Intelligent Vision Based Pneumatic Wall Painting Machine: an ANN Approach

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Abstract— **Painting the wall is normally done manually, which is very difficult and troublesome for humans to work in an upright position and also very dangerous for eyes and skin. Due to fatigue and surrounding environment, painting might not even all over the wall. To overcome these difficulties, an intelligent pneumatic wall painting machine has been designed and fabricated using vision and neural system. The machine has the arm which can extend upto 25 feet by carrying the pneumatic spray gun. The camera in the arm captures the image of the wall and the obtained image has been processed and gives as the input to the trained artificial neural network. The output from the network is used to control the pneumatic pressure supplied to the air gun. Apart from the automatic control, manual control switches are also used for the operation. Thus the developed intelligent machine is a low cost machine with automatic and manual control for perfectly painting the wall with reduced human fatigue, time and paint, even with an un-uniformly painted wall.**

Index Terms— **Artificial Neural Network, Image processing, Painting.**

I. INTRODUCTION

Painting is the process of applying paint, pigment, color or other medium to a surface for its ergonomic appearance. Theses medium are coated over the base with tools like brush, knives, sponges, airbrushes, etc. The appearance of the painted surface depends on the lighting, reflection, base coating, viscosity, miscibility, solubility, drying time, etc. A white wall also has different intensities at various point, due to shades and reflections from nearby objects. Acrylic paint is a fast drying paint containing pigment suspension in acrylic polymer emulsion with water-resistant. In all these methods, paints are coated manually. [1]

Due to human errors and fatigue, coating might not be uniform all the time. So spray painting technique had introduced which sprays a coating (paint, ink, varnish, etc.) through the air onto a surface. But the atomized paint particles mixed with the atmospheric air and pollute the air by creating respiratory problems to the humans. So a need arises to overcome all these constraints. In this research, an intelligent automatic painting machine had developed to overcome all the need in the painting.

To provide intelligence to the machine, Artificial Neural Network (ANN) concept is used. It is inspired by the way of human neural systems for processing the information, by means of large number of highly interconnected processing neurons. Initially these neurons work together to learn from the input information, distribute them for processing and ends with final output. ANN involvement and processing methodology are almost comprehensive with large amount of data obtained from image processing, due to the fact that it have the nature of adaptive learning.

Also having the capability of optimizing the relationship between the inputs and outputs via distributed computing, training, and processing. The image of the wall has been captured by the camera and the features are extracted using image processing techniques.

The processed image is given as input to ANN. The output from ANN decides whether to paint or not, if so how amount need to be deposited over the base. This decision is given to the Adrino processor which controls the pneumatic pressure and thereby control the amount of paint sprayed over the base.

II. LITERATURE REVIEW

As the nature of ANN and human neurons are similar, ANN has been proved to be a very useful for this type of new task [1, 2]. In the 1950s, neural networks made a revolution in the artificial intelligence community. In 1962, a method was proposed to train a subset of a specific class of networks, called perceptrons and proved the convergence for single-layer perceptrons [3]. ANN training algorithms for neural networks with larger number of nodes and complex threshold units were proposed [4]. Later it was proved that the algorithms were not providing the satisfactory results for the nonlinear and complex problems. Researchers realized the importance of the ANN and developed multi-layer perceptrons for the non-linear and complex problems. Back-propagation rule (BPN) is developed to solve the multi-layer network. For multi-layer network, BPN have been used by most of the researchers to solve the complex problems in less computational time. However, BPN were not the only type of ANN, some other network are also available like Hopfield network, Kohonen's self-organising map, Boltzmann machine, Neocognitron, etc.

Image processing techniques have been developed since last decade. Generally, visual perception of the human eye does not use the sensor for each wavelength, but there are only three center stimulus colors: red, green and blue and each ranges from 0 to 255. Three levels RGB intensity are combined to form a desired color numbers. The extraction of the features from the images is a complicated process which involves techniques like edge detection, watershed [5], snake modelling [6], region-growing [7] and segmentations as well as edge detections [8,9,10]. Inorder to reduce the computational time, techniques like data compression [11,12,13,14,15,16], image enhancement and noise

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suppression [17,18,19,20,21,22] are also applied by the researchers.

III. IMAGE PROCESSING

In general, image processing problems are solved by a chain of tasks such as pre-processing, filtration, data reduction, segmentation, object recognition and image Interpretation. Actual captured images contain noises and deteriorate the image quality by making image blur. This will bring lots of difficulties in interpretation and analysis. Therefore, the primary purpose is to remove noises. The traditional de-noising method is the use of a low-pass or band-pass filter to denoise. Wavelet analysis widely used in many aspects such as image compression, image noise removal, etc. There is irreconcilable contradiction between removing noise and edge maintenance. Then the size of the image is reduced without affecting the features of the images, thereby reducing the computational time in processing in the ANN.

IV. ARTIFICIAL NEURAL NETWORKS

The basic structure of a neuron can be theoretically modeled as shown in Figure 1.

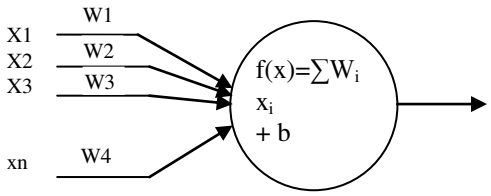

Figure 1: Theoretical Model of a Neuron

In the Figure 1, x_i, i=1, 2, . . ., n represent the inputs to the neuron and each input is multiplied by its weight w_i and to a transfer function f(x). The four basic transfer functions widely adopted for image processing are hard limit, linear, RBF and Sigmoid functions [23,24]. In this research, sigmoid function had been used and is given in the Equation 1.

$$f(x) = 1 / (1+e^{(-\sigma x)}) \qquad (1)$$

Similarly the training for a network can be supervised learning and unsupervised learning with a set of known images and unknown target data respectively. There are several different network models available for image processing applications, but one of the most commonly use network is Back propagation network (BPN). In BPN, the neurons in each layer of the network are connected to each other neurons in the adjacent layer. These connections are bi-directional, i.e. forward for fitness function calculation and backward for weight and threshold alteration. The process of obtaining the optimal value for the weight and threshold is called training or learning. For training, the algorithm iteratively altering the weight and threshold values based on the error in the network output value. Error is the function of difference in the obtained output and the desired output. Gradient descent algorithm has been used to alter the weight values and is given in the Equation 2.

$$W_{jk} = W_{jk} + \Delta W_{jk} \qquad (2)$$

The change in the weight value is given in the Equation 3

$$\Delta W_{ij} = h_{ij} (r_i - r_j) (x(t) - w_i(t)) \qquad (3)$$

Whereas i and j represent i^{th} layer neuron and j^{th} layer neuron respectively. The training of the network should not be under trained or over trained. The training duration vary from application to application. So to identify the current training duration, 10% of the input images will be considered as the test images. Once the network identifies the test images, then the weight and threshold valves can be assumed to be optimal and can be stored for the application.

Some of the consideration in constructing the network are information processing occurs in the simple elements called neurons, These signals are sent through the links between neurons and the links having weight values of its own, initially the weight values are assigned randomly, Each neuron has its own threshold values and receives input and sends output based on it.

V. EXPERIMENTAL IMPLEMENTATION

The primary aim of this research is to design, develop and implement automatic intelligent wall painting machine with vision which helps to achieve low cost painting. Despite the advances in robotics and its wide spreading applications, interior wall painting has shared little in research activities. Due to elegant and simple control systems, it can control noise and vibrations. The image of the developed machine is shown in the Figure 2.

Figure 2: Intelligent Automatic Wall Painting Machine

The entire machine is fixed on the movable base for the left and right movements and the too and fro movements are controlled by means of DC motor. The up and down motion of the spray gun is controlled by means of chain drive activated by stepper motor. The prime source for the spray gun is the compressed air from a portable compressor and pressure of the compressed air is controlled by the electro-pneumatic pressure control valve. Input to the valve is given from Adrino board based on the ANN output. The camera present in the casing near the spray gun is continuously capturing the image of the wall to be painted and send it to a digital machine. In the computer, in the rate of a frame/25 frame have been stored in ".bmp" format. As the bitmap image format is having the detailed header and info header information of the captured image. The next stage is the image processing stage.

In the image processing stage, the noises present in the image have to be removed. This had done by comparing each

pixel of the image with the surrounding neighbor pixels. Generally the images obtained from the camera are in inverted format and as the work concentrates on the colors, image inversion algorithms had not been used. Each pixel is having three color value in it and that should be converted to the pixel intensity and thus the image size reduced to one third of the original size. Again to reduce the image size further, SPIHT algorithm had used and given as input to the ANN module. Because the image of smaller size can be processed easily [24,25].

The developed ANN is a six layered network with 1024, 2000, 1000, 500, 250, 10 neurons in input layer, four hidden layers and output layer respectively. Each neuron in a layer should have a link with each other neuron in the adjacent layer. Initially the threshold value of the neuron and the weight value of the links are set by random numbers. A sample set of 100 different images have been taken for training the network. In the sample, eighty images for training the network and twenty images for testing at random have to be selected. The images are given as input and the transfer and the BPN functions are allowed to operate over the image data. Once the network has been trained, the ANN output needs to be decoded for pressure function. The pressure function equation is the product of a constant with the inverse decimal value of the binary digits obtained from ANN. Then that value will be given as the input signal to the processor and the processor controls the pressure limit of the paint gun proportionally. Thus the paint sprayed over the base accordingly. In the mean time, the arm moved to the next segment of the base and captures the image. The same procedure has to be repeated. Again once the arm reached the top of the wall, the electrical limit switch in the top actuates and sends the signal to the processor to retract the arm down and to move the machine in the horizontal direction. The sample output of the developed machine is given as follows,

ANN o/p	Pressure in the gun
0000000000 -	0 bar
0101010101 -	1.5 bar
1111111111 -	2 bar

VI. Conclusion

Thus an automatic intelligent wall painting machine has been designed and fabricated for painting walls easily and effectively. It reduces human effort, climb risk, problems due to pollution and time required to complete the process of painting. The machine can able to coat 22 feet height in a pass. So the painting time can be reduced. It also saves the wastage of paint by analyzing the wall surface and coat the surface as required i.e. based on the surface condition it controls the coating layers and intensity of the spraying paint particles.

The module is developed by assuming that the entire surface is best suitable for painting. The analysis on wetness nature of the surface and the paint quick drying mechanism can also included fulfilling the pitfalls in the process of painting.

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