Implementation of advanced electric metering and billing system on Arduino using Artificial Neural Networks

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Abstract—Electricity plays an important role in our lives. The use of electricity is increasing every day. It has been used everywhere and for different purposes and life cannot be imagined without electricity. The traditional method of energy meter billing is out dated, inefficient and time consuming process. Since the existing methodology of traditional electric meter reading is not feasible with the increasing consumption of electricity and has a lot of disadvantages like time consumption, more human resource requirements and is prone to lot of errors. Advanced Meter reading follows the process of obtaining the values of electrical meter by using a camera that takes a photo of the meter. The image is then processed using MATLAB R2017a software to extract the number from reading and store it in a variable. Artificial Neural network (ANN) have been used for number recognition. Previous month's reading is subtracted from this month's reading. The difference thus obtained is multiplied by the tariff and converted into electricity bill. The bill calculated is then sent to the consumer and to the electricity board through SMS using a GSM900A module and then saves the output in a text file.

Key Terms— Artificial Neural Network (ANN), GSM900A, Image processing, Number recognition, MATLAB R2017a.

I. INTRODUCTION

During these days there are several consumers who are not satisfied with the facilities provided by the electricity board .At present a person hired from electricity board visits every house in order to provide the monthly bill .Research shows that about 30% of the consumers are getting erroneous bills. After getting erroneous bills it is the problem of the consumer to go to the electricity board and get the bill corrected. In certain situations when there is no one in the house the average of last month's reading will be calculated and bill will be generated. Hence traditional metering and billing system has lots of disadvantages. Because of human intervention the traditional metering are prone to errors. So the paper aims the simulation of electric metering system in MATLAB R2017a .The proposed paper will not only help in reducing the manpower but also help the customer to keep a track of the units consumed.

II. LITERATURE SURVEY

This section presents similar researches, the steps they followed in their systems, and the techniques they used in each step. Shivani B. Sonune, et.al [3] has designed a work which makes use of a RF Transmitter for remote observing and control of Energy Meter. The Micro controller based work will record the meter reading that can be sent to the Hand held gadget. The recipient end contains RF beneficiary, which get the information from the transmitter. The information got at the recipient end is sent to microcontroller, which is available at accepting end .The microcontroller is interfaced with a LCD which displays the energy consumed.

Manish Mishra, et.al [6] has presented a paper on Artificial Neural Network or ANN which provides information on its various characteristics and business applications. This paper also show how neural been made in developing intelligent system, some inspired by biological neural networks are and why they are so important in today's Artificial intelligence .The paper also gives information regarding ANN which provides a very exciting alternatives and other application which can play important role in today's computer science field.

M. N. Mangoli, et.al [7] has presented a paper on offline cursive writing character recognition system using a Neural Network. The features of each character written in the input are extracted and then passed to the neural network. Data sets, containing texts written by different people are used to train the system. The proposed paper gives high levels of accuracy as compared to the conventional approaches in this field. This system can efficiently recognize cursive texts and convert them into structural form.

Mr.Bhushan D.Sawarkar, et.al [13] has presented a paper which describes a method for handwriting recognition using back propagation algorithm. They have used Back propagation

algorithm which is most widely used neural network because of its some advantage such as quick speed, classification ability and good recognition effect methodology.

III. METHODOLOGY

Digital image processing is the use of algorithms to perform image processing on digital images. As a field of digital signal processing, digital image processing has many advantages over analog image processing. This will allow a larger range of methods and algorithms to be applied to the inputs and can avoid challenges such as the build-up of noise and signal distortion during processing. As shown in Figure1 the methodology describes image acquisition, image pre-processing, number recognition and billing.

A. Image acquisition

The first stage in image processing is the image acquisition stage. Image acquisition system consists of two main stages: capturing the image and image storage. The image capturing stage consists of a camera. The captured images are stored in database which can be used for further steps.

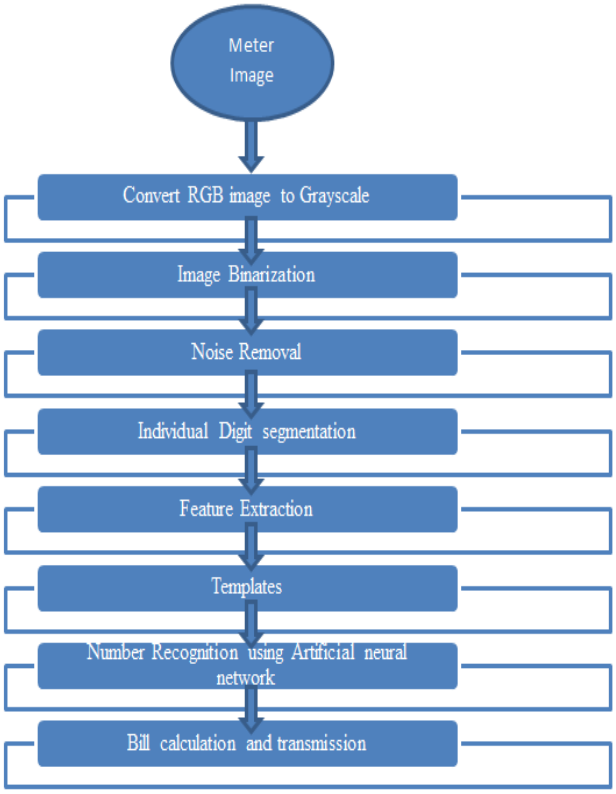

Fig. 1. Methodology.

B. Conversion of RGB images into grayscale

Coloured images are made up of the red, green and blue (RGB) components. They are called the primary colors .The combination of the three colors in different proportion gives different colors. The colors are identified with the relative values of the pixels in each of the 3 primary component values. If each of Red, Green, and Blue represented by 8 bits then 1 RGB pixel is represented by 24 bits. Hence the number of possible combinations of colors is 2^{24} which is equal to 16,777,216 different colors. The 24 bit represents depth of the color image.

The grayscale image can be represented by luminance using 8 bits value. The luminance value of a grayscale image ranges from 0 to 255. Hence the conversion of a color image into a grayscale image can be considered as converting the RGB values which has 24 bits into grayscale value consisting 8 bit. The conversion algorithm uses approximation of RGB values using luminance RGB components approximated RGB values will be reduced by factor of 3, then it is added with chrominance value and average of these four values will result in good quality of grayscale images.

C. Image binarization

A binary image is a digital image that has only 2 values for each pixel. The two colors used for a binary image are black and white. The grayscale image is then converted into black and white image by using binarization. The pixels below a certain threshold value is assigned 0 (i.e. black) and pixels above the threshold is assigned 1 (i.e. white).The main aim of image binarization is for easy analysis of the image.

D. Sources and types of noise and its removal techniques used in image processing

Noise is introduced in the image at the time of image acquisition or transmission. The main sources of noise in the digital images are: a) The image sensor may be affected by environmental conditions during acquisition of image b) Improper illumination of light c) temperature of sensors can introduce the noise in the image. d) Transmission channel may also disturb the image. e) The presence of dust particles on the scanner screen can also produce noise in the image.

1) Gaussian Noise

Gaussian noise is one of the common sources of noise that should be dealt with digital images .Major sources of Gaussian noise in digital images happen during acquisition for example sensor noise produced by low illumination, high temperature, and/or transmission e.g. electronic circuit noise. Gaussian noise can be removed by using a smoothing filter, though when smoothing an image, output may be blurred. Blurring of fine-scaled image edges and details because they also correspond to blocked high frequencies. The probability density function (PDF) of Gaussian noise is given by Eq. (1)

$$P(z) = \frac{1}{\sqrt{(2\pi\sigma)}} e^{-(z-\mu)2/2\sigma^2} \qquad \text{Eq. (1)}$$

Where $P(z)$ is the PDF of Gaussian noise, μ is the mean and σ is the variance.

2) Salt-and-Pepper Noise (Impulse Noise)

Salt and pepper noise is sometimes called impulse noise. Salt and pepper noise can be caused by sharp disturbance in the image. Generally this type of noise will only affect a small number of image pixels. When an image with salt and pepper noise is viewed, the image contains dark and white dots, because of this the term salt and pepper noise. The probability density function (PDF) of Salt and pepper noise is given by Eq. (2)

$$P(z) = \begin{cases} Pa \ for \ z = a \\ Pb \ for \ z = b \\ 0 \quad otherwise \end{cases} \qquad \text{Eq. (2)}$$

Where $P(z)$ is the PDF of salt and pepper noise.

3) Shot noise

Shot noise occurs in the lighter parts of the image. Shot noise can occur from an image sensor typically that is caused by statistical quantum variations, which is caused by the variation in the number of photons which are sensed at a given exposure level, this noise is also known as photon shot noise.

E. Removing Noise from Images by Filtering

Noise is unwanted disturbances that occur in an image which are of no interest. Image analysis can be simplified if this noise can be removed or can be filtered out. There are two types of noise removal approaches: (i) Linear filtering (ii) Nonlinear filtering.

1) Linear Filtering:

Linear filters can be used to reduce some types of noise. These filters reduce noise by convolving the original image with a mask that represents a low-pass filter or smoothing operation. The output of a linear operation due to the sum of two inputs is the same as doing the operation on the inputs individually and then summing the results. Linear methods are fast but they do not reserve the details of the image.

F. Image Segmentation

Image segmentation is the process of dividing a digital image into multiple segments. The aim of image segmentation is to simplify the representation of an image into something that is more meaningful image and easier to analyze. Image segmentation is used to find the objects and boundaries in images. Image segmentation is the method of allocating a label to every pixel in an image such that picture locations with the same label have certain common features.

G. Template matching and number recognition using artificial neural network (ANN)

The aim of number recognition is to recognize samples which are mostly saved as digital images. The process of the recognition consists of several steps. MATLAB R2017a has a special toolbox, called Neural Network Toolbox, which helps in constructing the best suiting Neural Network.

The following methods are very important when one want to know how the neural network works when recognizing characters. These methods give a clear idea on how actually the neural network goes through with change its parameters to identify the wanted numbers.

H. Feed forward Back propagation (FFBP):

The feed forward back propagation is one of the most widely used algorithms for training of neural network. (FFBP) algorithm's unique feature is the error that the neural network gets on its output. This error will be equal to difference between the actual and required output values. When FFBP is used, more concentration should be given to weight change, which reduces the error in the output. The learning starts when all of the training data is shown to the network at least once. The learning method, for any network learning algorithm, consists of the modification of the weights. The algorithm of FFBP can be shown as in Figure 2. Main steps involving for constructing of a neural network

1) Training

- Pre-processing: Processing the data in the form which is easy and in the required form.
- Feature extraction: Reduction in the size of the data with saving only the required information.

2) Defining the data set

Every neural network needs data to be trained. These data consist of input and target data. The training of one character can be done with an input and an output vector. For the neural network training image data set of numbers from 0 to 9 for both analog and digital numbers have been collected .These images form the data set for the neural network. The performance type can changed according to learning rate momentum and goal parameter values of the neural network. After changing or modifying the values, network has to be trained again.

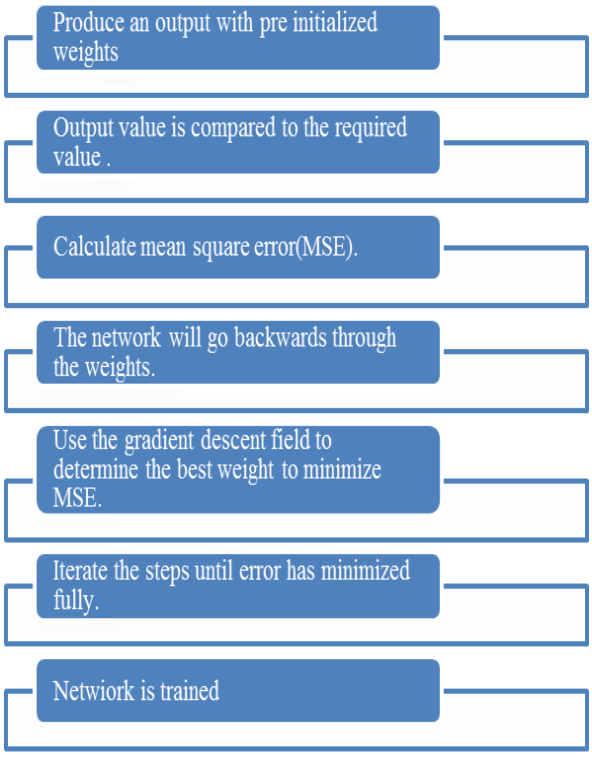

Fig. 2. FFBP algorithm

The performance type can be Sum Squared Error and Mean Squared Error. The goal describes the minimal error value, at which the training must be stopped. Momentum and learning rate helps get through local minimum easily, so they have to be chosen carefully. More values make training faster Clicking on the training button, starts the training of the network with the data described for the neural network and with the specified parameters.

I. Calculation of bill and transmission

After number recognition using the neural networks gives the current month reading. The difference of the current month reading and previous month reading gives the number of units used for that particular month. This amount is multiplied by the tariff as specified by the electricity board and the bill is calculated. The bill amount is sent to the customer through SMS by using a GSM 900A module. A copy of this SMS is also send to the electricity board for documentation purpose.

IV. ADVANTAGES AND LIMITATIONS

This section tells about the advantages and limitations of the proposed paper.

A. Advantages of proposed method

1. Number of units consumed will be precisely known to consumers.
2. Clear and Accurate Billing.
3. Image processing enhances the accuracy rate of recognizing numbers when compared to manual.
4. Human error while taking the meter reading will be eliminated.
5. Manpower Requirements will be reduced
6. Better and Faster Consumer Service.
7. There will be elimination of fake bills.

B. Limitations

- Interference of shadows in the images may result in distortions while detecting the number.
- Non uniform illumination on the meter readings may also cause difficulties in detecting the numbers.

V. SIMULATION RESULTS

The proposed paper has been successful in recognizing the meter readings of both analog and digital-meters. The obtained results are shown in the following

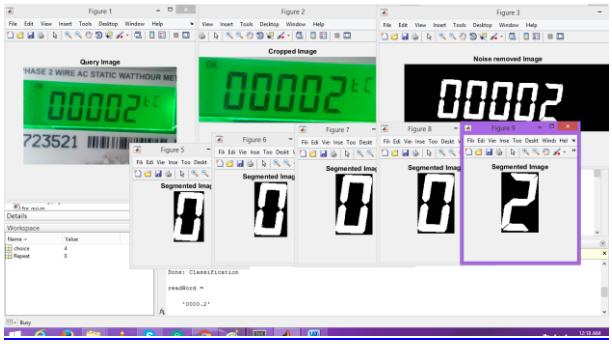

Fig. 3. Previous month's reading

As shown in Figure 3 the previous month's reading is captured using camera. Figure 3 also shows cropped image, binary converted image, individual segmented images and the recognized meter reading in command window.

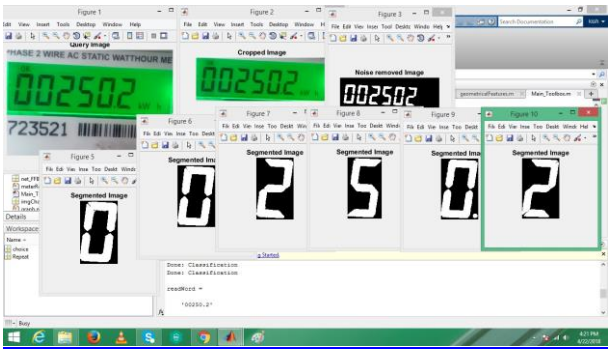

Fig. 4. Current month's reading

As shown in Figure 4 the current month's reading is captured using camera. Figure 4 also shows cropped image, binary converted image, individual segmented images and the recognized meter reading in command window.

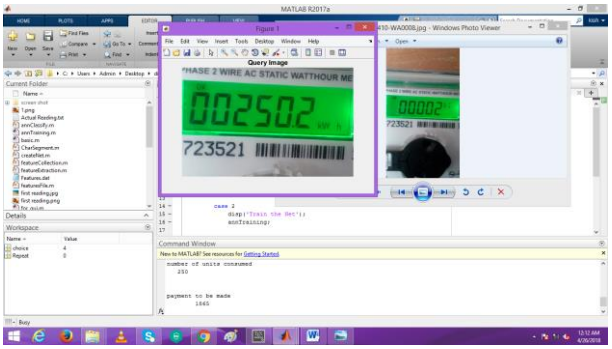

Fig. 5. Difference calculated and bill generated

Figure 5 shows both previous and current month's images and the difference calculated and the bill generated in command window.

Fig. 6. Monthly payment bill received in Consumer's mobile

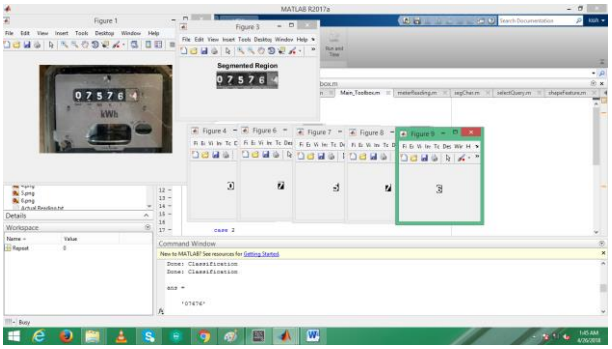

Fig. 7. Previous month's reading

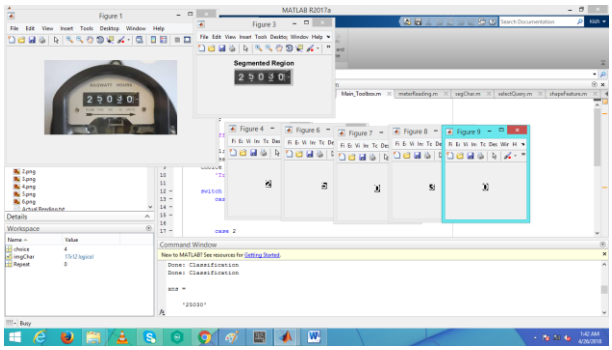

Fig. 8. Current month's reading

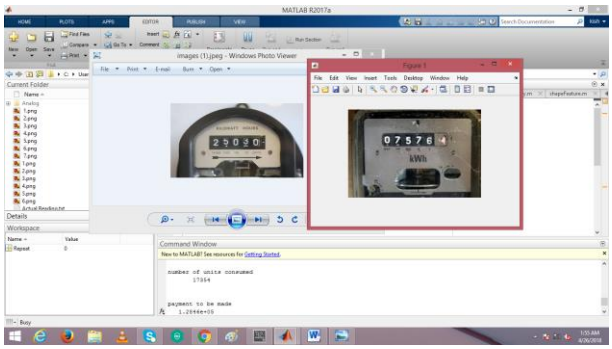

Fig. 9. Difference calculated and bill generated

VI. CONCLUSION AND FUTURE WORK

The proposed paper has been successful in recognizing the meter readings of both analog and digital meters. The proposed paper eliminates the intervention of humans for the electricity metering and billing system. It removes the need of manpower and also requires no paper for billing purpose. The chances of losing the bill will also be removed as the bill amount is being sent to the customer as SMS using a GSM 900A module.

The future work shall concentrate on removal of shadow interference which helps in detecting the numbers in a more correct way.

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