result for face recognition. To prove our point we have performed experiment on three neural network techniques which areas below: Of all the above discussed techniques neural techniques have advantages of high speed, better accuracy and low hardware requirements. To prove this we performed an experiment with database composed of 20 images of resolution 180x200. The results for the same are shown below:

Table: 1. Comparison in Terms of Accuracy Techniques

Techniques	Eigen Faces	Feature-Based	Hidden-Markov	Neural Network
Accuracy(%)	85	75	67.1	83.09

From Table 1 it is observed that Eigen faces technique have better accuracy with over 30 Eigen values. Increased number of Eigen values improves the accuracy but also increases the computational cost. Whereas due to high speed, low hardware requirement and low cost neural techniques are more advantageous. Thus it can be concluded that neural network techniques are the best for face recognition. Thus we now checked which neural network technique is the best that can be used in our proposal. For this we took three popular techniques as follows:

2.1 Back-Propagation Neural Network (BPNN)

In this technique the network has a layered structure. The basic layers are input, hidden and output layer. This network is different from others in the way that the weights are calculated during learning. When the numbers of hidden layers are increased, training becomes more complex. There can be more than one hidden layer in the network, but one layer is sufficient to solve our purpose. The training of BPNN is done in three stages:

- Feed-forward of input
- Calculation of weights and error
- Back-propagation of error

Input layer consists of units which receives external input. There are no connections within a layer. The input is fed to the first layer of hidden units. Hidden unit apply activation function and receives weighted bias, the output of the hidden units is distributed over the next layer of hidden units. This process continues until the last layer of hidden units. The outputs are fed into a layer of output units. Though training of BPNN is very slow, once the network is trained it produce results rapidly.

Back Propagation Error

$$\mathcal{R}_i\text{: If } \mathbf{x} \text{ is } A_i \text{ then } y_i = \mathbf{a}_i^T \mathbf{x} + b_i,$$

$$y = \frac{\sum_{i=1}^{K} \beta_i(\mathbf{x}) y_i}{\sum_{i=1}^{K} \beta_i(\mathbf{x})} = \frac{\sum_{i=1}^{K} \beta_i(\mathbf{x})(\mathbf{a}_i^T \mathbf{x} + b_i)}{\sum_{i=1}^{K} \beta_i(\mathbf{x})}$$

$$\mathcal{R}_i\text{: If } \mathbf{x} \text{ is } A_i \text{ then } y_i = b_i,$$

$$y = \frac{\sum_{i=1}^{K} \beta_i(\mathbf{x}) b_i}{\sum_{i=1}^{K} \beta_i(\mathbf{x})}$$

$$\mu_{B_i}(y) = \begin{cases} 1, & \text{if } y = b_i, \\ 0, & \text{otherwise}. \end{cases}$$

Multi layer Neural network

$$z_j = \sum_{i=1}^{p} w_{ij}^h x_i = (\mathbf{w}_j^h)^T \mathbf{x}, \quad j = 1, 2, \ldots, m.$$

$$v_j = \frac{1 - \exp(-2 z_j)}{1 + \exp(-2 z_j)}, \quad j = 1, 2, \ldots, m.$$

$$y_l = \sum_{j=1}^{h} w_{jl}^o v_j = (\mathbf{w}_l^o)^T \mathbf{x}, \quad l = 1, 2, \ldots, n.$$

2.2 Recurrent Neural Network

RNN is a neural network technique where connections between units form a directed cycle. A simple recurrent network must have an active feedback which has short-term memory. Layer Recurrent network have number of hidden layers. Each hidden layer is updated not only with the external input of the network but also with activation from the previous forward propagation. To form RNN a context layer is added to the structure to retain information. Each time new input pattern is fed to the RNN, the previous contents of the hidden layer are stored in the context layer and provided as feedback to the hidden layer. The feedback also has the option to modify set of weights. RNN is a time based neural network which accepts the input at each time step. Here the activation function used to compute output is purely non-linear. The feedback layer gives a direct impact on the output as the error once introduced in the network affects the final outcome through feedback path.

2.3 Cascade Forward Neural Network

CNN is also having layered structure in which each hidden layer includes a connection from the input layer and all previous layers. The network grows on demand, new neurons in the hidden layer are added and trained one by one. Training of the network starts with only input and output layers and does not have any hidden layer neurons. During the training process new neurons are added to network and trained. This newly added neuron is called as candidate neuron which has connection to all input and hidden layer neurons. Weight adjustment can be performed only with the candidate neuron while all the other weights in the network are fixed. CNN starts with one input node and then keep on adding new input and hidden neurons. The trained CNN has minimum number of input, hidden neurons and connections.

Table: 2. Comparison of Neural Techniques

	BPNN	CNN	RNN
Time Taken (s)	2.56	11.48	3.20
Accuracy (%)	83.09	65.2	62

Now our aim was to test which neural network gives best accuracy. For this we performed an experiment in which we calculated accuracy and time complexity. The results are shown in the Table 2. On the basis of the above overall comparison Table 2, the following points can be inferred as follows:

- The Back-propagation technique is best in terms of accuracy. The accuracy obtained in our experiment of this technique is nearly 83.09%.
- The elapsed time taken by BPNN is also very low (2.56s).Thus using this technique makes pattern recognition faster.
- The order of neural network techniques in terms of accuracy is BPNN, CNN and RNN while in terms of time elapsed is BPNN, RNN and then CNN.

To improve further accuracy we combined neural network techniques with the fuzzy inference system the results are observed to be much better and accurate.

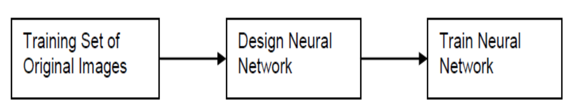

Fig: 2. Training of Neural Network

3. Proposal

At present many methods for image recognition are available but most of them include feature extraction or processing related to type of image. The method proposed in this paper can be applied to any type of images. The proposal is divided into two phases: the training phase and the recognition phase.

3.1 Training of the Neural Network

The training of neural network consists of following steps as shown in Figure 2. • The first step for training is to provide the network with data set. For this purpose identical row from the image matrix is considered as input for designing the structure The dataset obtained from step 1 is now used to design the neural network architecture as shown in Figure 3. The network designed has number of input equals to number of columns in the dataset matrix. Here, BPNN is working in feed forward mode. This network [1, 7, 8] has a layered structure. The basic layers are input, hidden and output layer. This is different from others based on the way the weights are calculated during learning. When the numbers of hidden layers are increased, training becomes more complex.

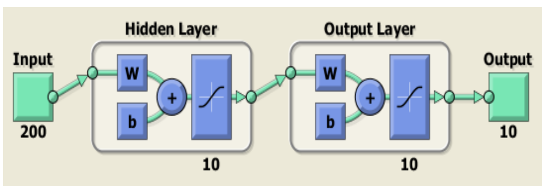

Fig: 3. Designed Neural Network

In the final step training of neural network is performed, after the database is created target is set corresponding to the images we want to store in our database. The above designed network is then trained such that output of the network well matches with the target values. Much closer the trained value, accuracy comes out to be more. Thus, for this purpose network can be trained up to 4 to 5 times. This step completes the first phase.

4. Recognition of the Data using Fuzzy Logic

Accuracy of the neural network is calculated on the two parameters namely Epochs- Fewer epochs mean network learns in small repetitions. Less time means network achieved goal easily and shortly. Lower value of epochs is associated with higher network accuracy.

Gradient- Low value of gradient plot indicates that the network is learning up to a large extent which means finer adjustments in the weights and bias. This in turn makes network more accurate and reliable, avoiding chances of false predictions.

Fig 4 depicts two output parameters of neural network on basis of which accuracy is calculated is given to Fuzzy Inference System as inputs. The two input blocks in the figure shows the same.

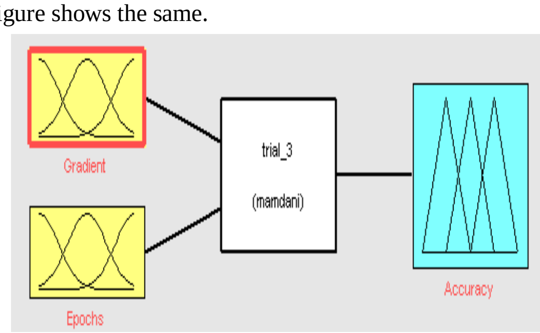

Fig: 4. Designed FIS

The input to the FIS is defined by the membership function which is defined between the ranges in which the two input values lies. Here range is selected as 0 to 50. We can select from any membership function which are already defined or customize our own membership.

Figure 5 shows the membership function selected for inputs Gradient & Epochs.

The central block consists of the rules for the network which are based on the combination of two input parameters to provide the desired output. The fuzzy rules are redundant for each input, we must repeat the set of rules for input parameter. The following rules were used in our experiment.

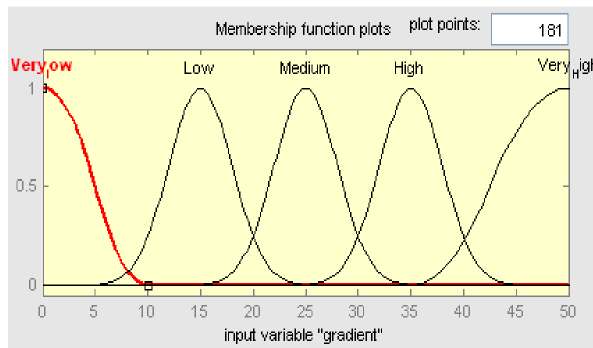

Fig: 5(a). Membership Function for Input Gradient

The central block consists of the rules for the network which are based on the combination of two input parameters to provide the desired output. The fuzzy rules are redundant for each input, we must repeat the set of rules for input parameter. The following rules were used in our experiment.

1. If (gradient is Very_low) and (epochs is VVL) then (Accuracy is known) (1)
2. If (gradient is Very_low) and (epochs is VL) then (Accuracy is known) (1)
3. If (gradient is Very_low) and (epochs is Low) then (Accuracy is known) (1)
4. If (gradient is Very_low) and (epochs is Medium) then (Accuracy is known) (1)
5. If (gradient is Very_low) and (epochs is High) then (Accuracy is known) (1)
6. If (gradient is Very_low) and (epochs is VH) then (Accuracy is >Identical) (1)
7. If (gradient is Very_low) and (epochs is VVH) then (Accuracy is >Identical) (1)
8. If (gradient is Low) and (epochs is VVL) then (Accuracy is known) (1)
9. If (gradient is Low) and (epochs is VL) then (Accuracy is known) (1)
10. If (gradient is Low) and (epochs is Low) then (Accuracy is known) (1)
11. If (gradient is Low) and (epochs is Medium) then (Accuracy is >Identical) (1)
12. If (gradient is Low) and (epochs is High) then (Accuracy is >Identical) (1)
13. If (gradient is Low) and (epochs is VH) then (Accuracy is Identical) (1)
14. If (gradient is Low) and (epochs is VVH) then (Accuracy is <Identical) (1)

15. If (gradient is Medium) and (epochs is VVL) then (Accuracy is known) (1)
16. If (gradient is Medium) and (epochs is VL) then (Accuracy is known) (1)
17. If (gradient is Medium) and (epochs is Low) then (Accuracy is known) (1)
18. If (gradient is Medium) and (epochs is Medium) then (Accuracy is Identical) (1)
19. If (gradient is Medium) and (epochs is High) then (Accuracy is <Identical) (1)
20. If (gradient is Medium) and (epochs is VH) then (Accuracy is <Identical) (1)
21. If (gradient is Medium) and (epochs is VVH) then (Accuracy is <Identical) (1)
22. If (gradient is High) and (epochs is VVL) then (Accuracy is known) (1)
23. If (gradient is High) and (epochs is VL) then (Accuracy is >Identical) (1)
24. If (gradient is High) and (epochs is Low) then (Accuracy is >Identical) (1)
25. If (gradient is High) and (epochs is Medium) then (Accuracy is Identical) (1)
26. If (gradient is High) and (epochs is High) then (Accuracy is <Identical) (1)
27. If (gradient is High) and (epochs is VH) then (Accuracy is <Identical) (1)
28. If (gradient is High) and (epochs is VVH) then (Accuracy is unknown) (1)
29. If (gradient is Very_High) and (epochs is VVL) then (Accuracy is >Identical) (1)
30. If (gradient is Very_High) and (epochs is VL) then (Accuracy is >Identical) (1)
31. If (gradient is Very_High) and (epochs is Low) then (Accuracy is >Identical) (1)
32. If (gradient is Very_High) and (epochs is Medium) then (Accuracy is Identical) (1)
33. If (gradient is Very_High) and (epochs is High) then (Accuracy is <Identical) (1)
34. If (gradient is Very_High) and (epochs is VH) then (Accuracy is unknown) (1)
35. If (gradient is Very_High) and (epochs is VVH) then (Accuracy is unknown) (1)

The third and final block in recognition phase is the output membership function which is defined in the range of recognition rate from [0 100]. When the two inputs are low in range accuracy is calculated to be more as defined by the rules. Figure 6 shows the output membership.

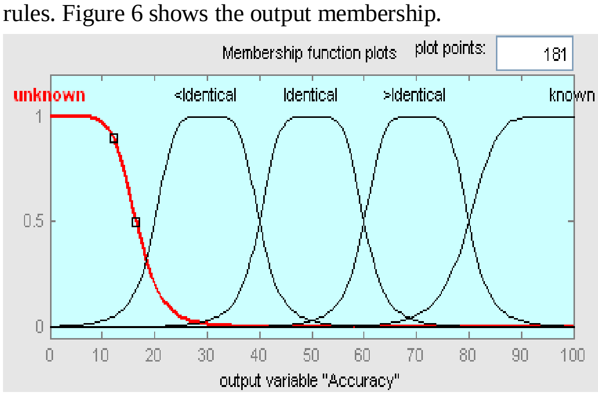

Fig: 6. Membership Function for Output Variable "Accuracy"

The combined algorithm of both the phases is shown in Figure 7:

The "TextBox" GSMSMS Controller System:

To tap the industrial applications market for GSM, EACOMM Corporation Embedded Systems Division developed the TextBox. The TextBox is a multifunction, microcontroller-based device that is designed to receive and send data via the GSM network. In its hear is a Zilog Encore! microprocessor with 64KB of Flash RAM and a Siemens GSM Cellular Engine. It is capable of receiving analog data from eight tenbit analog to digital converters (ADC) and digital data through a serial port.

The generic set-up shown above is easily configurable for use in telemetry systems (by using the ADC lines) or for remote instrumentation controls (through the serial port). The TextBox was designed in such a way that very minimal modification on the hardware needs to be done to customize it to a specific application. Much of the customization occurs in the operating system running in the microprocessor. Using the Zilog Encore allows EACOMM's engineers to develop using ANSI-C rather than assembly programming. By programming in C, development time is reduced by almost half. Thus, the Embedded Systems Division can deploy a fully customized TextBox within weeks of the client's order rather than months.

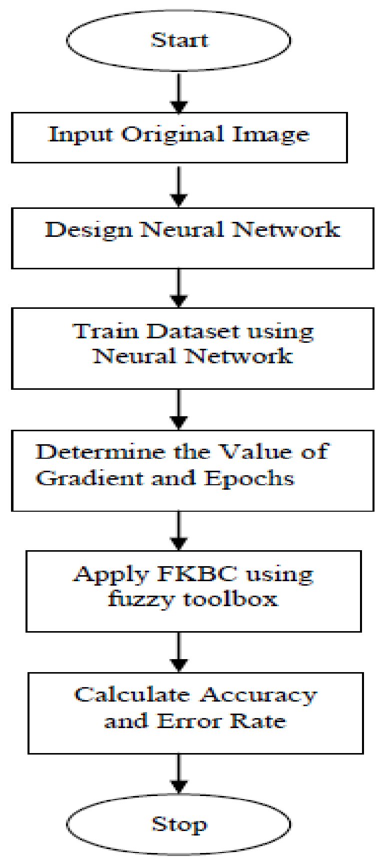

Fig: 7. Algorithm for the Proposed Method

5. Simulation Set up Parameters

5.1 Designed Architecture

After the compilation of the two phases designed network is shown in Figure 8. The figure shows the combination of neural network and the fuzzy system. The first two blocks in the figure shows the input to the network. Membership function is applied to the inputs. Rules are implemented on the basis of defined input and output membership function. The final output block gives the accuracy of the complete network and is the final output of the combined networks.

Output of the above network is studied with the help of Figure 9. The figure represents the rule base and the corresponding inputs and output. The use of fuzzy inference makes the system more flexible in a way that it accepts all the values between specified range.

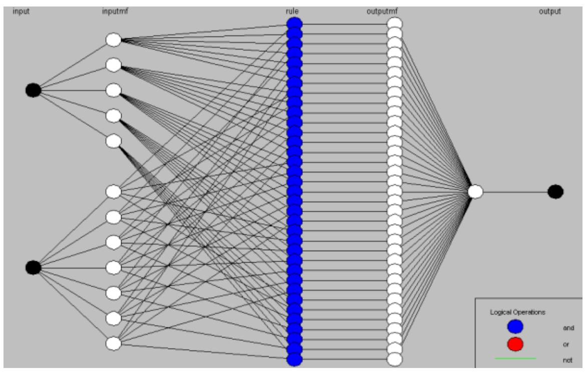

Fig: 8. Designed Architecture of Neuro-Fuzzy Network

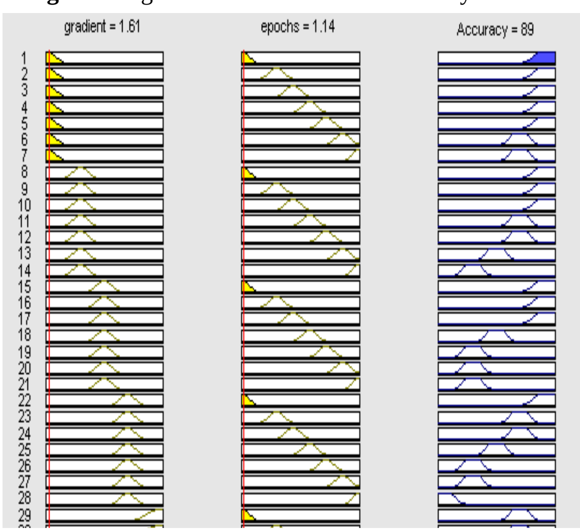

Fig: 9. Rules for the Fuzzy System

5.2 Performance Metrics

The performance of the system is analyzed on the basis of two metrics:

Accuracy- The ability to match the measured value of quantity to actual value is termed as accuracy. Accuracy here is measured by Epochs and Gradient value, fewer epochs mean network learns in small repetitions and smaller gradient means the fine adjustment of weights and bias which avoid false prediction.

Error Rate- Error rate is a term that describes the degree of errors encountered during data transmission or network connection. The higher the Error Rate the less reliable the system will be.

5.3 Setup Parameters

For the conclusion we have performed the tests with database composed of 20, 40, 60 and 80 images of resolution 180x200. These are images of 10 Plant captured at different time with varying expressions and lightening variations.

Table: 3. Shows the various simulation set up parameters used in our experiment. Setup Parameters

Total number of images	20, 40, 60, 80
Image of each Plant	2, 4, 6, 8
Image resolution	180x200
Background	Plain Green
Lighting variation	Yes
Expression variation	Yes

6. Conclusion

In this paper fuzzy logic is used to classify the colour of the chlorophyll according to the colour shade variations the Neural Network is used to adjust the colour and variation in the adjustment according to the growth. The neural network is the best method for shade adjust and the growth adjustment for the Fuzzy rules provide better classification and the GSM technique for data transmission through short message sending according the processor. This process is better control than any other agricultural online monitoring system.